Maternal Mortality and Choice of Birth Attendants in Kenya

A system dynamic Approach

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Acronyms

ANC	Antenatal Clinic
BAU	Business as Usual
CLD	Causal Loop Diagram
GOK	Government of Kenya
MOH	Ministry of Health
MMR	Maternal mortality ratio
MP	Medical Personnel
SBA	Skilled Birth Attendants
SDG	Sustainable Development Goals
SFD	Stock Flow Diagram
TBA	Traditional Birth Attendants
WHO	World Health Organisation

Abstract

This paper aims to investigate the dynamics between maternal mortality and decision-making on the choice of delivery (skilled or unskilled) in Kenya. Unskilled birth attendants (TBA) are common practice in Kenya, especially in marginalized rural regions. Faced with a myriad of risks and challenges, including distance, few medical personnel, finances, access, and social issues, home births, unlike in developed countries, do not have emergency services, i.e., ambulance service, which is not even an available option, especially in rural areas unlike in developed nations. Hence making some maternal deaths that were avoidable be unavoidable.

Using system dynamic feedbacks mechanisms, we identify the leverage points at which policy intervention could be targeted to reverse the maternal mortality trend. Free Maternity programme and the mobile clinic have been among the policies in existence, though with some positive effect on maternal mortality; this requires a better understanding of mechanisms behind its uptake vis-a-vis the costs associated with it. With further probe and different scenario testing, a combination of the advocacy, hiring, comprehensive mobile clinics policy, and free maternity programme has shown that these can be achieved and, in turn, increase the 'share of women using skilled birth attendants (SBA).'

Study results showed that the effectiveness of the policies differed depending on the budgetary allocation done to the hiring, advocacy, and mobile clinics. These can be used to inform the discussion on fiscal budgets based on available funds.

The application of appropriate policy interventions can enhance decision-making among pregnant women.

Chapter 1: Introduction

1.1 Background

Maternal mortality is defined as 'the death of a woman while either pregnant or within 42 days after pregnancy termination, regardless of its duration or any other non- pregnancy-related accidental deaths' (WHO, 2010). These deaths mostly occur within the first 24 hours following birth, and 99 percent are in developing countries (WHO, 2015).

According to the World Health Organisation, at least 300,000 women (i.e. 211 maternal deaths per 100,000) live births die every year worldwide because of childbirth-related and pregnancy complications (WHO, 2010) of which approximately 200,000 of these deaths registered in Sub-Saharan (i.e. 533 maternal deaths per 100,000 live births) (UNICEF, 2019). Kenya records atleast 5000 of these maternal deaths annually (Economic survey,2019). From the statistics a study shows Most of which occur in low resource settings, poor communities, and about 60% of low-income sub-Saharan countries where health systems exhibit inequalities between urban and rural health facilities (Koblinksky, 2003) (Ndola et al., 2011).

Approximately 60 million child deliveries are done outside a healthcare facility (Darmstadt et al., 2009). Home delivery is higher among low-resource nations. Most of these home deliveries are done without the assistance of personnel (Cheptum et al., 2017). Efforts have been adopted to encourage all women to utilize skilled labor while giving birth to reduce the incidence of maternal mortality. These include free maternal care services to enhance uptake and safe delivery in health facilities.

When used as a key health indicator, maternal mortality tends to highlight wide disparities between high-income developed and low-income countries (WHO, 2010). Whereas women in developing nations have a higher probability of dying during pregnancy, their counterparts in developed nations have better access to health care and emergency services that deal with pregnancy complications and easy access to antenatal clinics and services. It is estimated that most maternal deaths are evitable with appropriate health care and management.

In most low-income nations, choices made by mothers regarding where to give birth usually determine maternal and neonatal mortality as it is exacerbated by home birth (Black et al., 2010). In their study, Darmstadt et al. (2009) explained that over 50% of births are done at home by traditional birth attendants. The traditional/unskilled birth attendants services have been proven to help during home delivery for those who chose this delivery, and they also serve as breastfeeding counselors and peer educators.

1.2 Traditional Birth Attendants

Seeking traditional birth attendants' services has been and is still widespread in most developing countries, increasing usage in the rural areas. As the name suggests, they offer unskilled delivery services.

A traditional Birth Attendant (TBA) is a person who aids women during the delivery process of a baby and initially honed their skills through experiences of delivery or traineeship from other experienced TBAs (WHO, 2014). They have existed over a long period and have offered delivery services to many people in societies (Byrne & Morgan, 2011). These TBAs are burdened with essential obstetric care in most rural areas. Although Skilled Birth Attendants are vital services towards preventing maternal and infant mortality, mothers often prefer to use their traditional counterparts. Some of the attributes for their continued usage of TBA range from economic reasons, long-distance, low access to health facilities, and their perception of skilled medical personnel knowledge and expertise.

Over time, the Kenyan government has introduced a raft of measures geared towards health sector reforms to increase skilled (SBA) use as opposed to unskilled (TBA). Notwithstanding these efforts, only 10 percent of mothers in the pastoralist's regions (Samburu and Laikipia Counties, Kenya) delivered in health facilities with SBA assistance while the majority continued using TBA. Hence the need for the collaborative health care system programme to better utilize both SBA and TBA to ease and increase the transition to SBA deliveries over time (Bryne et al., 2016).

1.3 Skilled Birth Attendants

Skilled birth attendant (SBA) refers to a midwife, a gynaecologist, doctor, nursing staff, and other professional health personnel who offers essential and emergency health care services to pregnant women and their newborns during the prenatal period childbirth, and postpartum period (WHO, 2015).

In 2012, approximately 40 million child deliveries in low and middle-income countries were attended by skilled health professionals (Jhpiego, 2016). The skilled birth attendants in this paper are the medical personnel, specifically doctors and nurses.

The presence of SBA during delivery is crucial in reducing maternal and child mortality; as they are trained and have proficient skills required to handle normal/uncomplicated pregnancies, childbirth, and the immediate postnatal period while looking out for complications (WHO, 2015).

1.4 Problem Statement

Access to skilled care and facilities with capacity to provide emergency obstetric and newborn care is critical to reducing maternal mortality. Over the last two decades, efforts and programmes focused on decreasing maternal mortality in Kenya have not yielded the desired results (Figure 1).

Figure 1: Mortality rate graph

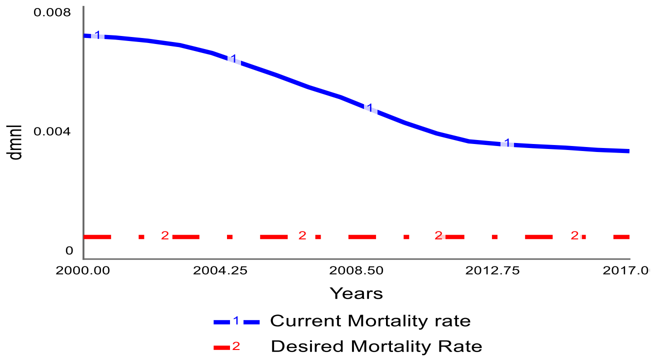


Figure 1 shows the maternal mortality rate in Kenya against the target SDG goal of 70 deaths to 100000 live births.

This is attributed to the complex nature of maternal mortality that goes beyond its simplified definition. Elements such as immediate access to skilled care and health facilities with the capacity to provide emergency obstetric and newborn care consistently emerge as critical in reducing maternal mortality. Furthermore, in Kenya, many women still chose to have births at their homes with the help of traditional birth attendants as opposed to skilled birth attendants, with over 42 percent of women still delivering at home in rural Kenya (WHO, 2019, (Bidhan, et al., 2020).

Despite many concerted government efforts, uptake of skilled birth attendant (SBA) delivery remains low in Kenya. These efforts targeted a 90 percent skilled delivery by 2015, doubling this from 43 percent in 2008; this is yet to be achieved.

The SBA uptake is skewed with at least 89 percent in Nairobi as of 2008 and at least 10 percent skilled delivery in the rural areas of Kenya, especially among pastoralist communities. These results were corroborated with a 2012 survey conducted in Laikipia and Samburu pastoralist communities. At least 92 percent were home deliveries, with 57 percent TBA assisted deliveries, and the rest were self and family help deliveries. (Bryne et al., 2016).

This paper assesses the determinants of decision making on choice of birthplace and attendant in Kenya among women of reproductive age and its effects on maternal mortality.

1.5 Research Challenge

Maternal mortality is a dynamic problem with embedded complexity within the feedback processes interrelating the decisions making processes of pregnant women when determining choices for birthplace. From existing literature, there are limited studies that explore the relationships between pregnant women decision-making processes relative to access to skilled care, facilities with capacity and overall maternal mortality.

This limitation in research evidence, restricts investments, and policies within the health sector, geared towards supporting maternal mortality reduction. There is therefore a clear need to fill the existing research gaps by harnessing and using system dynamic analysis and simulation techniques to fully understand these decision-making processes with the sole purpose of identifying policy interventions that can advise policy makers when designing maternal mortality reduction policies.

1.5.1 Research Questions

The research objective is to gain insights of the decision-making process of pregnant women relative to the choice of birthplace in Kenya. The paper aims to explore the following research questions.

1. What factors are responsible for determining the choice of birthplace among pregnant women in Kenya?
2. What are the causal feedback mechanisms influencing decision making of birthplace among pregnant women in Kenya?
3. Can a generic simulation model be developed and utilized that approximates from variety of factors to influence decision making?
4. What are the potential policies that can influence decision making processes of pregnant women when choosing birthplaces in Kenya? How can these policies be cost effectively implemented?

Chapter 2: Theoretical Overview & Hypothesis

2.0 Overview

This projects’ primary hypothesis is to develop a simulation model that can shade light to the historically observed behavior patterns of decision making and its effects on maternal mortality at an aggregate level; by looking into the different relevant issues raised during the research and further understand the mechanisms pregnant women use in decision making as to whether to choose traditional birth attendants or opt for skilled birth. Several highlighted issues can be categorized as convenience-related, social and economic factors, financial, human, and capital infrastructure, etc. are further discussed in the literature. These include:-

low access to health facilities; a limited number of medical personnel; low presence of skilled birth attendants; level of maternal education and literacy; high costs of delivery in hospital, poor attitude of health workers, family-related factors, and limited awareness creation.

2.1 Literature Review

2.1.1Low access to Health Facilities

Basic health care plays a key role of improving matters maternal health during pregnancy. Having access to well-equipped health facilities with skilled medical attendants significantly boosts pregnancy outcomes while reducing risks surrounding childbirth. Access to basic health care is a key challenge in most developing countries especially in the rural areas, hence an impediment to those in the rural to access good basic health services (Bourke, et al., 2012), (Gamm, et al., 2003) (Medicine., 2005)

A study to assess reproductive health looked at the correlation between the 'use of maternity services (prenatal and postnatal) and the frequency of maternal health complications (both prenatal and postnatal)'. From the findings, more than 50 percent of women reported some form of difficulties experienced during prenatal/ antenatal period. Less post-partum complications were reported in comparison to during pregnancy and child-birth period. It was observed that women who underwent full term antenatal care and had less incidence of complications during and after delivery period (Gogoi, et al., 2014).

Despite many government interventions and programmes, maternal mortality still is challenge for most developing countries. This associated with several factors among which non/ under-utilization of maternal reproductive healthcare especially antenatal and post-partum care among mothers was largely associated to low accessibility/ availability to basic health care and to some extent lack of awareness of its importance when linked to safe delivery /maternal mortality. A large proportion of pregnancy related deaths can be greatly reduced if pregnant women can access reproductive health care both during pregnancy and postpartum period. In Kenya, reproductive care can be accessed through private and public health facilities which offer maternal services (MOH 2019).

One of the other reasons women prefer TBAs is because of factors related to the health system. Adatara et al. (2019) study shows that majority of women seek TBAs because of the poor quality of services offered at the clinics and lack of access to healthcare facilities. Some of the issues related to health facility accessibility include long physical distance, the inadequacy of health facilities, and time constraints (Ogbo et al., 2020). In most rural and deprived areas, the number of women who prefer the use of TBAs is way higher than those who use health professionals like village midwives (Cheptum et al., 2017). Sialubanje et al. (2015) study indicates that most rural areas, there were about 10 TBAs compared to only one village midwife. This ratio creates a higher physical distant difference between the village midwife and the community Health centre. As a result of this distance, most women would still prefer to use TBAs instead of going to get the services of a village midwife even if their services are free.

2.1.2 Limited number of medical Personnel

World Health organisation recommends a minimum medical personnel density of 23 skilled medical personnel (doctors and nurses/ midwives) per 10000 persons. This is a requirement that would ensure attainment of at least 80 percent skilled birth attendance (WHO, 2006).

Kenya and most sub-Saharan Africa countries have an average of atleast two doctors and 11 midwives per 10,000 population, of which most are clustered in urban areas in comparison to Europe where there are atleast 23 doctors and 68 nurses per 10,000 people. (Ndola, et al., 2011)

Kenya, like many developing countries, has a fair share of inadequate medical personnel to the population. It is approximately 9.8 to 10,000, which is low compared to the recommended 23 medical personnel (doctors, nurses, and midwives). In 2015, the nurse ratio to the population was 8.3 while the doctors stood at 1.5, with Nairobi having the highest at 9.5 medical doctors. These statistics varied per the 47 counties. The ratio of nurses retained in Kenya to the population varies by county, with a national percentage of 8.3 per 10,000 (MOH, 2015). (MOH, 2015).

Cheptum et al. (2017) study in Migori County, Kenya, it was shown that 53.4% of women delivered with skilled attendance while 28.6% of those who used unskilled birth attendance sought the services of TBAs. There are 126 public health facilities in Migori County, translating to a nurse-patient ratio of 32 per 100,000 people. The doctor-patient ratio in this county is 4 per 100,000 people, and the percentage for clinical officer-patient is 19 per 100000 people (Cheptum et al., 2017). The ratios are significantly lower than the minimum nurse-patient ratio that the government has set to be 55 per 100,000 people, while that for the doctor-patient is 10 per 100000. The low number of healthcare professionals necessitates women to utilize the services of TBAs during delivery.

Table 1: Ratio of Medical personnel to population (Pop Estimate: 2009&2019 Kenya Population Census)

	Annual Output	Total No. registered	Total No. Retained	Ratio per 10,000 pop	Density 1: N population 2009
Medical Officer	611	9497	5660	1.5	1: 6,822
Nurses &Midwives	6,326	63,113	31,896	8.3	1.605
Total		72,610	37,556	9.8	1:734
WHO recommendation per 10,000				**23**	**1:400**

Source: Kenya National Bureau of Statistics

2.1.3 Low Prescence of skilled birth attendance during delivery

During delivery, averting maternal mortality is dependent primarily on skilled birth attendance. Assisted delivery by trained personnel also was a key to reducing maternal mortality (Koch, et al., 2012). In Kenya, this is still low and remained long below 50 percent, and as by Kenya Demographic Health Survey 2008/09, 44 percent of births were by skilled Birth attendant's way below a national target of at least 65 percent. A study done in Makueni County in Kenya examined pregnant mother's traits, access to antenatal care (ANC), and skilled birth attendants.

A study conducted in rural Kenya, Kikoneni location showed that skilled attendants' coverage was relatively low compared to the national average of 40 percent, which was still below the 2010 target of 80 percent (cotter, et al., 2006).

2.1.4 Level of maternal education and literacy

Several studies relate the importance of maternal literacy with little focus on its threshold level that would be key in influencing skilled birth delivery. A national demographic and health survey conducted in Tanzania, Malawi, and Zimbabwe supported the results that mothers with higher education levels had more knowledge on childbirth. Those households with a maternal education threshold of more than ten years of schooling reported delivery in health facilities and attending Antenatal Clinics. A study conducted in Chile linked mothers' education and decreased maternal mortality level with each additional schooling year for mother's being beneficial towards maternal mortality reduction. Study findings indicated that additional schooling years decreased maternal deaths by 29.3 to 100,000 live births annually (Koch, et al., 2012).

A cross-sectional survey investigates factors causing maternal mortality in 24 countries across Latin America, Asia, and Africa. The study showed the prevalence of maternal mortality in all these regions being higher where women were less educated. These were majorly attributed to teen births, not attending ANC, and traditional practices (Karlsen, et al., 2011).

A study on the impact of informal maternal education and their choice of health facilities in Enugu State, Nigeria, showed a strong correlation between health facility choice and maternal levels of education. The level of maternal education played a vital role in the number and level of antenatal care expectant women received (Onal, et al., 2006)

Mother's level of education greatly influenced the choice of birthplace, with those with higher /tertiary education 8.6 times more likely to use skilled attendants. Partner's education level influences at least 2.9 times, attending ANC and proximity of at least 5kms from a health facility influence use of skilled attendants (Gitimu, et al., 2015).

The Kenyan government, in January 2003, introduced a free primary education programme (FPE) whose aim was to provide free primary education to all its citizens and improve the low strides recorded in educational sector over time. It's aimed at promoting equity and make education affordable to all, hence making it essential and accessible to all (Muyanga M., 2010). In the long run, this could, to some extent, play a role in maternal literacy and foster the use of skilled birth attendants during delivery (Koch, et al., 2012)

2.1.5 High costs of delivery in hospitals

One of the reasons that have been cited for women to prefer TBAs is the high cost associated with childbirth in hospitals. According to a study by Titaley et al. (2010), there are many requirements that a woman must meet to labor in health care facilities. Most of the women are unable to acquire these items, and as a result, they prefer the use of unskilled delivery, which has lesser requirements. The study by Sialubanje et al. (2015) explained that the basic needs to be met by prospective mothers during the antenatal clinic (ANC) and prevent women from visiting healthcare facilities during labor. Some of the participants in the study explain that midwives often scold pregnant women who present to deliver without carrying the required items. As a result, women only visit ANC facilities, but when labor starts, they call the TBAs (Wang, Alva, Wang, & Fort, 2011). This concern was raised by participants who had delivered in hospitals.

2.1.6 Poor attitude of health workers during ANC and facility delivery

Past negative experiences with nurses are among the reasons women prefer TBAs instead of health professionals. From previous birth, women who had had a negative experience with the nurses were more inclined to use TBAs perceived to be more caring. Most of the participants in this study explained that they were not treated well during their ANC or delivered previously at the clinic and therefore preferred to deliver at home (Ebuehi & Akintujoye, (2012), Titaley et al. (2010). The teenage mothers who had given birth for the first time in health care facilities explained that they would consider using TBAs in their subsequent pregnancies due to the harsh approach of the nurses in labor wards and the use of abusive language towards them (Tabong et al., 2021).

Sarker et al. (2016) study indicated that health care facilities offer low quality of care whereas the skilled personnel had poor attitude towards the pregnant women. The nurses were cited to verbal or improper language use, neglect just before delivery, and denial of the use of traditional practices while in labor and during delivery. The perception of a woman regarding the attitude of the healthcare professionals from their previous pregnancies affects their future decision to use their care, specifically during childbirth (Titaley et al., 2010). A study conducted in Ghana replicated similar findings. The participants revealed that nurses and midwives shouted and mistreated women by insulting them and speaking harshly during labor and delivery (Tabong et al., 2021).

2.1.7 Family-Related Factors

Family-related factors has been cited as reasons why many women prefer delivery by TBAs. A study conducted by Ebuehi and Akintujoye (2012) indicated that women depending on finances and decision-making from their partner were significant reasons women delivered at home. Given the low economic levels of their partners, preference was on traditional birth attendants as they were perceived to be relatively cheap in their services and had a flexible payment plan (Adatara et al., 2019).

With low income, this translated to a delayed and reduced number of recommended antenatal clinic visits. And in most cases, they resorted to home delivery using a traditional birth attendant (Titaley et al., 2010). These are reasons that played a significant role in introducing free maternity programs in most low- and middle-income nations. With such programmes , it was expected that most women would prefer free maternity services as they don't entirely depend on their partners for financial support during the delivery process (Sialubanje et al., 2015), MOH, 2019).

2.1.8 Limited awareness creation of maternity initiatives

A study on free maternity service by (Omollo, 2015) showed that most women and staff were not aware of free emergency medical services offered to women during delivery at home. It was extensively highlighted the laxity by the government on cascading information at all levels on free medical emergency response resulting in its underutilization and aggravating maternal deaths that could otherwise be managed.

From the study, postpartum care reduced maternal mortality though quite a low number of women sought these services, especially after home delivery. Most women were not aware of the free postpartum service offered (KNH, 2015, MOH, 2015)

Though Kenyatta National Hospital has a 'Safe Motherhood Initiative' though staff and patients knew little about it, this strived for the following free and quality services: skilled attendants during delivery, emergency obstetrical care and reproductive health care, family planning, and safe post- abortion care (KNH,2015). From the study, little is known about such initiative by the government showing a disconnect in information flow.

2.2 Hypothesis

This projects' primary hypothesis is to develop a universally simplified model that can adequately explain the historically observed behavior patterns of maternal mortality at an aggregate level.

We look into the different relevant issues raised during the research and seek further understanding pregnant women use when deciding whether to choose traditional birth attendants or opt for skilled birth. Several issues ranging from convenience, social and economic factors, financial, human, and capital infrastructure are further discussed in the literature.

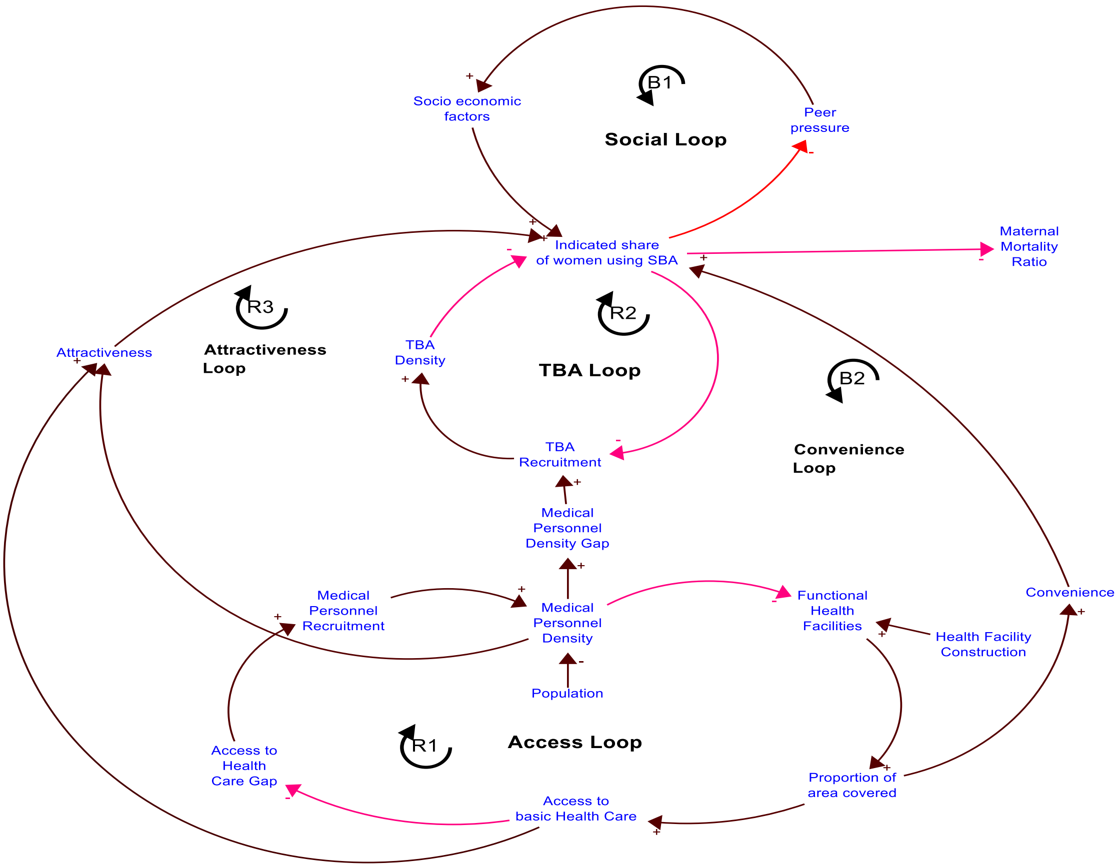
Pregnant women consider several factors directly affecting them before deciding where to give birth. Some of which include access to primary health care and distance to be covered, the maternity costs, socio-economic factors (family influence, peer pressure, perception of risk, literacy level, income levels e.t.c), and the general attractiveness in terms of medical personnel adequacy, traditional birth attendant's availability and perception among other factors. The study considered several factors, and these are not the only explanations that determine maternal mortality. Figure 2 shows a simplified causal loop and feedback influencing the choice of birthplace and maternal mortality.

Given the complexity surrounding maternal mortality, the maternal mortality ratioin this paper is represented as a function of maternal deaths and pregnant women. Maternal deaths are calculated as a proportion of risk from the skilled birth and home birth.

In the model, the proxy indicator is 'indicated share of women using skilled birth attendants'; from this, we can calculate the proportion of women using skilled health care and those using traditional birth attendants. An assumption of a negligible number of multiple births and that fertility rate is normal at around three children per woman in reproductive age. As more women chose skilled birth, and the feedback mechanisms reduce the number choosing homebirths reduce from the influence of peers as shown in the 'social Loop.' With fewer opting for home birth, few TBAs are recruited, and preference is now on skilled birth as shown by the 'TBA loop.'

In the access loop, the critical consideration is the 'access to primary health care, which is determined using the number of functional health centers. This is evaluated based on the presence of medical facilities, the funding level to these facilities for their operations, and the adequacy of medical personnel for it to be considered fully functional and operational. Based on the health center coverage and the number of medical personnel density to the population, this influences how attractive the skilled birth is. Hence the higher both are, the more attractive they are to women than unskilled birth and if more attractive and convenient, more opts for skilled birth, and as such, few TBAs are recruited hence influencing the TBA loop and social loop through peer influence to choose skilled birth.

Figure 2: ***Simplified Causal Loop Diagram***



Alongside the theoretical challenge of understanding the decision-making process to choice of birthplace, the practical challenge of developing a simulation decision mechanism is to inform informed policy structures. Assessment tools to determine maternal mortality exist in the research field (WHO, 2010). Most of these applications do not operationalize the feedback mechanism, which is critical in system dynamics modeling. It captures how the different sectors interact and respond to such interactions. This research recognizes such models and their shortcomings and design simulation while considering these feedback mechanisms (Forrester, 1987). And after that, design policies to address these policies issues accordingly.

Chapter 3: Model Description

3.1 Introduction

To examine this problem, we develop a simulation model to represent maternal mortality and decision making, and we test the endogenous behavioural response. The simulation builds on extensive review of the literature and identified assumptions within the hypotheses. It serves as pre-requisites to the understanding decision making in choice of birth attendant given the access to primary health care, health personnel in compared to home deliveries using the traditional births attendants. Although much literature is available, most of it focuses more on the technical aspects and less on the feedback processes. Hence the preference of system dynamic modelling to other methodology as feedback is key and taken into account.

A simulation model is developed using the System Dynamics (SD) modelling methodology, which explores decision making and maternal choices of birth attendant. SD modelling is a simulation approach applied to complex, dynamic problems. It involves a dynamic definition of the problems as they develop over time while focusing on an endogenous view on the complex feedback between various elements in the system. Those elements will be represented as variables, stock, and flows and are explored as continuous quantities. SD modelling as an approach is considered as being "an iterative and interdisciplinary process, which views problems holistically" and can be used in all fields and applied to a complex, interconnected problem (Forrester, 1987).

A variation of methodological approach will be employed to address the assumptions of the hypotheses made. The reviewed literature focused on decision making and maternal choices. Data will be obtained from secondary sources, both published statistics and from accredited institutional online databases.

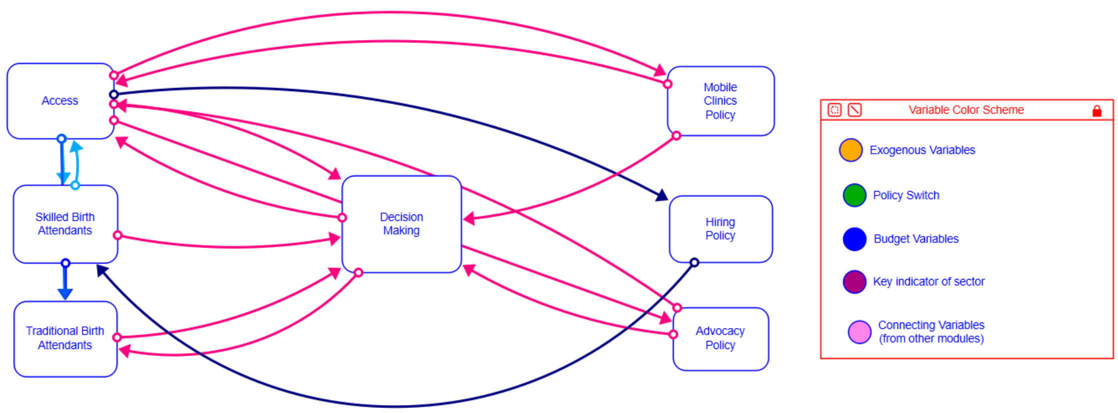
SD approach has been developed and used over time as an applied method focusing on policy design and testing. It will lay the foundation for the application of feasible policy options. It has also been used as a tool to develop and test theoretical insights (de Gooyert, 2018). Using this approach, we create a system dynamics model, which will serve as a framework that incorporates the many components presented in different literature and studies.

3.2 The Model Structure

The simulation model is built in Stella Architect Version 2.1.1 and Euler Integration Method with a DT of 1/16. The model start time is the year 2000 and stop time is the year 2040 giving a time horizon of 40 years. The start time 2000 gives the base initial data and conditions and in recent past when the Kenya economy had some growth in all sectors and the key reforms had been implemented in Key sectors. The target year for achievement of most policies is per the SDG 2030 and Kenya Vision 2030 and the health sector plans (MOH 2019); this would give sufficient time to observe patterns of model behaviour and trends.

The model of 7 modules all feeding into the decision-making module and finally access module which has the key sector measuring maternal mortality as depicted in the figure 3. In the model graphics depicted in following sections, the colour-coding of the variables are as shown.

Figure 3: Overall model outlook



3.2.1 Access Module

Basic/primary health care access' is a critical challenge in developing nations, especially in the rural areas, hence an impediment to those in the rural to access good essential health services (Bourke, et al., 2012), (Gamm, et al., 2003) (Medicine., 2005). In this module, we use the health centre infrastructure to measure access to primary health care.

3.2.1.1 Maternal Mortality

The Maternal mortality sector indicates the core parameter of the project as it is our crucial health performance indicator. The red coloured centre variable shows the estimated 'maternal mortality ratio', which is a division between total women dying from pregnancy and births over the number of pregnant women. Maternal mortality can be caused by haemorrhage, pregnancy-related hypertensive disorders (i.e. preeclampsia, eclampsia), and other medical conditions like chronic heart disease, diabetes, and hypertension. These conditions heighten the risk of complications during pregnancy or postpartum (WHO, 2019) (CDC, 2020). As such, the risk of death under skilled birth is lower than home delivery as proper diagnosis and management can be done.

Here in this Stock flow diagram (SFD), 'the indicated share of women using SBA' measures the number of women having hospital delivery and directly determines the proportion of skilled births. With this, we can calculate those births by TBA and further estimate deaths caused by birth at the hospital or home, given their risk factors.

According to Pregnancy Mortality Surveillance System, maternal risk variability in death arises from a range of factors, including immediate access to skilled care, health care quality, and chronic conditions prevalence, among other in pregnant women ((CDC, 2020).

Figure 4: Maternal Mortality Sector

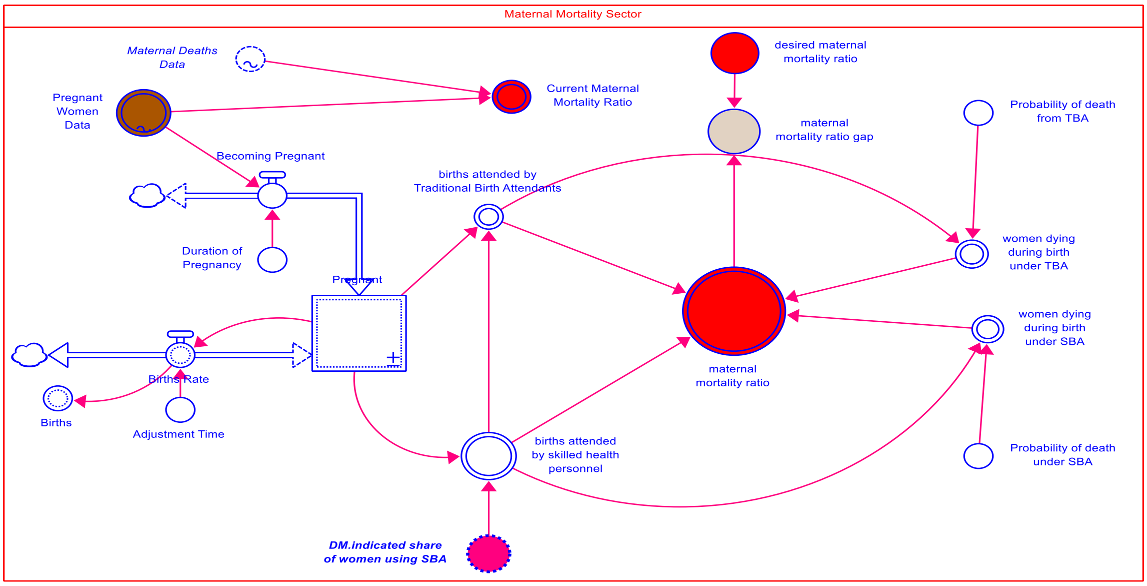


Figure 4 provides a descriptive simulation of maternal mortality, given the number of births and deaths of pregnant women compared to the current maternal mortality statistics. The recent maternal mortality is obtained as the ratio between maternal deaths and the number of pregnant women.

The 'indicated share of women using SBA' is modelled in a dynamic structure under decision-making, which tries to capture the various factors identified under the hypothesis and modelled in the other different modules and introduced exogenously, e.g., literacy levels, fertility rate e.t.c.

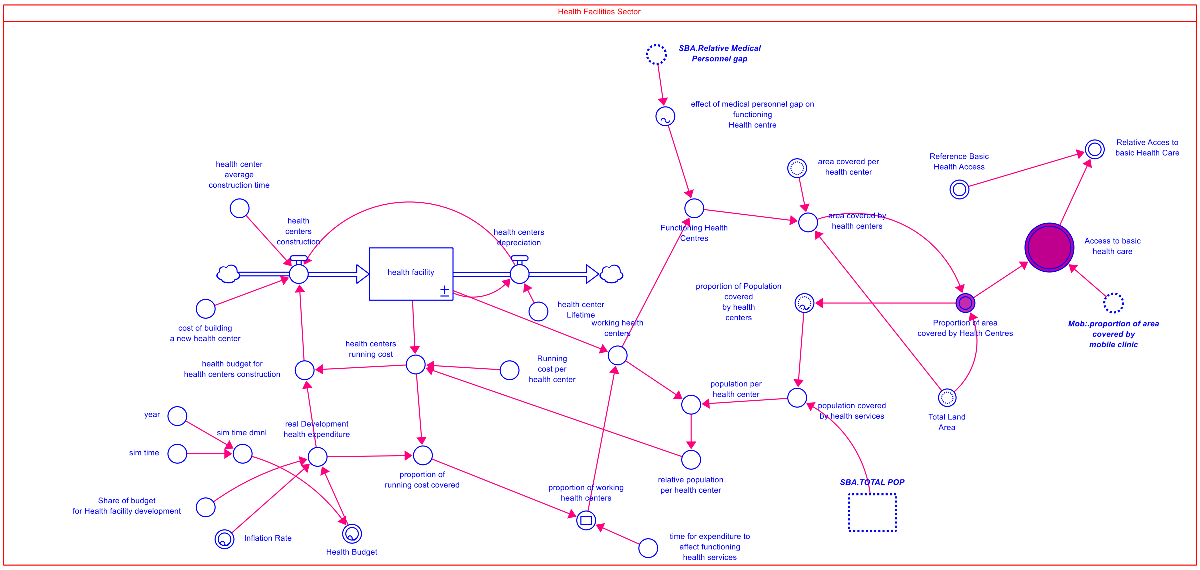
With further improvements in the health sector through policy intervention later in chapter 5, we model different policies and see their impact on the 'indicated share of women using SBA' under the decision-making module and the maternal mortality ratio under 'access module'. The introduction of the policies is tailored and geared to ease decision making among women and increase the number of birth with skilled personnel increases and, in turn, reduce maternal mortality.

3.2.1.2 Health Facilities Sector

We initialised our Health facilities stock at 1679 which was number existing as of 2000 start year stock. With the Health development budget, we are able to calculate how many additional health facilities can be constructed given after deduction of running costs of existing facilities as such the delay function is introduced into the flow structure. This delay takes into account the legislative and bureaucratic reality of actualising such development programmes. We calculate a proportion of working health facilities as a proportion of running costs covered. To obtain functioning hospital, we multiply with the effect of medical personnel density. With this we intend to show that some hospitals could have the required allocations but still have inadequate staffing; this has a negative relationship on proportion of functional health facilities.

Having number of functioning health facilities and the total coverage from these facilities, we use that to calculate ‘access to primary/basic health’ as a proportion of the total land area.

Figure 5: Health Facilities Sector



3.2.2 Medical Personnel Sector

With the ‘access to basic health care’ we use that to generate the requisite medical personnel that will ensure we achieve the ‘reference basic access’ of atleast 80 percent (WHO, 2019). The medical personnel sector investigates the general capacity levels of doctors and nurses in hospitals. These medical personnel play a critical role during childbirth.

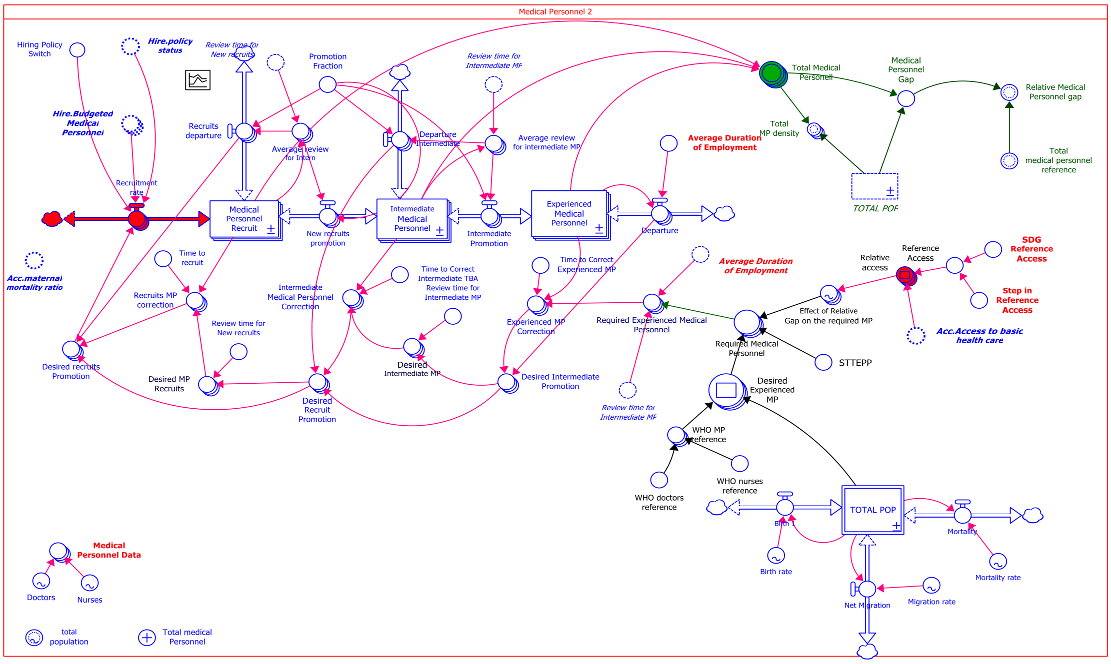
We use 3 stocks to represent the different levels of experience: recruits, intermediate and experienced medical personnel. The stocks are initialised to their desired level after adjustments of the desired prior stock promotion to ensure equilibrium.

In each stock, the desired promotion originates from its respective stock correction gap function, the following, and an addition of to its outflow. The total number gives the quantity required to bring the system in a steady state. For example, the desired MP recruits is the summation of the recruit’s departure, recruits MP correction, and the desired new MP promotion. This principal applies to all the other stock correction mechanism.

The three stocks also have a correction variable which is a gap function which calculates the difference between the desired stock level and the actual MP over the time required to correct this disparity which is one year and tracks the annual statistics by the number of persons. For example, the intermediate MP correction calculates difference between the desired and the actual intermediate MP over the time required to correct this disparity which is one year.

Hiring is controlled by the budget that is available and the desired recruit promotion; this is defined by minimum function of both and a third order delay.

Figure 6: Medical Personnel Sector



3.2.3 Traditional Birth Attendants Sector

Most women also prefer to use the services of TBAs since they perceive that in health care facilities, there are a lot of unnecessary operations performed on them (Tabong et al., 2021). Some women also perceived that when one visits a healthcare facility during the delivery process, and there are some delays in labor, a caesarean delivery would always be performed, unlike TBAs, where a woman would always be given some herbal medications to facilitate delivery through the vaginal birth (Tabong et al., 2021). Some of the women in rural and deprived communities link motherhood to vaginal delivery. They, therefore, take pride in the ability to give birth via the natural unmedicated birth (Tabong et al., 2021). Titaley et al. (2010) believed that children who are delivered via the C-section are weak compared to those delivered through vaginal delivery.

The primary strength on TBA use was their availability and accessibility especially in remote areas where there is limited accessibility to health facilities. TBA are equipped with indigenous undocumented knowledge especially on herbs and foods to be (or not) consumed during pregnancy and at childbirth which is not possessed by SBA. From SBAs perspective, the TBA strength is drawn from their emotional and practical support they to mothers and played a huge role in encouraging mothers to attend antenatal clinics and adhere to practises immunisation. As such were widely trusted and had good communication and relations with mothers and hence their immense influence in communities. Though they were faced with challenges especially with managing complications in childbirth, some practised unhygienic and dangerous practises mostly linked due to lack of training and knowledge (Bryne, et al., 2016). Several studies have identified women mistreatment in form of verbal abuse, neglect and abandonment during delivery in health facilities as a key deterrent to accessing facility-based delivery compared to emotional support offered by their counterparts TBA (Bryne, et al., 2016) (Balde, et al., 2017).

This sector is triggered by the medical personnel gap. When there are in adequate doctors and nurses in the health facilities especially in rural areas, women would prefer to childbirth by assistance of traditional birth attendants (TBA). This sector represents the personnel responsible for home deliveries. This normally consists of women who play the role of midwives during childbirth especially in rural Kenya where the health facilities are not easily accessible. In this sector the TBA are classified into 3 stocks representing the level of experience from recruitment: new recruits, intermediate and experienced stocks. The new recruits are affected by inflow of the new recruits and an outflow of new recruits' promotion and departures. The Intermediate stock is affected by the inflow of recruit promotion and an outflow of intermediate promotion and departures. The third stock of experienced is determined by an inflow of intermediate promotions and an outflow of attrition.

The stocks are initialised at the desired level, this gives the equilibrium state where the respective inflows equal the outflows. The module uses the Supply and demand correction concept, where the capacity is corrected based on the existing gaps and hence bring the system to equilibrium.

Once one is recruited, they are birth attendants for the rest of their life hence the retirement period of 60 years as compared to professional doctors who work half these years. The total TBA only includes the intermediate and the experienced; since we assume that the recruits hardly deliver alone as they work as assistance to the intermediate or experienced which is normally the case.

The desired experienced TBA is determined by the number of mothers seeking the traditional birth attendants and the desired density of experienced TBA which is a smooth function of the density affected by the medical personnel gap. So that when the gap is wide there is need to have more additional TBA to supplement this emerging gap.

In each stock, the desired promotion originates from its respective stock correction gap function, the following and an addition of to its outflow. The total number gives the quantity required to bring the system in a steady state. For example, the desired TBA recruits is the summation of the recruits departure, recruits TBA correction, and the desired new TBA promotion. This principal applies to all the other stock correction mechanism.

The three stocks also have a correction variable which is a gap function which calculates the difference between the desired stock level and the actual TBA over the time required to correct this disparity which is one year and tracks the annual statistics by the number of persons. For example, the intermediate TBA correction calculates difference between the desired and the actual intermediate TBA over the time required to correct this disparity which is one year.

A study done in West Pokot County indicated that 66.7% undertook home delivery which is 6.3 percent lower compared to previous statistic of 74%. These figures are still pretty high in comparison to other similar rural setups. This gives a clear overview of the huge disparity in utilization of maternity services in rural and urban settings and shows the preference of women towards home delivery as opposed to skilled birth assistance in Health facilities despite the many initiatives done by the government (Otieno, 2015).

Below is the basic structure used to populate the 3 stocks in additions to the various adjustment times.

Figure 7: Simplified Traditional Births Attendants Sector

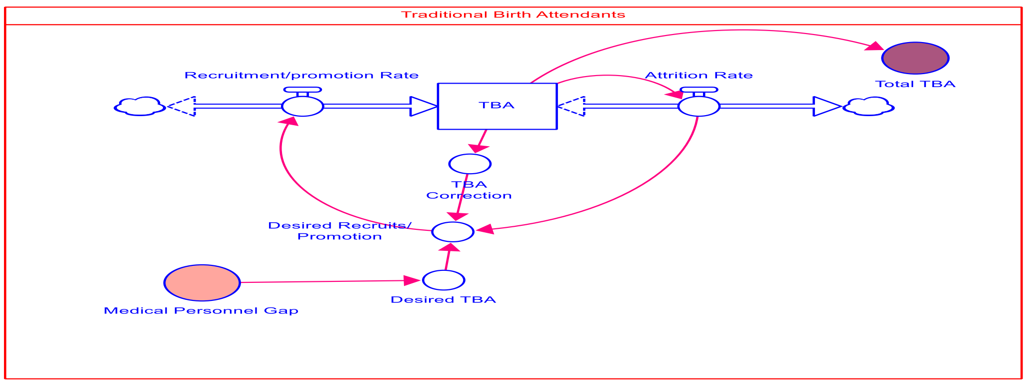
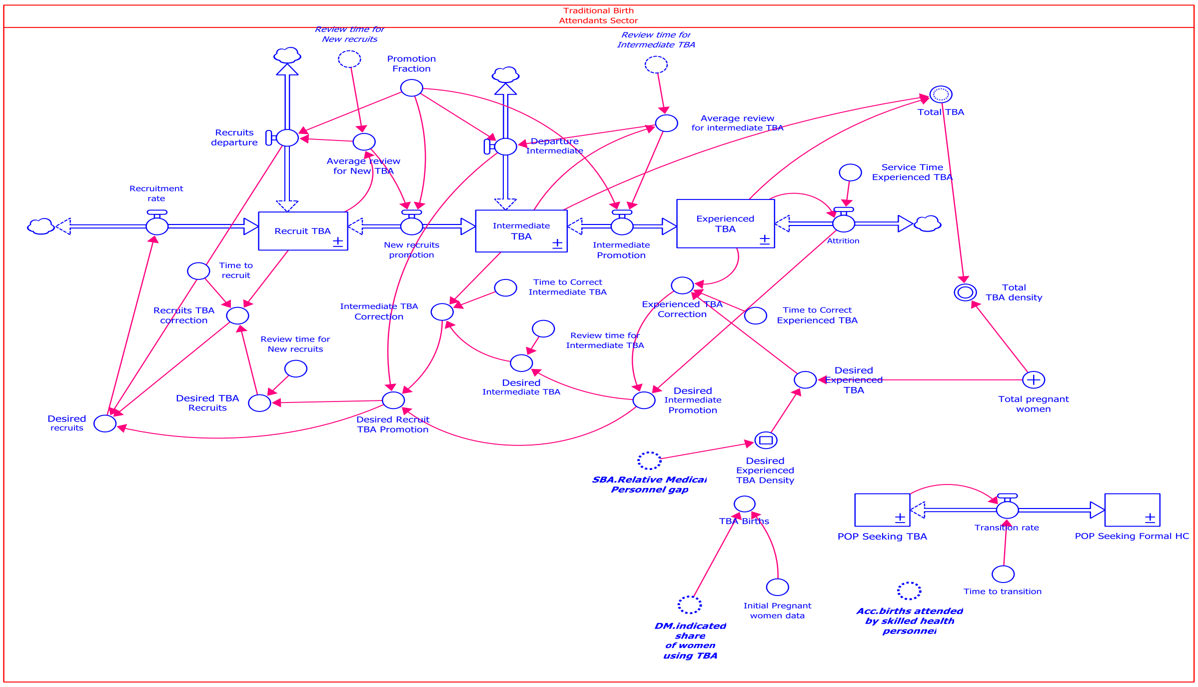


Figure 8: Detailed Structure of Traditional Births Attendants Sector



3.2.4 Decision Making Sector

According to International Confederation of Midwives, decisions making at an individual level impact individuals at other levels (ICM, 2019). In this case, the decision made at individual level or family level when aggregated at community level affects what is done regionally and at the national level. 'Chapter 15.1 pg. 598 of (Sterman, 2000) focuses on human decision making: This best summarizes decision making among pregnant women as he puts it 'Bounded rationality results from our knowledge constraints, cognitive skills, and time factors. Our views/perceptions about things are selective, our real-world knowledge is incomplete, our mental models are imperfect and simple, our mind powers to deduce and infer is weak and fallible. Emotions, subconscious, among other non-rational factors influence our behaviour.''

This sector investigates some of the critical issues that women consider when choosing whether to have a home or hospital delivery. In this we look at the cost associated with delivery both at home delivery and hospital delivery, the convenience, social factors, attractiveness, and other factors which would cover all other factors not addressed in the research work.

3.2.4.1 Maternity Costs and Pregnancy related Costs

Sialubanje et al. (2015) study explained most women used TBAs because they have a perception that there are various barriers that would prevent them from skilled delivery. Major challenges explained include inadequacy of finances to purchase baby clothes and the requirements that a mother must meet during and after labor. Another study by Titaley et al.

(2010) supported the outcome of this research, which explained that high costs are why most women prefer to use TBAs. The research participants in the study explained that the average cost of delivering a baby by a midwife is approximately 35dollars. Most of the research participants stated that is amount is high for most community members. Furthermore, health care facilities don't have a flexible payment model. Most of the participants in the study by Titaley et al. (2010) explained that they prefer TBAs since they have a flexible payment method that is convenient for them.

Most healthcare facilities in deprived and rural communities are also quite far (Cheptum et al., 2017). The vast distances to the healthcare facilities translate to increased costs to travel to the health facilities. TBAs, on the other hand, are within the communities. They are easily accessible and often come to the homesteads of pregnant women to offer their services. According to Cheptum et al. (2017), TBAs are preferred by most people because they are readily available as they live within the community in comparison to the skilled care providers in healthcare facilities are far. This approach takes away the transportation costs associated with hospital delivery.

Delivery cost is divided as costs associated with home or hospital delivery. The costs vary and home delivery is cheaper as compared to hospital delivery. Home delivery cost is initiallised at atleast Kshs. 1,000 and Hospital delivery at Kshs, 5000 which is the cost government subsidies in free maternity programme. In 2013/2014, the Kenyan government free maternity services was introduced in all public health institutions which ensured all costs associated during delivery was scrapped off; this was pitched towards improving the women lives/lives of women and ease access to quality maternal health. This aimed to reduce maternal mortality which was still high at 360 to 100000 live births against the SDG target of at least 70 births to 100,000 live births (GOK 2013). We discuss this later under the scenarios in chapter 5

We capture the incidental costs which captures the transport costs during hospital visits, average antenatal costs which is based on number of visits and the fee charged is mostly associated with the tests one has to conduct during pregnancy and pregnancy incidental costs which captures the extra cost during pregnancy resulting from special diet, extra supplement or medication and additional baby stuff budget.

Convenience captures effect of health center density and the distance to be covered to nearest health facility. All these have an inverse relation to convenience so that if the health center density is low then its effect on convenience is low and hence not convenient for hospital delivery. With an initial distance to be covered and the introduction of mobile clinic programme increases the convenience by reducing the distance to be covered.

Cheptum et al. (2017) study in Migori county showed that motorcycle is the most used form of transport. These motorcycles, however, do not have comfortable carriers that can carry pregnant women securely.

Socio-economic factors this captures all the factors that influence at the societal level. Family expectation in the rural setup plays a huge role in decision making especially for young mothers; proportion of women giving birth had a major feedback loop on the peer pressure and its influence is positive so that if many women gave birth at home in a certain regions, then one would give birth at home. Overtime as one has more births the subsequent births can take place at home especially if they did not have complications in prior births. A study in Bangladesh like the case in many third world countries showed that home delivery remains the most preferred and poverty was cited as the main reason for its preference (Bidhan, et al., 2016). Perception of risk is influenced by the proportion of women who dying during childbirth at home and statistic in east Africa (Tanzania) shows that 1 in every 126 women die as a result of maternity complications, and the same was replicated in Ghana too.

Some social and cultural norms have contributed to pregnant women preferring the services of TBAs. Majority of older women preferred the use of TBAs as opposed to going to health care facilities because they hold the belief that a male staff in a clinic or a younger nurse should not help them to deliver. In this case, most women prefer to stay away from these facilities and instead deliver at home through the assistance of TBAs who are female and aged older than them. Some of the participants, most of whom are young teenagers and inexperienced women, explain that they deliver at home because they don’t have experience in child delivery and don’t understand the time, they were going into labor. (Sialubanje et al. 2015),

A study in rural Northern Ghana regarding cultural beliefs and practices of women influencing home births, it was explained that the cultural beliefs of pregnant women play a significant role for them while deciding where to give birth. The utilization of TBAs offers the birthing woman an opportunity to be around some of the family members like their mothers or sisters and other women who would provide them with support like back massaging that allows the pregnant women to deliver with ease and reduced anxiety (Adatara et al., 2019). In healthcare facilities, on the other hand, they do not permit family members to go inside the delivery room to provide support. The study also recounted that TBAs were excellent at maintaining the confidentiality of the delivery process as opposed to cases of exposure in the health care facilities.

One of the participants in a study by Titaley et al. (2010) explained that TBAs are closer to the community, and as such, they have earned a respected position in society. Some of the participants also explained that they use TBAs because of the influence from their family members, like their older sisters or parents who have used these services before (Titaley et al., 2010).

Attractiveness: when the health sector that fall below the 23/10000 threshold, they strive but fall short to provide skilled care hence has direct consequences on the maternal deaths. Hence it becomes less attractive for women to deliver in the hospitals. This is calculated based on perception of availability of TBA, effect of access to health care and effect of adequacy of the medical personnel in the health centers.

The primary strength on TBA use was their availability and accessibility especially in remote areas where there is limited accessibility to health facilities. TBA are equipped with indigenous undocumented knowledge especially on herbs and foods to be (or not) consumed during pregnancy and at childbirth which is not possessed by SBA. From SBAs perspective, the TBAs strength and preference is drawn from their emotional and practical support they provide and played a huge role in encouraging mothers to attend antenatal clinics and adhere to practises immunisation. As such were widely trusted and had good communication and relations with mothers and hence their immense influence in communities. Though they were faced with challenges especially with managing complications in childbirth, some practised unhygienic and dangerous practises mostly linked due to lack of training and knowledge (Bryne, et al., 2016).

TBAs were deemed to be always available and upon reach within the shortest time possible during labor and delivery regardless of the time of the day or the weather conditions. This was in contrasts with the nurses who are perceived as not always available in clinics (Sarker et al., 2016) (Sialubanje et al. (2015))

Most of the older women have a perception that TBAs are the safest form of delivery and therefore influence the younger mothers also to use the services of TBAs. Some women perceive some skilled midwives as young and inexperienced, while TBAs were perceived as mature, patient, and caring (Manyiwa, 2018). These perceptions have resulted in more women preferring the use of TBAs as opposed to younger health professionals. There is also a perception among some women that health professionals are only needed when there are complications, such as women who have experienced obstetric complications (Ebuehi & Akintujoye, 2012). A study by Ogbo et al. (2020) explains that most community members in the rural and deprived communities believe that the services of midwives should only be sought when the TBAs cannot handle the situation.

Other factors

Good interpersonal relationship and practices by TBAs/perception was one of reasons preferred TBA. It has also been noted that most women have developed trust with the TBAs. Women perceive the delivery process as a personal procedure that requires the services of someone they trust. The study also explained that TBAs had created an excellent interpersonal relationship with the women (Sialubanje et al., 2015). This makes the woman more comfortable without services; hence they can freely discuss with the TBAs their personal feelings and fears as compared to health professionals.

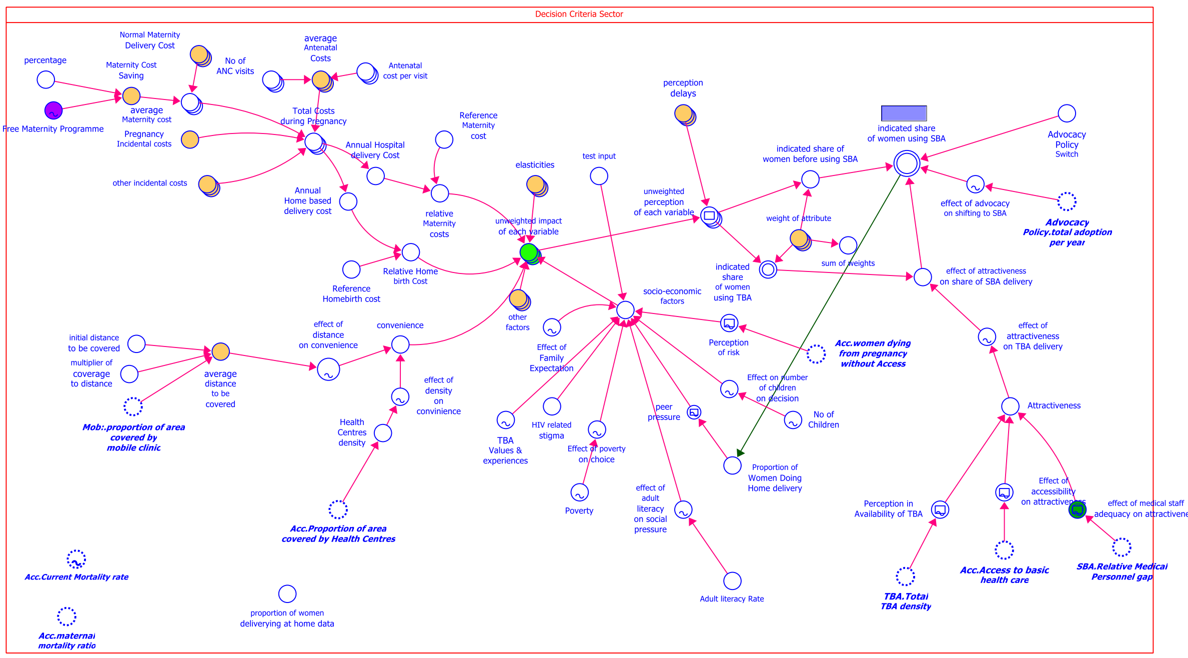
This reason has been supported by the study by Adatara et al. (2019), where the study participants explained that they prefer to use the services of TBAs since they accorded the opportunity to choose their preferred birthing position. In most health care facilities, pregnant women are forced only to adopt the supine delivery position. The TBAs, on the other hand, are more flexible and allows a woman to choose any positions they are comfortable with as long as it does not harm the mother or the unborn baby (Adatara et al., 2019). Some of the participants explained that while using the services of a TBAs, they have even given him birth on a sitting position, standing or squatting; positions they perceived to be more comfortable and ease the delivery process. Since they speak the same local language as most of the TBAs, live in the same community, and share most of the cultural practices, the TBAs have earned a high level of trust in the community (Sarker et al., 2016). These factors have left most of the women preferring to stay at home and get the services of the TBAs as opposed to going to the clinic where nurses are hardly available.

Several studies have identified women mistreatment in form of verbal abuse, neglect and abandonment during delivery in health facilities as a key deterrent to accessing facility-based delivery compared to emotional support offered by their counterparts TBA (Bryne, et al., 2016) (Balde, et al., 2017).

Indicated share of women using SBA is supported by the study done in Zambia rural areas. The study assessed the determinants of home delivery in rural Zambia, showed that 42% of delivery was done at home citing persistent challenges in accessing quality maternity care. From the study its imperatively noted that access to skilled birth with capability to support emergency obstetric and newborn care was essential to reducing maternal mortality. (Nancy, et al., 2018); In 2010 a study showed that 69 percent of maternal mortality in sub-Saharan Africa, Kenya included was largely centred in 16 countries where not more than 50 percent of births was attended by skilled medical personnel. In these countries there was presence of large, underdeveloped rural areas where women gave birth traditional at their homes. The rural population ranges from 44% to 90% and is largely characterised by high poverty rates, large distances to health facilities, and inadequate and or improper transportation and therefore serious complications during childbirth too often led to the death of a mother and/or the new-born (Ndola, et al., 2011)..

Indicated share of women using SBA is influenced by factors beyond individual control. In this model its widely influenced by the factors discussed above including attractiveness, convenience, delivery costs, social economic factors among others.

Figure 9: Decision Criteria Sector



3.2.5 Summary Table of exogenous variables

Table 2 shows the summary of some of the exogenous variables used. All other variables are further detailed and described in the model documentation (Annex 1)

*Table 2: Brief **Summary table of variables***

Variable		Unit	Description	Source
Probability of death under SBA	**130/100000**	**dmnl**	Maternal death risk in a low-income country is approx. 130 times higher compared their counterparts in a developed country	https://www.who.int/data/gho/data/themes/maternal-and-reproductive-health
Probability of death under TBA	**1/55**	**dmnl**	An estimated 1 in 55 women face a lifetime risk of dying of maternal causes in developing countries	**https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3126980/**
Fertility rate (children per woman)	3.363 (2021) Table function	**Children/person**	The fertility rate has decreased from at least 8 (the 1970s) to less than 5 (1990s), and recent past plateaued at just over three children. In 2021, the fertility rate shows a 1.55% decline from 2020 (births per woman)	https://www.statista.com/statistics/451135/fertility-rate-in-kenya/ https://www.macrotrends.net/countries/KEN/kenya/fertility-rate
Literacy Rate	Table function	**dmnl**	The adult literacy rate estimates the proportion of persons (over 15yrs) who can read and write with some basic understanding of short, simple statements about their everyday lives. In 2015, youth female illiteracy was 47.4 % (2015), showing a gradually decline from 54.5 % (2000) We assume that the literate population is (100- illiterate female rate)	https://data.worldbank.org/indicator/SE.ADT.LITR.FE.ZS?locations=KE&most_recent_year_desc https://knoema.com/atlas/Kenya/topics/Education/Literacy/Youth-female-illiteracy

4.Model Analysis

4.1 Model Validation

Models are useful tools if they generate the right behavior and explain or support existing literature. The purpose of model validation is to:-

i. Build confidence in the usefulness of the model for the intended purpose and address the research questions;
ii. Provide extensive and descriptive interpretation of model behaviour;
iii. Highlight the key variables and attributes influencing decision making that would influence the key performance indicators.

In this case we developed the model to show the test decision making process of the pregnant women and their choice of place of birth and how this play critical role in maternal mortality rate of the country. The causal loop diagram (figure 2) stands for the causal hypothesis describing the interaction of relation and interactions of the factors over time. Several model validation testes such as unit consistency test, comparison of reference and model simulated behavior test, structure-behaviour test, extreme condition test etc. are done to boost confidence on the usefulness of the model. ((Barlas, 1996) (Sterman, 2000)). Of these validation tests, two of them are presented below.

Table 3: Model Validation Test

S/No	**Test**		**Description**
a.	Structure Confirmation		Based on the literature review above cited the mechanisms behind the decision making to choose of birthplace, the structure described above was developed. From the literature, we developed the structure; in future research this can be expounded to cover any other areas or purpose
b.	Parameter Confirmation		The parameters used in this model are estimated based on the existing literature. A detailed analysis can be found in the model documentation Annex 1 The structure is appropriate for model purpose.
c.	Dimensional Consistency		The model exhibits dimensional consistency and variables with real-world equivalents;
d.	Integration error test Method		The model behaviour remains the same i.e. Not sensitive; with quarter, half and a sixteenth time step, as well as with a different integration method (Runge–Kutta 4 and Euler). The model setting choices are appropriate.
e.	Extreme conditions and Sensitivity Tests		The system is dominated by reinforcing loops and, as such, is sensitive to the parameters determining the strength of those loops. The system passed the extreme condition test. For all the sensitivity runs, Incremental Distribution, Random sampling (20 runs) were used. The sensitivity runs were

			performed on the baseline scenario (for detailed parameter values scenario, see Annex 2).
f.	Boundary adequacy test	Strongly valid	Cognizance is taken on structural exclusions and noted as opportunities for inclusion in future researchwork; structure is appropriate for model purpose
g.	Behaviour reproduction	Sufficiently valid	Simulation results give a similar shape and direction as the reference mode; discrepancies in absolute values traced to difference scales of reference and model data as seen in the medical personnel (doctor and nurse), health facilities and the key indicator Maternal mortality as shown in figure 10
h.	Behaviour sensitivity	Sufficiently valid, recommends parameters for further sensitivity testing for model analysis.	Behaviour modes are consistent for decision confirmed; multiple modes of behaviour for financial variables confirmed; sensitivities in time variables traced to parameter values which recommends parameter sensitivity testing for model analysis; multiple modes of financial variable behaviour recommends for consideration in policy analysis.

Please refer to Annex 2 for detailed results of these tests.

4.2.1 Direct structure tests

The direct structure tests is used to assess the validity of a model's structure by comparing it with existing knowledge about the "real world" system. These tests include the structure verification test, parameter verification test, direct extreme-conditions test, boundary adequacy test, and the dimensional consistency test. (Barlas, 1996)

Structure Verification Test: Aims to determine the extent to which a model's structure conforms to existing knowledge about the structure in the "real world" system (Barlas, 1996) This involves comparing the model formulated equations and the existing system and data in 'real world (Forrester & Senge, 1980). The theoretical aspects are compared to existing known knowledge and information in the existing literature and research (Barlas, 1996) or through interviews or primary collection methods (Forrester, 1992).

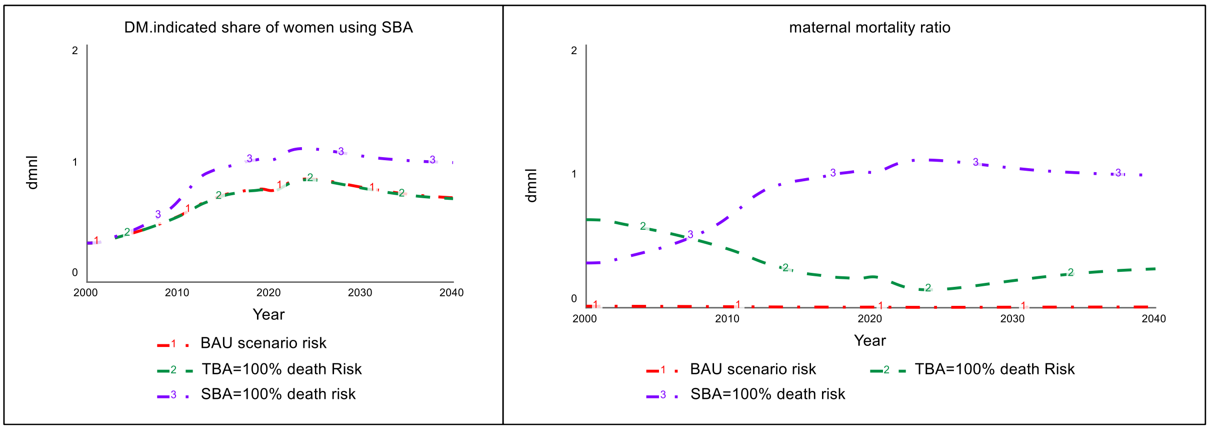
As reported in Chapter 3, the model component representing different modules was replicated and translated into a stock-and-flow structure from the well-founded literature and interaction of variables and causality established from the secondary source review. This part of the model can therefore be considered to pass the structure verification test on an empirical basis as shown in figure. The model variables are developed and backed through the literature reviewed and the secondary data, published scientific reports and case studies which was translated to the stock and flow diagram in the seven modules (Sterman, 2000).

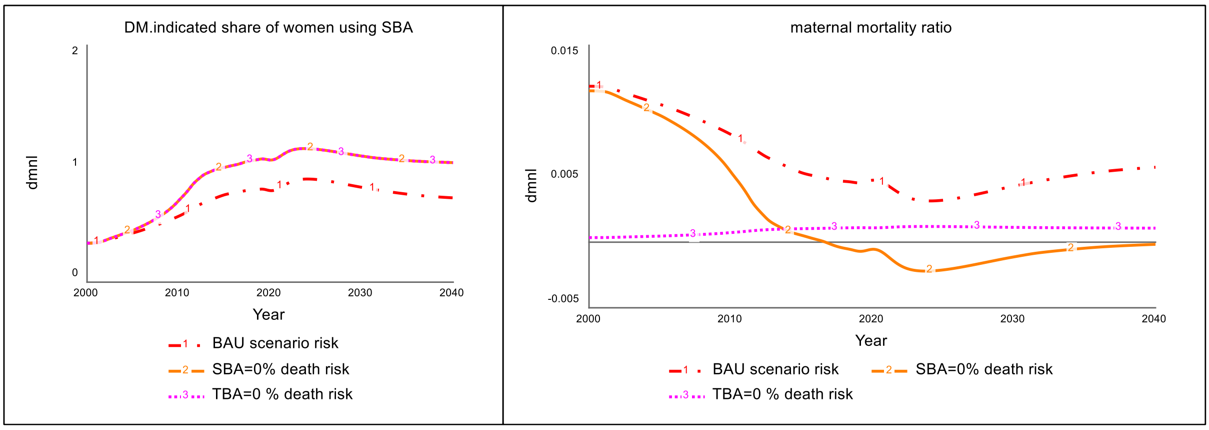
In instances where exogenous variables were used, we referenced that to existing literature as they were not implicitly formulated within the model to enhance the numerical validity. These include the poverty rate, female literacy rate, medical personnel reference e.t.c.
On a theoretical basis, the model can therefore be considered sufficiently valid given its strong grounding in published sources, while proposing some explicit formulations of implicit or hypothesised causal relationships. With Exogenous variables these represents areas of future research.

Parameter verification test aims to estimate and compare each constant exogenous variable against its 'real world' corroborates with the known components of a "real" system (conceptual) and whether their values lie within plausible ranges (numerical) (Barlas, 1996) Based on Chapter 3 and the above discussion of structural validity, the corroboration between the model parameters and existing knowledge of the system can be considered sufficient to provide basis of conceptual parameter validity. Where parameter data was unavailable, assumptions were made and stated using the proxy indicators or available information e.g., the time series data for literacy rate was built on illiteracy rate of women; assuming sum of 100% for both (literate and illiterate).

Direct extreme-conditions test was done to evaluate the responsiveness of the model to extreme setting of each parameter (Forrester & Senge, 1980). This was done by altering either low or high values for each parameter. No errors were detected and as such the model passes the extreme condition test as shown in figure 11. With 100% risk in death both in TBA and SBA,

Figure 10: Extreme condition test





Boundary adequacy test was done to check whether all structures necessary to meet the purpose of the model were present (Sterman, 2000). This model seeks to answer the research objective and specially the research questions hence its functionality must be adequate to identify key structures that are dynamic in decision making on the choice of birthplace and thereby it influencing the maternal mortality.

Given the strong grounding of the model in documentary evidence spanning decision making surrounding maternal birth and maternal mortality, the model boundary can be considered adequate for the purpose. Some of the variables are represented as exogenous variables with the rest included under other factors. In 2013, the government introduced free maternity programme, and as such has been considered a part of the model structure (Sterman, 2000).

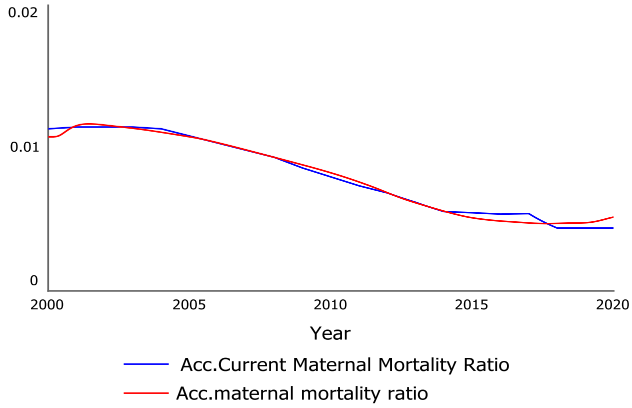
Nevertheless, the purpose of the model was to seek endogenous causes of choice in birthplace as expounded in the hypothesis.

Dimensional consistency test was used to check the mathematically consistency of the units used when formulating the model equation (Barlas, 1996). In Stella, we use the 'check unit function'; in this model, the units of measure are consistent with equations and there are no unit errors hence overall dimensional consistency. On the other hand, it also checks that units have "real world" equivalents such that no 'cheat' variables are introduced with the aim to forceful adapt the model to functionality.

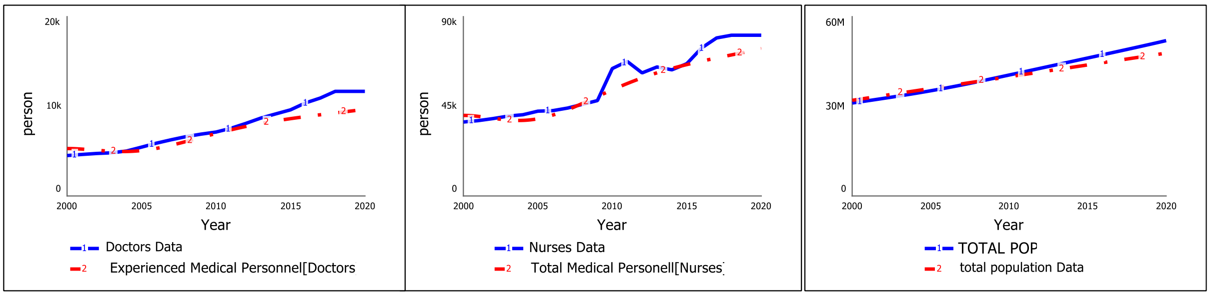
4.1.2 Structure Oriented Behaviour tests

Structure-oriented behaviour tests is useful in determining the model's structure validity and helps uncover any structural flaws. The tests we use is integration error test which tests whether the model simulation results are sensitive to different time steps or the different integration methods. (Barlas (1996), Sterman (2000)). To check for sensitivity, we simulated using different timesteps (0.25,0.5, 0.0625); and using Runge Kutte (RK4) integration all in comparison with Euler integration method. There was no difference in the simulation results; confirming that the model is not sensitive or responsive to different timesteps or integration method.

Figure 11: Reproduction of Reference mode behaviour (historical data vs simulated)



The purpose of the qualitative features test is to assess whether the major qualitative behaviour patterns of simulated model variables correspond to actual data (reference modes) for those variables in the "real" system under specific conditions as shown in figure 11 and it determines whether output behaviour being generated is justifiable (Barlas, 1996, p. 186).



To perform this test, the results of the Base Case, Worst Case, Base Case and Equilibrium simulation runs were compared with reference mode data for the maternal mortality.

As mentioned, table 2, even though the absolute numbers appear sensitive to parameter settings, these actually define local conditions, while the structure produces reasonable behaviour for such conditions. This test thus provides confidence in the validity of the model structure while also recommending parameter sensitivity tests be used to support the interpretation of results. Results of parameter sensitivity tests are reported in annex 2.

4.1.3 Model Calibration

Calibration builds confidence to the structure especially where estimates are used and no real data is available. It gives reasonable real-world variables estimates that would otherwise be very difficult to estimate. The following variables were run through the calibration routine to obtain the estimates:

a. **Initial indicated share of women using SBA;** In 2015, a study showed that only 44 percent women delivered using skilled birth attendants in Kenya (Calverton, 2010) , and with calibration we are able to identify an initial of 48.9 percent which is higher and has been reducing with interventions in maternity services.
b. **Elasticities:** For the 4 categories (yearly costs, convenience, attractiveness, socio-economic factors and other factors we obtained through calibration which obtains a reasonable estimate to capture shows their response in relation to the parameter. How responsive is the parameter over time?
c. **Initial distance covered:** This shows the approximate distance one has to travel to nearest health facility; with calibration it captures 99.5 km; which is intandem with literature which states any distance above 20kms makes women reconsider their choice of birthplace. Initial Distance to health facility varied and for some like Mandera County from 1-301 km (FAO, 2016)

The Calibration details is attached in annex 3

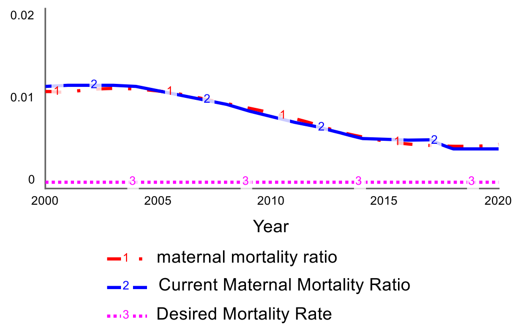
4.2 Behavioural Analysis

We analyse maternal mortality rate using the decision of whether women opt for skilled or traditional birth. The key indicator in the decision-making sector that connects us to maternal mortality sector is the 'indicated share of women using SBA'; using this we are able to estimate the proportion of births attended by skilled health personnel and traditional birth attendants.

From the simulation, the indicated share of women using SBA grows over time from an initial 48.9 percent from 2000 to 2020 as more women make the decision based on the inherent factors such as attractiveness, convenience, and socio-economic and yearly delivery costs over time. This plays a major role determining the maternal mortality statistics.

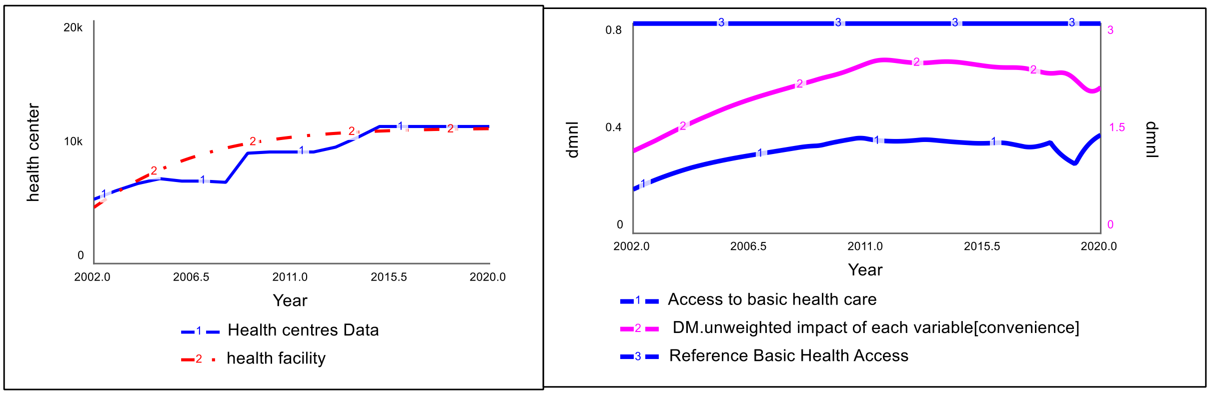
The calibration of the model compared with historical data is accurate as it captures the overall decreasing trend in maternal mortality. The model assumes the input values as of the year 2000 with the existing statistics of the number of health facilities which is 1679 health facilities and the number of pregnant women, the population statistics as at 1999 population census. Some assumptions are done where limited research has been done and an optimization done to beef up the data as shown in annex 3.

Figure 12: Historical data and simulated data for maternal mortality ratio.



There has been a positive trend towards the goal, it is insufficient and falls far behind the 70/100000 live birth's goal as shown in figure 13. The births attended by skilled attendants has increased significantly over the last 20 years. Likewise, on the right graph though the maternal mortality ratio is decreasing, though there is a dire need for further improvements in the health sector that can enhance this reduction at a faster pace. The model gives an almost good historical fit of maternal mortality to the mortality statistics data in Kenya over the years and suggests that with all things held constant overtime the deaths would maintain almost 475 deaths to 100,000 live births.

Figure 13: Access to Basic Health care



Over time 'access to basic Health care' has increased as the number of health facilities are constructed as shown in figure 14. The construction is dependent on the budget available and the proportion of running costs financed; with this the remainder is used for construct additional facilities. As more hospitals are built, the convenience to hospitals also increases as the access increases concurrently, this is concurrent with the reinforcing loop R1 (the access loop). This leads to an increase in share of women who chose skilled birth as opposed to home birth.

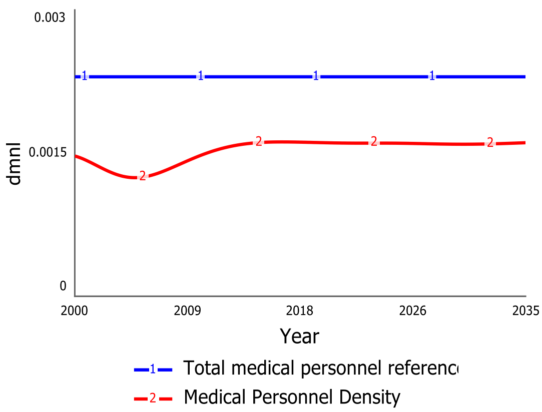


Figure 14: Medical personnel gap

Over the years, as the population increases, the total medical personnel density decreases and increases before it stagnates (figure 15); this put a strain on medical personnel adequacy, their capacity constraints spill over and influences the decision of pregnant women especially in rural areas on the choice of place of birth. The balancing feedback from B1 (social loop), see to it that with such inadequacies, more women would opt for traditional birth attendants who step in with a stronger reinforcing loop R2 and more are recruited to fill this medical personnel gap. With the balancing loop B1 as more opt for traditional attendants the influence it has on peer pressure is higher and this reduces the 'indicated share of women using skilled birth' and vice versa.

In rural Kenya, the hospital density is quite low and access to basic health care (figure14) coupled with medical personnel staffing is limited so in most cases mothers opt for services of TBA. From figure 16, the total TBA density is increases tough in different magnitude to the medical personnel density, high in comparison to the total medical personnel density. As access increases, the attractiveness to health facilities increases and more women opt for hospital births, and this affects the socio-economic factors inversely hence the declining trend and fewer women opting for home births. With time the share of women seeking TBA decreases as the 'indicated share of women using SBA' increases as shown below

Figure 15: CLD on impact of share on SBA and personnel density

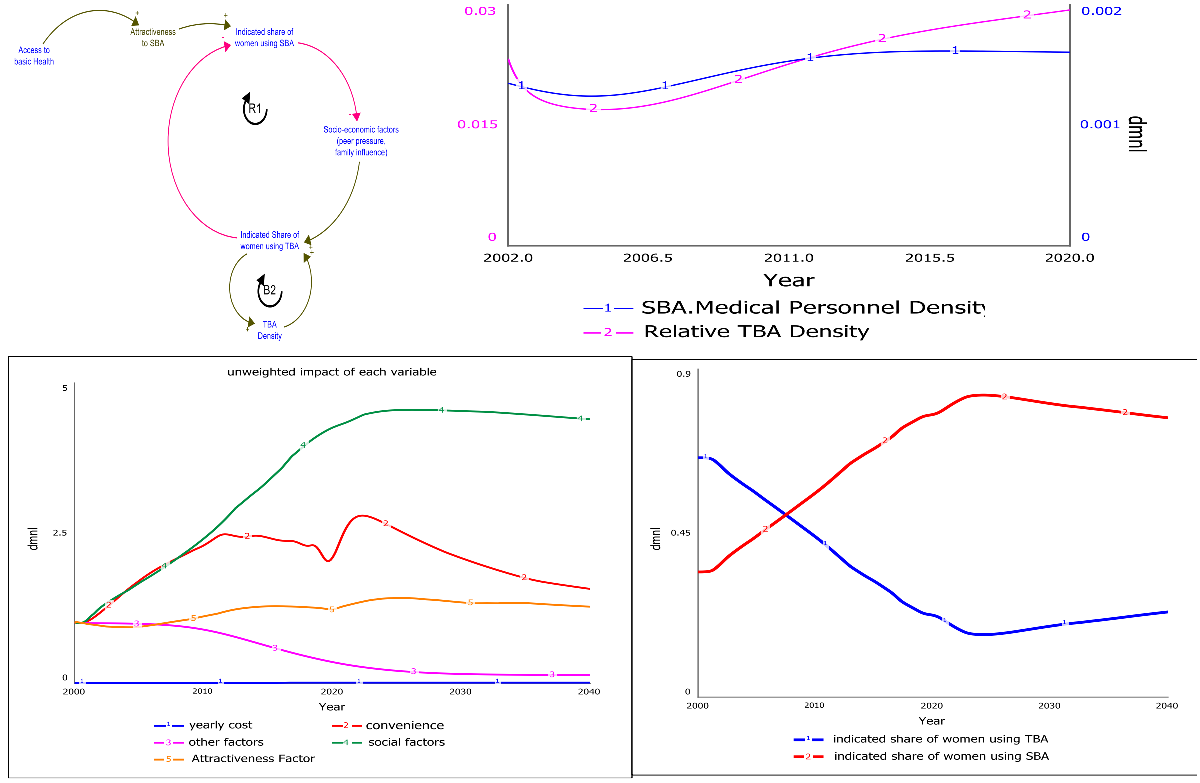
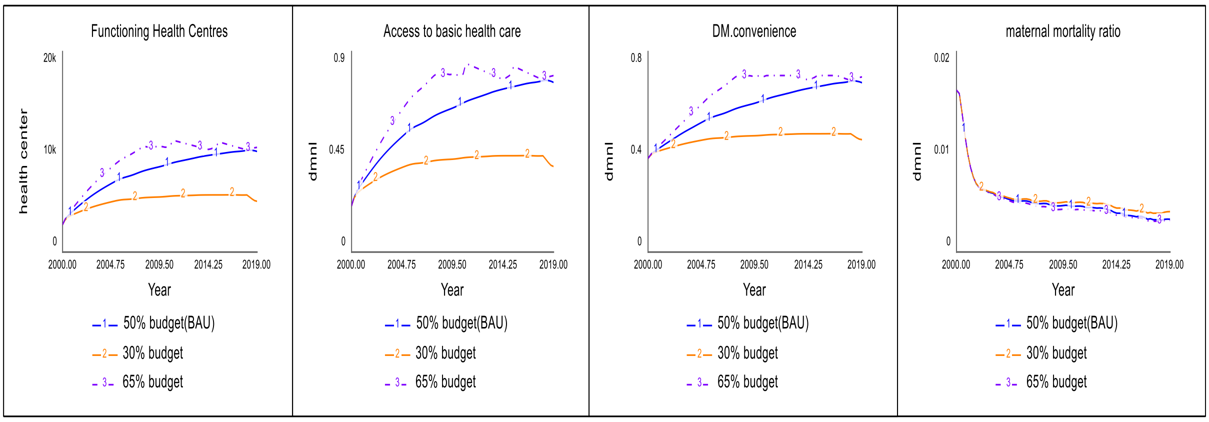


Figure 17 shows the variation of funding and its effect on the various aspects as regards to access to basic health which is measures through a proxy 'Health facilities'. Changes in budget changes the funds available for construction and servicing the operational budgets of existing hospitals. An increase in budget, increases the share of functioning health facilities and their operationalization increases. This attracts more women to deliver under skilled assistance as the it is more convenient to go to hospitals especially in rural areas due to reduced travel distance. Access increases in tandemly and this effect translates to lower maternal mortality as the share of women seeking skilled birth increases.

Figure 16:Changes in Health Development Budget



In 2013, the government introduced free maternity which aimed at ensuring that no fee payment was done during childbirth. Its main aim was to encourage women to use skilled birth; This is detailed discussed in Chapter 5 under existing policies. As more chose hospital delivery the maternal mortality decreases over time. The margin may not be much showing that there are more factors affecting the decision making than money issues; hence the convenience, attractiveness and socio-economic factors.

4.3 Understanding of Basic SFD and Decision making.

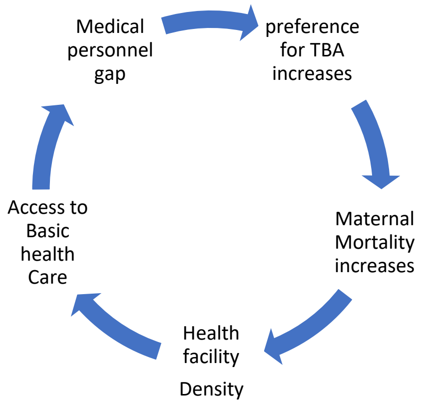
Research Question 1,2 and 3 seek better understanding of the dynamic structure responsible for promoting the choice of birthplace among pregnant women in Kenya. The results of the model analysis revealed that the stock and flow structure of accumulating cause and effect relationships were central to the slow decline in maternal mortality. Here several structures are developed to answer this, figure 18 gives a simplified version of framework behind decision making.

We look at the 'access to basic care'; here we develop a proxy to access through the availability and density of health facilities. The sector is represented by stock and flow diagram (SFD) with this we look at the coverage of existing functional health facilities to the total land area to get the 'proportion of area covered by health facilities' which is a proxy for access to basic health care while taking into consideration the population. To look at the adequacy of medical personnel, we develop a SFD following concept of demand and supply correction mechanism; we start with the desired staffing as per WHO medical personnel requirements and the 'access to basic Health care'; the stocks are divided into 3 (recruits, intermediate and experienced) medical personnel and initialised at their respective desired levels. The desired levels are obtained from the sum of the departures and medical personnel correction.

This ensures the model begins at steady state with the inflows and outflows equal. The recruitment rate in influenced by the recruit start and the hiring rate once the hiring policy is on and budget available to hire additional staff. From the experienced medical personnel (MP) we are able to get the total medical personnel density by dividing with the total population. The WHO gives a reference of 23 medical personnel to 10000 persons and given the MP density; we obtain the Relative medical gap against this reference (WHO,2019).

With the medical personnel gap, this is where the traditional birth attendants come in to fill this gap during childbirth, and the higher the medical personnel gap, the more women opt for home births with traditional birth attendants. This further heightens the maternal mortality especially in avoidable cases where childbirth associated risks and medical emergencies are not accessible. All these factors are critical to decision making among the other individualistic factors further discussed and developed in the decision-making sector.

Figure 17: Basic framework behind decision making (Health center→maternal Mortality)



The additional insight this thesis provides is that the influence on decision making varies according to the operationalised structure developed in this model does not represent a strong reinforcing mechanism to increase input the 'indicated share of women using SBA' and hence influence the maternal mortality.

Research Question 2 on 'what are the causal feedback mechanisms within the dynamic structures influencing decision making of birthplace in Kenya?' seeks took look at the casual relations between the various parameters. These are extensively shown in the causal loop diagram in figure 2 which captures the main reinforcing loops R1 (access loop), R2 (TBA loop), R3 (Attractiveness loop) and the balancing loop B1 (social loop), B2 (convenience loop).

The dynamic structures translate decision changes into the key indicator maternal mortality through the different parameters in the modules. These insights can be used to help inform the design of policy interventions such as advocacy, mobile clinic policy and hiring policy which require some financial investment.

5. Policy Design

5.1 Policy Aims

The government has set the goal for ensuring that by 2030, maternal mortality is reduced to the SDG level of at least 70 deaths to 100000 live births (MOH, 2019). To align its Vision 2030 (national development plan) with the SDG's agenda, the Kenya government has to improve access to primary health care, medical personnel adequacy and create awareness of initiatives done in the health sector regarding maternal health. These are some of the policies suggested, developed to help advance the strides in maternal health and reduce maternal mortality.

Currently, the access is still low due to a few factors. To boost low access, there has been continuous construction of hospitals to boost the current coverage and recruit the medical personnel to much the growing number of health facilities. In 2014, the first lady launched the Beyond Zero Campaign, which focused on the provision of mobile clinics, and its main aim was to boost access, especially for pregnant women and reduce maternal deaths and infant mortality. In 2013, the government introduced a 'free maternity programme', and the worst-case scenario was taken as when with 'paid maternity cost' and business as usual (BAU) as when there is 'free maternity programme' were considered to represent these respective situations (MOH,2019).

This thesis is focused on exploring the potential policy to ensure that this goal can be reached in a practical policy and its cost-effectiveness by analysing the policies and their cost of implementation.

In the design of policy interventions, 2030 was considered the target year for achieving desired outcomes in maternal mortality. The policy horizon was considered from 2020 (approximately the present day) to the target year of 2030. Based on insights from the model analysis and validation testing (Chapter 4), the differentiation of two categories of decisions is the place of birth: home birth as opposed to hospital birth.

5.2 Policy Structure

5.2.1 Mobile Clinics sector

5.2.1.1 Mobile Clinic Policy Design

The basic principle behind this policy is that it tries to address the hypothesis of low access and the long-distance the pregnant women in the rural areas have to cover during childbirth. Investing in mobile clinics helps 'kickstart' increased access within the shortest time possible with cost-effective benefits compared with the heavy financial investment and time requirements in the health centres if we require to achieve the SDG goal of at least 80 per cent access to health care by 2030.

The leverage point being targeted is inaccessible areas in rural and ASAL areas, especially since women in rural Kenya have a higher fertility rate per woman than women of reproductive age in the urban areas. They have a higher mortality rate as more opt for home births (GOK, 2013, KNBS, 2014).

The introduction of the mobile clinics' policy aims to increase access to health care, especially in rural areas. The First lady launched this programme in Kenya as a Beyond zero campaign in the 2013/14 financial year. Currently, the programme runs on donations from well-wishers and has no government support. Its main aim is to reduce maternal deaths during and immediately after childbirth.

In our model, the stock captures the number of mobile clinics with an inflow of the purchase of mobile clinics and the outflow as the depreciation of mobile clinics.

The mobile clinic purchases are determined by the Beyond zero budget and the purchase cost per mobile clinic. After the launch of the programme, the budget available for additional purchase is left after the running costs of the existing mobile clinics are catered for fully.

With an operational programme, the functioning mobile clinics are calculated as a proportion of the running costs covered by the total budget. So that when the operational/running expenses are greater than the total budget, it reducing the number of functioning mobile clinics as some expenses are not met. To get the additional access covered by the mobile clinics, calculate the product of the functional mobile clinics with the area covered per mobile clinic. Road density is considered when calculating the coverage by mobile clinics; with this, we obtain the proportion in relation to the total arid and semi-arid land (ASAL) area. These mobile clinics were launched in the rural ASAL areas where it was not accessible to get health facilities.

We initialised our mobile clinics stock with 0; an assumption is made that there was no existing mobile clinics service. With the input we get from the previous sectors, we could determine how many mobile clinics need to be purchased at any given time. Moreover, we introduced several delays to the flow structures and the functioning mobile clinics as there is a need for their running cost to be covered. We needed to consider the budget delay not to undermine the legislative and bureaucratic reality of actualising such arrangements. After having a certain number of functioning mobile clinics, we could calculate the total area covered by mobile clinics from the data we obtained from the infrastructure sector.

The policy was constructed to increase access to health care, especially in Kenya's ASAL and rural areas. Women had to travel long distances to acquire health care and maternity services. This policy structure aimed to activate a feedback loop between mobile clinic acquisition and maternal mortality through improved access by additional coverage and convenience in terms of the less distance covered. Hence more women would choose hospital birth due to increased proximity. With these, the share of women opting for skilled birth increases and the effect is directly seen on maternal mortality through mitigation of the risks that accrue with home birth. (R2, B1 and B3 in Figure 19).

Looking at the policy structure, the variable "real expenditure budget" activates "the mobile clinic purchase" at the onset; since it was launched in 2013/14, the programme has been using 'Beyond zero budget' which we assume to have grown to about Kshs.120 million. The 'Zero switch' decides to invest in the mobile clinics; this activates the Government's budgetary allocations to get 80 per cent access to the SDG goal. This requires additional support of Kshs.84.1 billion in the ten years.

Mobile clinics are among the effective strategies to accelerate progress towards SDGs number 3.1 by the additional area coverage that the mobile clinics cover and therefore increase access to primary health care and therefore reduce the maternal mortality rate in Kenya. In Kenya, this is purely a donor-driven initiative, and the staffing of medical personnel is from the Government.

The 'additional budgetary requirements for mobile clinics' shows the additional investment required if the access goal is reached through the mobile clinics' coverage.

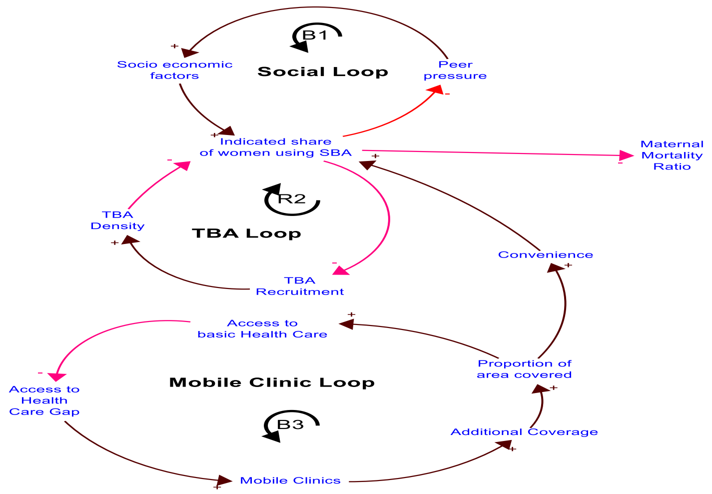
The policy structures are depicted in Figures 19 according to their stock and flow structure and CLD. For a simplified version, the policy introduces a structure that activates R2, B1 and B2 in Figure 19.

With the policy, women now find it more accessible to visit the clinics as the distance to be covered reduces, reducing maternal deaths as more opt for hospital birth.

Figure 19: Causal Loop diagram with mobile clinics policy

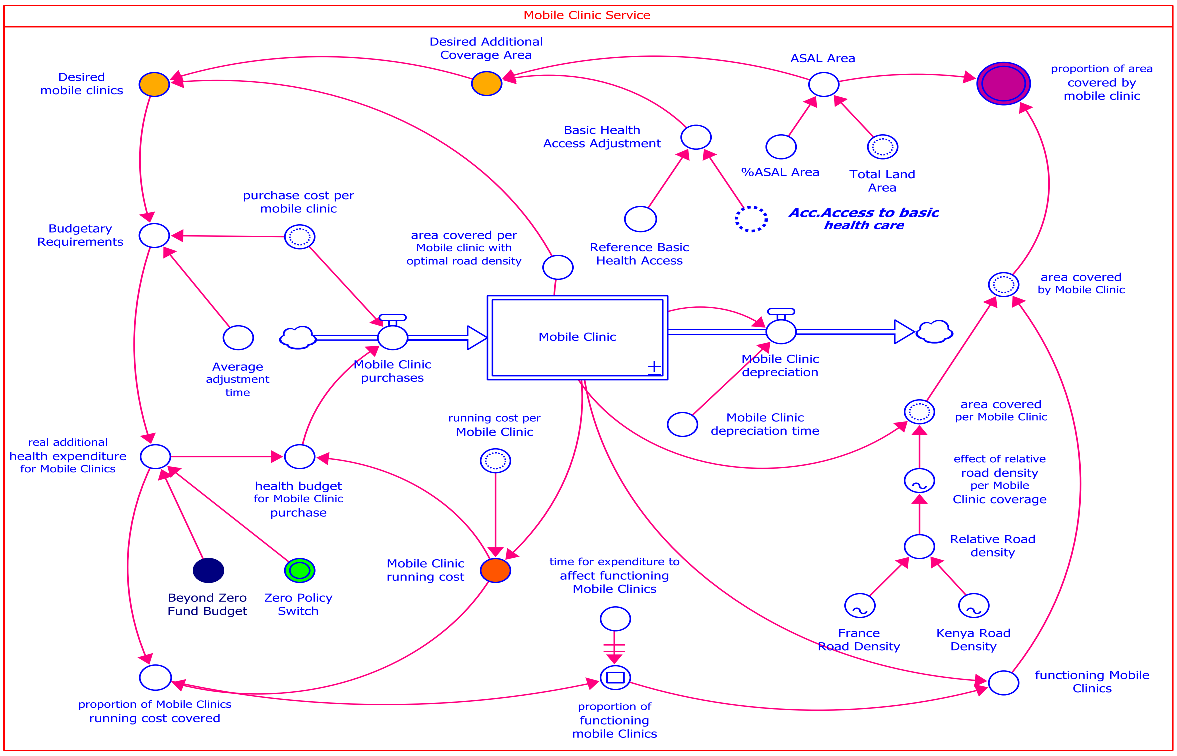
In dynamic terms, the reinforcing loops R2 (TBA loop) was able to exert enough influence despite the intense action of the balancing mechanisms of B1 (Social loop) and B3 (mobile loop) (Figure 19). Despite this, however, the overall value of maternal mortality reduced as more mobile clinics are introduced, with this massive capital investment only enabling the avoidance of additional social costs compared to a situation without the investment. The social costs here is in reference to maternal death and the ripple effect this has on the community fabric. The access goal is not reached with the mobile clinic stock. We cannot build it sufficiently to high levels within the ten years with high adoption level in the community without other using variant mechanisms and the balancing mechanism of B1 and B3.

Figure 18: Causal Loop diagram with mobile clinics policy



In dynamic terms, the reinforcing loops R2 (TBA loop) exerts ample influence despite the intense action of the balancing mechanisms of B1 (Social loop) and B3 (mobile loop) (Figure 19). Despite this, the overall value of maternal mortality reduced as more mobile clinics are introduced, with this massive infrastructural investment only enabling the forestalling of additional social costs compared to a situation without these investment. The social costs here is in reference to maternal death and the ripple effect this has on the community fabric. The access goal is not reached with the mobile clinic stock. We cannot build it sufficiently to high levels within the ten years with high adoption level in the community without other using variant mechanisms and the balancing mechanism of B1 and B3.

Figure 19: Mobile Clinic Service Sector



5.2.1.2 Mobile Clinic Policy Analysis

The introduction of mobile clinics gives additional coverage, as shown in figure 18 below. We analyse this vis a vis worst-case scenario where there are no mobile clinics to show the benefits even if minimal towards the introduction of mobile clinics. The additional coverage is determined by the funding level, which ensures that the purchase and operationalisation of the mobile clinics are adequately catered for fully.

With the free maternity programme and the policy switch off, it means the women must travel long distances to access the health centres, preferring the TBA due to the long distance to get to the nearest health facility during delivery. This is the ‘business as usual scenario’ when the ‘mobile policy =0’. Although there is no policy cost being incurred in these situations since mobile clinic Policy is not activated, this results in slightly more deaths that could be preventable, thus confirming the need for intervention.

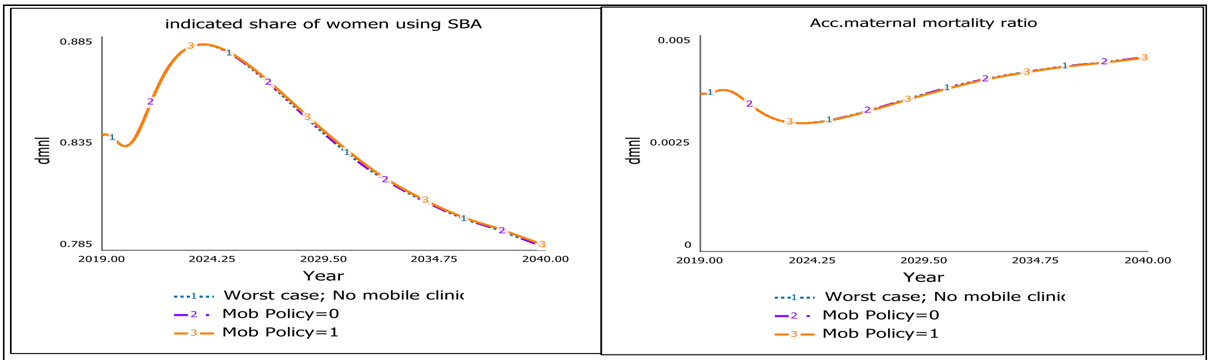
Without Policy, a scenario would occur where there are no mobile clinics; hence, additional coverage is not provided. With this, the only access is from the health centres whose density is low. The convenience is relatively low with an initial distance covered of 97.5km; finding from a study indicated that any distance above 10 km, women would opt for a home birth since the capability to provide emergency obstetric and newborn care is vital to reducing maternal mortality and with any distance above reduces such chances (Nancy, et al., 2018).

With business-as-usual scenario, it captures the current situation where the mobile clinics were introduced by the first lady Margaret Kenyatta called @beyond zero campaign' to increase access, especially to women in the rural. This programme is purely donor funded and from this, we acquire the mobile clinics; This initiative was launched in 2014 but the number of mobile clinics purchased depends on the fundraised zero budget. The stock of mobile clinics is dependent on the available budget, which increases over time; though it increases the 'access to basic health care ' through the additional coverage, this is by a small margin over time though it does not get to the policy goal. The mobile clinics increase the convenience by reducing the distance to be covered as the 'access to health care increases over time.

Since the programme was introduced in 2014 and largely relies on donation and charity funding, in 2020, they have a budget of Kshs. 120 million and have a stock of approximately 39 mobile clinics, which with all this the average distance covered still stands at 95 km from the nearest health facility or mobile clinic as access is still relatively low. The share of women using skilled birth attendants stands at 88.1 (worst case) and 88.2 per cent in 2024, with a maternal mortality of 323 and 322 compared to at least 0.0007 maternal mortality deaths as targeted in the SDG. It takes time for response and uptake of mobile clinic services by pregnant women.

The introduction of the policy sees that the government chips in and give budgetary allocation to the mobile clinic programmes. The government allocates Kshs.6.17billion, which facilitates the acquisition of 2880 mobile clinics and caters for their operational cost. This facilitates additional coverage and reduces the distance travelled from at least 75 km; with this, the 'share of women using skilled birth increases from 77.7 per cent in 2014 to 88.1 and 88.2 per cent with a decrease of maternal mortality to 323 maternal deaths per 100,000 live births as shown in figure 21.

Figure 20: Mobile policy introduction



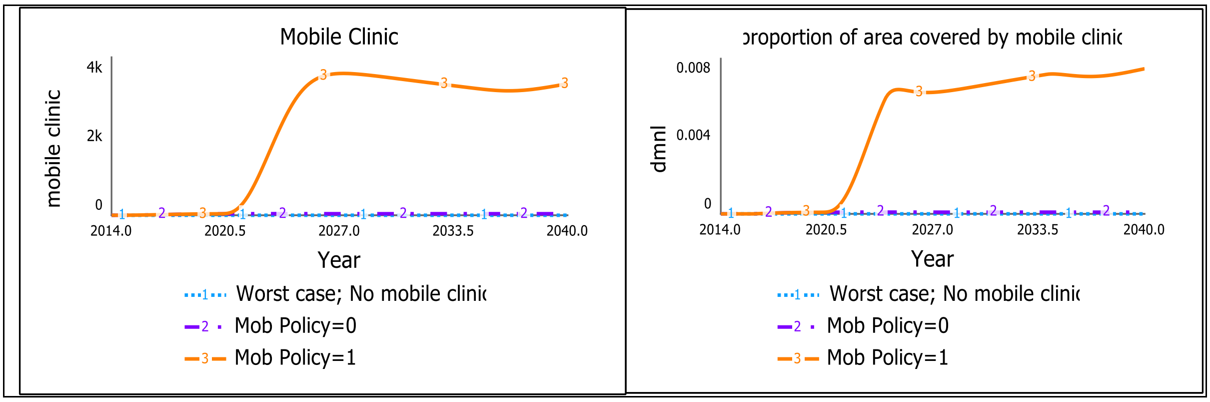
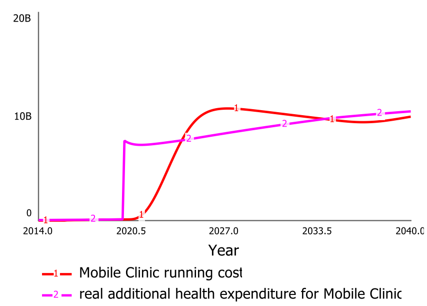


Figure 22 shows the budgetary provisions and the operational costs of the mobile clinics. With policy introduction as the budget increases over time the number of the mobile clincs increases and so does their respective operational costs. In 2024 and 2033, the budgetary allocation can only cater for the running costs and no purchases can be done; during this 9 year period the cost of operation and maintenance increases and the budgetary allocation does not increase intandemly. This would only result in cutting down of some of the costs so that what is available is used for the operations of the mobile clinics. This in the long run would influence usage of the mobile clinics and hence the behaviour of the 'indicated share of women using skilled attendants' and maternal mortality rate.

Figure 21 Budgetary provision and expenditure



This sector is major driven my funding for mobile clinic acquisition and operationalization. We look at the different budgetary provisions to show how much can be achieved given the budgetary allocations. Figure 21 shows the different scenarios, the behaviour analysis in figure above 21 shows the importance of this sector towards increasing access and coverage within shortest time possible.

The running costs were higher than the budget after year 2024 to 2033 in the business as usual after introduction of the policy. Although this running cost increased over the course of the simulation with policy introduction, the net effect is not felt immediately in the target goal as it takes time for the response though even in the longrun, the goal is not reached. This captures the effect of the balancing feedback loop B3 (Figure 19) whereby in spite of improvements in coverage through capital investment the target goal is not achieved.

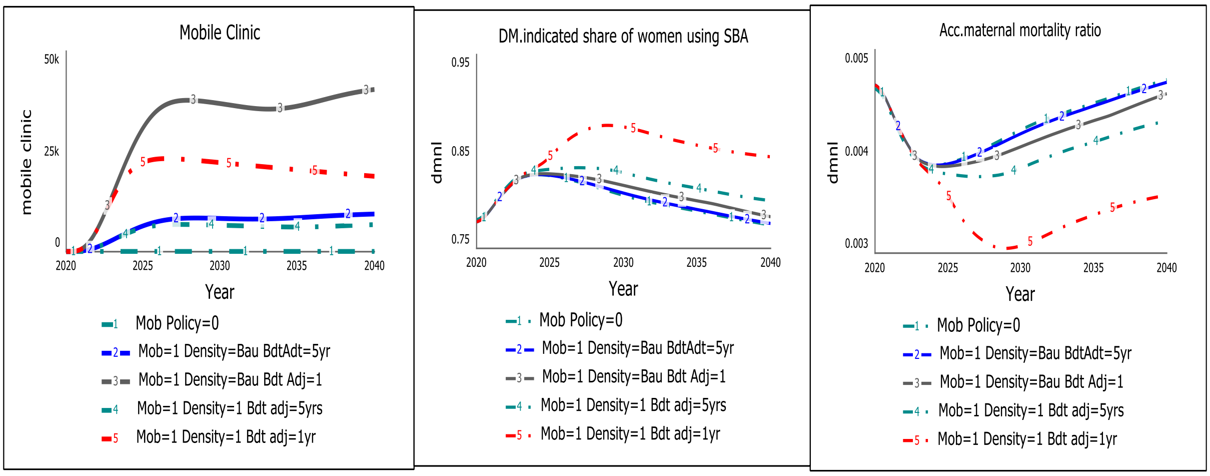
As shown in Figures 21 and 22, the effect of mobile clinics on ‘access to primary health care’ and the indicated share of women who opt skilled birth and inturn its influence on the maternal mortality differ depending on the scenario.

In best case scenario, the government intervenes and tries to allocate extra budget based on the gap between the reference and the access to basic health care. Being a goal seeking formulation, it tries to reach the SDG goal of 80 percent access, by purchasing only what is required to reach target by 2030, the government is required to inject an additional budgetary allocation of Kshs. 685 billion in the 10-year period. Introducing the policy also increased mobile clinics levels on the best case scenario and increased access to 70 percent in 2024 but failed to reach the policy target of atleast 80 percent ‘access to basic health care’ by 2030 despite the increased budgetary allocations overtime and improved access over the subsequent years.

Thus, introducing additional budgetary allocation from government, helps narrow gap towards achieving policy goal though over long time period. This can be done at which ever level of additional budget as it yields positive results.

Figure 23 and Table 4 show the various target output in the 2030 which is the target year as per the SDG target achievement year. We look at the scenario with mobile policy on and off; the budget adjustment time 1 or 5 years and the road density with business as usual condition or ideal condition when its 1 where the road network is good.

Figure 22: Scenario with Changes in Road density



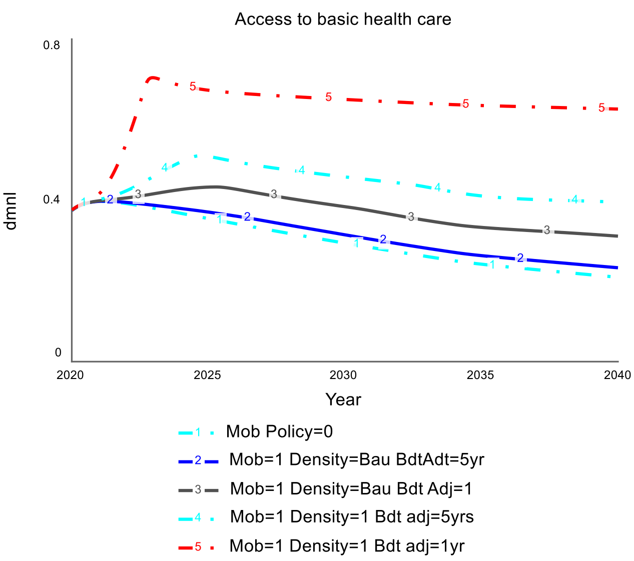
Scenario	Mobile clinics 2030	Budget (Kshs. Million)	Indicated share of	Maternal mortality ratio

			women using SBA	(x/100000)
Mobile Policy=0	64	120	80.5%	421
Mob policy=1; Road density =BAU;5 year budget adj time	8,290	15,500	80.7%	418
Mob policy=1; Road density =BAU;1 year budget adj time	36,900	65,900	81.5%	405
Mob policy=1; Road density =1;5 year budget adj time	6,600	10,900	82.8%	384
Mob policy=1; Road density =1;1 year budget adj time	22,200	23,800	87.5%	307

Table 4: scenarios with road density adjustment and budget adjustment time

Figure 23 and table 4 show a scenario where the road density is one is compared to 'business as usual' scenario. When the road density equals one; these represents ideal situation where the road network is good, and all parts of the country is accessible regardless of the weather conditions. From this, we see the positive results coming from an already established good road network in the country. This shows the need of balanced development of all sectors in the economy for synergy. With a road density similar to France, distance travelled becomes manageable in the even remote inaccessible areas. From figure 23, we see that with increased access the budget available has reduced so that the mobile clinics are less as their coverage of is almost at its optimal range 2000ha per mobile clinic. Greater road density increases transport connectivity which means that access to basic health services improves as emergency response services is easily availed in the rural areas (Rao, 2018).

Figure 23: access to basic/Primary health care



Best results are achieved with one year budget adjustment of 1 year, budget of 23.8billion; this increases those who opt for skilled birth to 87.5 percent and lower maternal mortality of 307 which saves atleast 114 women per 100,000 live birth (figure 23, 24, and table 4)

Adjustment time for budget provision ids also key as shown. When its 1 year, the budget is higher which implies more mobile clinics within a shorter achievement is almost achieved.

Figure 25 shows the changes in the adjustment time for ‘business as usual’ scenario and further adjustment of time. Currently, we assume the government will implement this in a 10 year period; since it requires massive investment of Kshs.674 billion to acquire and operationalize the mobile clinics. In 2020, the budgetary provision is Kshs. 65,9 billion. If this is done, then it takes time for uptake of skilled birth which reflects in the higher maternal mortality. With an adjustment of 1 year, the government allocates the whole budget of Ksh.674 billion; this gives its highest adoption in 2028 with a proportion of 87.5 percent of women using skilled birth with low maternal death of 308 to 100000 live births.

Figure 24: Mobile clinic Policy Scenarios with changes in budget

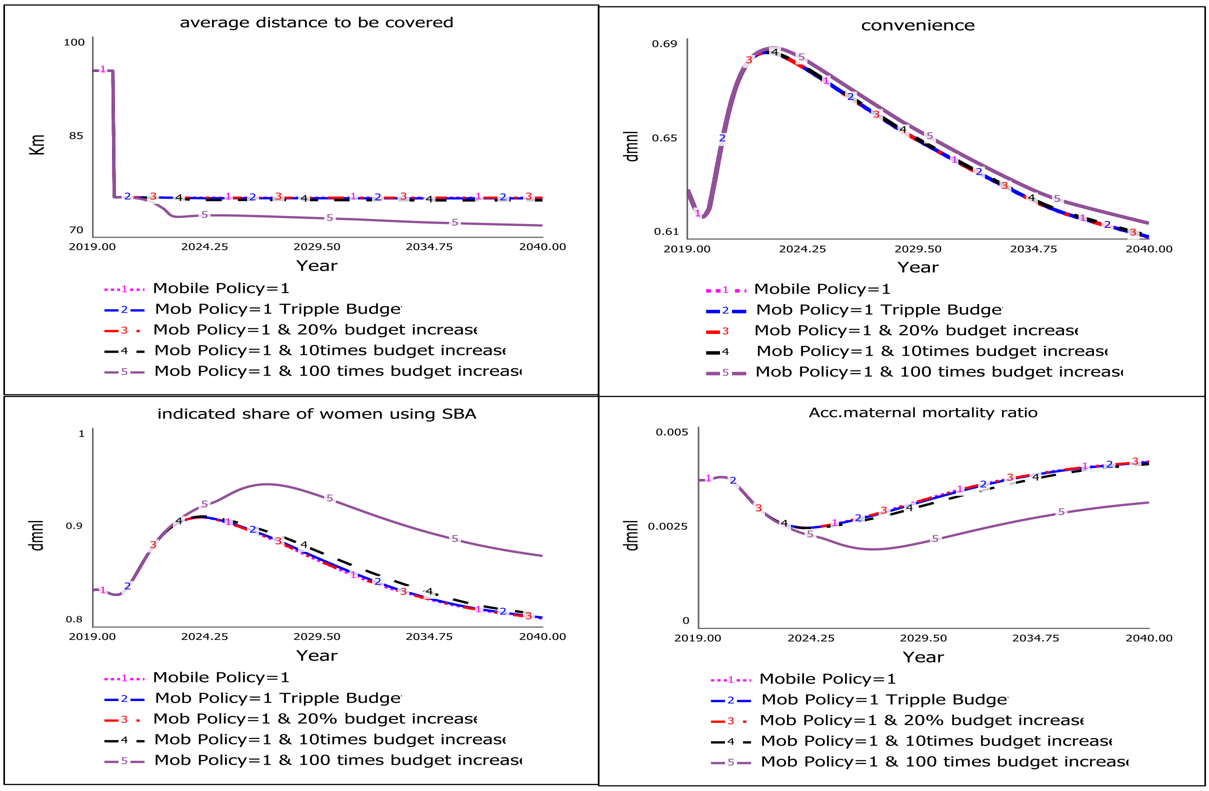


Figure 25: Scenario on different Budget adjustment time.

The overall benefit of the policy is presented in Table 3. It shows that policy introduction on the Best-case scenario delivered overall net benefits through lowering social cost compared to not introducing it, whereas, on a business-as-usual scenario, the social costs outweighed the cost savings for the government.

Investment by the government enables to mitigate the low access to health care, especially in the rural areas and the potential costs posed by the No Policy simulation. Maternal mortality, a key indicator, shows positive feedback during the policy period, though with some delay.

5.2.2 Advocacy Policy

5.2.2.1 Policy Design

A study on free maternity service by (Omollo, 2015) showed that most women and staff were not aware of free emergency medical services offered to women during delivery at home. This extensively highlighted the failure by the government to inform women of free emergency medical care services resulting in its underutilization and aggravating maternal deaths that could otherwise be managed.

Therefore, this policy was modelled as a government advisory structure designed to mirror the awareness campaigns in the health sector in promoting skilled birth and existing programmes, just as vaccination campaigns case studies are done in Kenya. Its purpose is toof this policy structure was to activate a feedback loop between skilled birth uptake, mobile clinics and other initiatives and its direct contribution to maternal mortality rate reduction through the reinforcing loop R3 and balancing loop B1 (attractiveness and social loop in Figure 2). Therefore, to initiate the more women to choose skilled birth attendants based on its advocacy principles. The idea is that as more women preference shift to skilled births, the preference for TBA shifts. The leverage point being targeted is SBA' awareness that includes existing programmes available like free maternity, mobile clinics, risks mitigation in SBA, and the cost-benefit assessment with the free maternity programmes. In this policy, we target women in the reproductive age from15-49 years who are fertile and taken as a proportion of the total population.

According to the International Confederation of Midwives, Advocacy can be done at different levels, starting with the grassroots community level to the highest global level. At the grassroots, the focus is mainly on changing community and cultural beliefs, attitudes and raising awareness to alter perceptions and affect their behaviour towards an issue. Today, it is imperative to note that the campaigners must reach the essential cultural grassroots or community level with their sophisticated social campaigns for Advocacy to work. At the national level would mostly have to do with the creation of enabling environment through policy formulation and Advocacy of such policies. Individual midwives are affected by decisions made at global levels, and they can inturn, change these decisions by influencing decision-makers (ICM, 2019) (Boyd, 2006)

This policy was constructed as a government advisory structure designed to mirror the awareness campaigns in the health sector in promoting vaccination campaigns case studies. The purpose of this policy structure was to activate a feedback loop between skilled birth uptake and its direct contribution to maternal mortality rate reduction (R3 and B1 in Figure 2). Therefore, to initiate the more women to choose skilled birth attendants based on its advocacy principles. The idea is that as more women preference shift to skilled births, the preference for TBA shifts. The leverage point being targeted is SBA' awareness that includes existing programmes available like free maternity, mobile clinics, risks mitigation in SBA, and the cost-benefit assessment with the free maternity programmes.

A study concluded that awareness and accessibility of primary health care equipped with modern maternity facilities significantly influence women's health-seeking behaviour. Establishing properly staffed health facility may not be an easy task; hence there is a need to increase community awareness about the benefits of using available health facilities for improved pregnancy outcomes (Agarwal, et al., 2007)

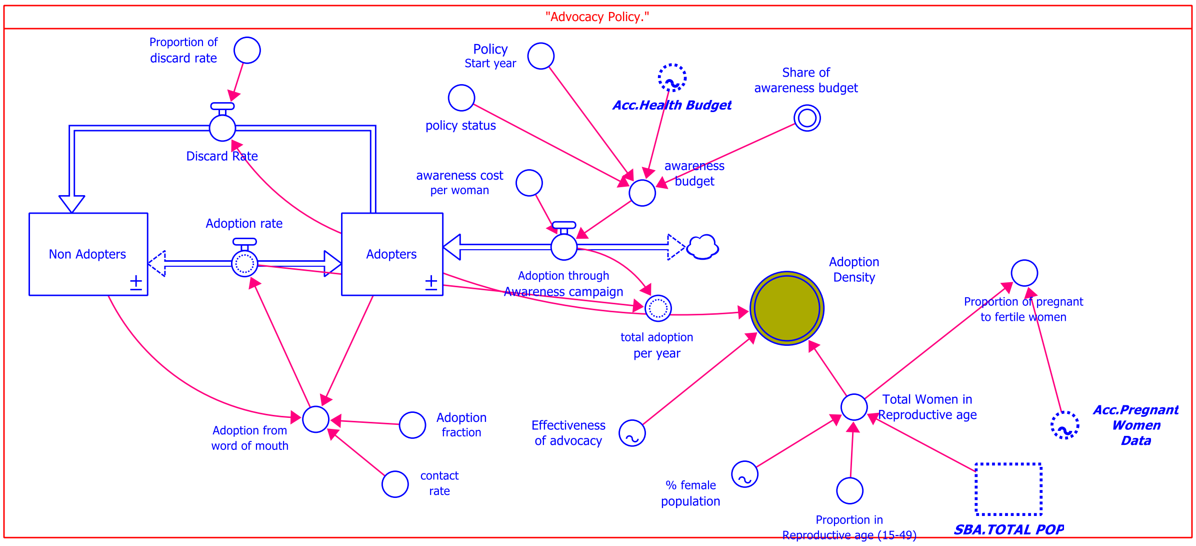
From various studies use of comprehensive maternal healthcare reduces risks during delivery and the postpartum period.

Therefore, community awareness plays a crucial role in maternal health as a driver to women utilizing more prenatal care services to reduce childbirth-related risks and reduce maternal mortality.

The Advocacy policy works with the basic stock-flow structure with two stocks of adopters and non-adopters. The non-adopters, in this case, represent the women seeking service of the traditional Birth attendants, whereas the adopters' work represents the women having birth in the hospital with the help of the skilled medical personnel, as shown in figure 27.

The inflows are represented by adoption rate and adoption through awareness campaigns, whereas the outflow is represented by discard rate. The discard rate is obtained as a fraction of the adopters and the proportion of women who chose not to undergo skilled birth attendants in subsequent births or after attending the campaigns. The adoption rate captures the total number of pregnant women who adopt birth by skilled birth attendants following Advocacy and word-of-mouth from fellow women. Advocacy works and depends on how effective the Advocacy is; the more effective it is, the more non-adopters are converted. It has a positive relationship. Adoption through awareness campaigns is strongly dependent on the awareness budget so that with a high budget, more women can be reached; it works well with how effective the Advocacy will be. We obtain this by division of the awareness budget into the awareness cost per woman. This gives the number of women who can be reached through the campaigns. Adoption from word-of-mouth works following the Susceptible infectious (SI) concept. This is obtained using the proportion of women adopters from the total number of pregnant women, and this is multiplied by the contact rate of each woman, the adoption fraction representing those who have adopted and practise skilled birth and can use their influence on the non-adopters and the total number of the non-adopters who are susceptible to the influence on skilled birth. Over the years, the proportion of women pregnant has been less than 10 per cent of the women in the reproductive age; this is supported by a study on fertility levels by Opiyo C (2003), which showed that an average of 7.8 per cent of women were pregnant with the north-eastern region having highest at 11.5 per cent whereas central region had lowest at 5 per cent (Collins, 2003).

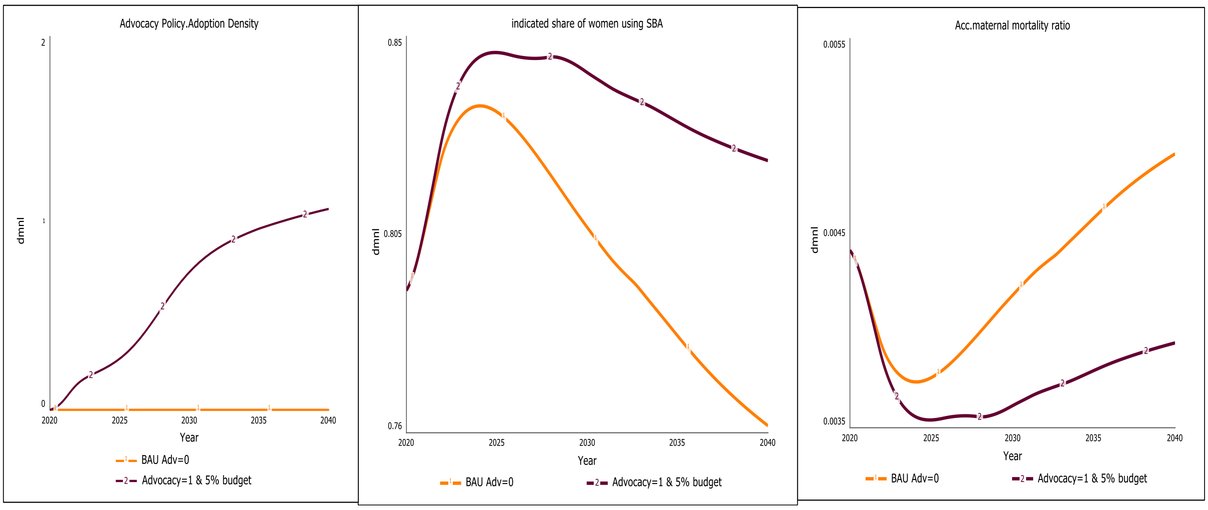
Figure 26: Advocacy Policy Sector



5.2.2.2 Policy Analysis

The advocacy policy is introduced in year period 2020; hence the behaviour prior to this remains the same for all the scenarios. As shown in Figures 28, the effect of advocacy on 'indicated share of women using SBA' and maternal mortality ratio showed differing levels of the results depending on the scenarios. We assume the government invests Kshs. 3.37 billion for advocacy through awareness creation campaigns.

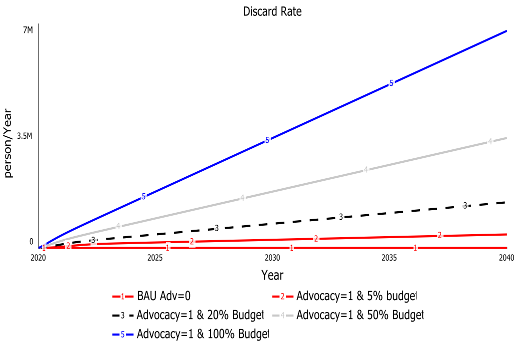
Figure 27: Effect of advocacy policy



Without advocacy, the maternal mortality runs as shown with an indicated share of women at approximately 83.4 percent in 2024 which is the highest it gets without advocacy from an initial 48.9 percent. The maternal mortality declines away with an exponential decay pattern with its lowest being 374 maternal deaths from 383 before it increases after reaching its peak; whereas the 'indicated share of women using SBA' increases increasingly to reach 83.4 percent and starts decreasing increasingly. The maternal mortality declines towards the SDG goal of 70/100000 live births, though it does not get to the desired level. This could be the ripple effect of the balancing loop B1 (social loop) which affects the social factors through peer influence, so that as the share using SBA decreases the

In contrast, introducing advocacy shift the indicated number of women using SBA as more women opt for the skilled birth with atleast 84.6 per cent; this has its benefits on the health system as more deaths that are preventable are managed during delivery and afterwards. This trend works well over the 10-year simulation period as the stock of the non-adopters is depleted and the subsequent adoption rate comes from the 'word of mouth as the remainder are absorbed from an assumption of one percent discard rate which rises based on the budgetary allocations.

Figure 28: Discard rate and adoptee(/non)



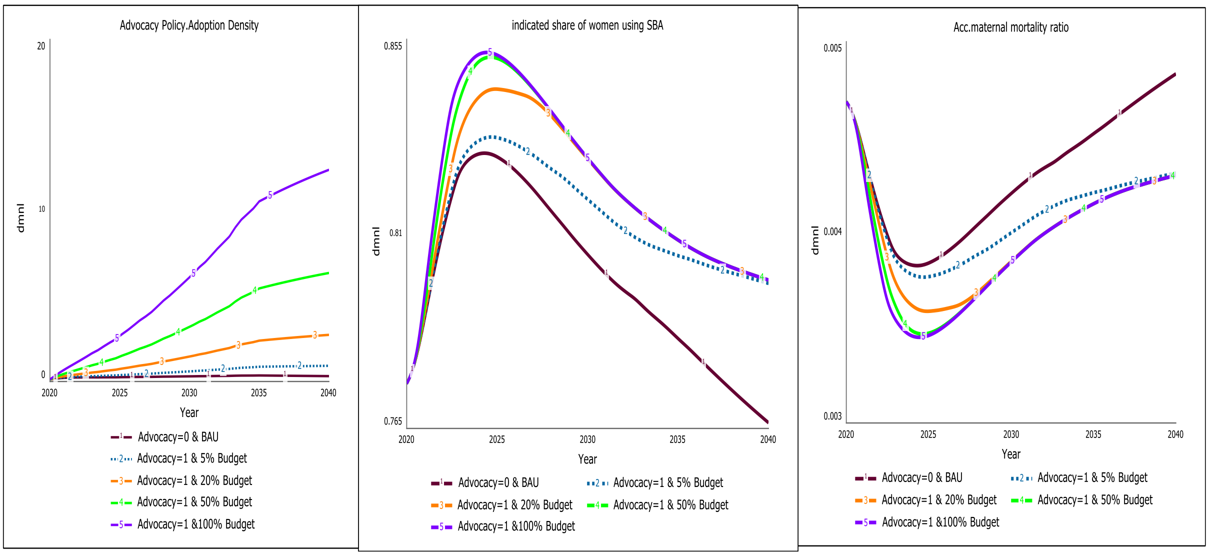
This is so as more adopt through the campaigns or word of mouth as conformers and deliver via skilled birth attendants; some will revert back to the fraction of those who are non-adopters/non-conformers and deliver with TBA as shown in figure 29. This is despite the investment in advocacy, during the 10-year simulation period.

Introducing the policy increased the adopters and also non-adopters and in turn the 'indicated share of women using SBA' but was unsuccessful at achieving the 2030 policy target. The adoptee stock rises as more adopters are trained from the women in the reproductive age. This is an increasing stock of women from the total population.

For the Best-Case plots, additional investment in awareness campaigns enabled the mitigate and improve maternal mortality and reduce the deaths unlike with No Policy simulation where there is no budget to conduct the advocacy. From figure 30, we see that little budgetary allocation to awareness budget yields positive results. So does 20 percent. Half of budgetary allocation leads to higher numbers trained; so does 100 percent though this does not translate to equivalent reduction in maternal mortality; this can be attributed to the fact that the awareness is done to all women in the reproductive age whereas the proportion of the pregnant to women in the fertile age accounts for only 9 percent of the population; hence the need to focus on the awareness campaigns specifically to mostly pregnant women to get achievable results in the short run and the all-female fertile population in the long run. This approach targets all women in the reproductive age so that it is easier to have adequate covering also using word of mouth and peer influence. Results are summarised in Table 4 after the 10-year policy period.

From figure 30, we can also deduce that with a higher budgetary allocation we are able to reach a higher number within a short time as compared to low budgetary allocation, this results in a maternal mortality ratio of 346 deaths to 100,000 live births.

Figure 29: different budget policy scenarios

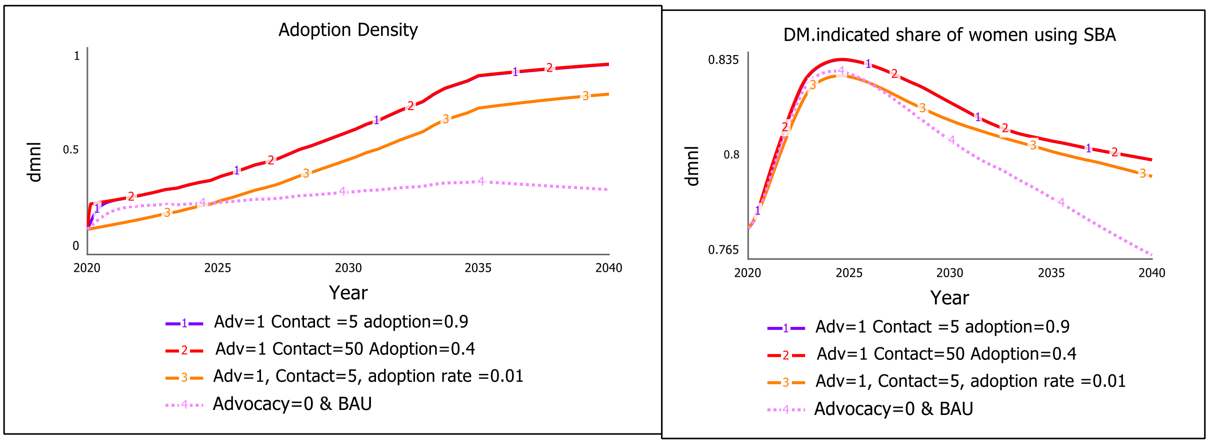


Scenario	Budgetary Allocation @ (KShs.Billion)	Adoption Density	% share using skilled Birth	Maternal Mortality ratio (x/100,000)
Advocacy Policy off	Nil	0	82.5%	383
Advocacy Policy=1 & 5% Budget	3.37Billion	0.45	83.2%	377
Advocacy Policy=1 & 20% budget	13.5Billion	0.903	84.3%	359
Advocacy Policy=1 & 50% budget	33.7Billion	2.68	85.1%	347
Advocacy Policy=1 & 100% budget	67.3Billion	3.89	85.2%	346

Table 5: Summary findings of advocacy policy

A further analysis to strengthen contact rate and an adoption rate as in figure 31 shows that a higher contact rate generates similar results with a higher adoption rate. To ensure the mechanism works we allow an increased awareness campaign budget (see figure 30). It is very likely that the adoption rate and contact rate might be unrealistically high as it only allows us to identify how effective the policy would be and after how fast we can reach the desired targeted adopters. We do not know what the actual potential contact rate and adoption rate would be ideally as these are based on assumptions.

Figure 30: effect on contact rate and adoption rate.



5.2.3 Hiring Policy

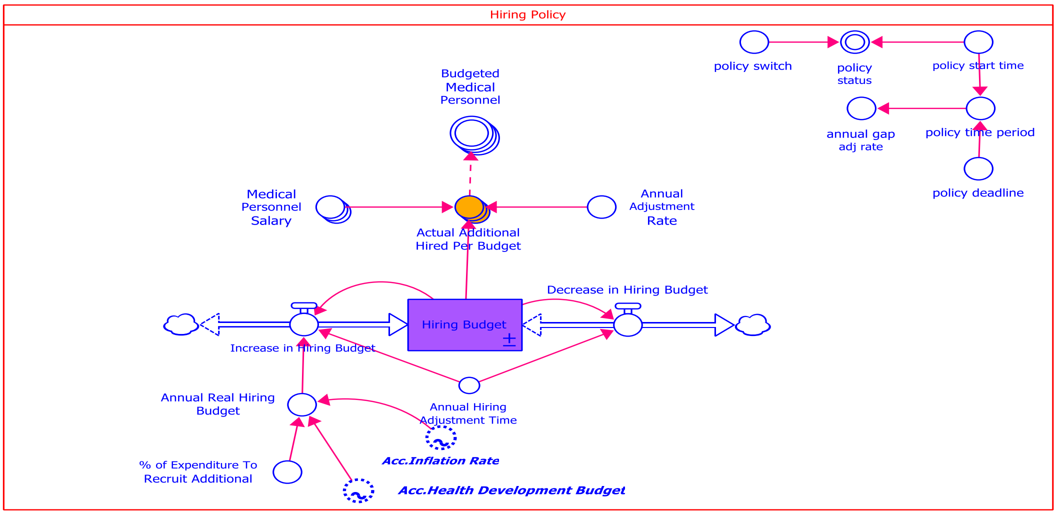
5.2.3.1 Policy Design

The hiring policy works to correct the gap in 'access of basic health care'. In Kenya, the basic to health care is still limited with widening gap to the SDG goal of atleast 80 per cent access to basic health and atleast a ratio of 23 medical personnel to 10,000persons. With not so low maternal mortality, the medical personnel adequacy plays a critical role on how attractive the health care system is during decision making on choice of place to give birth.

The health Sector staffing is done in line with guidance of Public Service commission (PSC-K) Human resource policy. Each Ministry in this case Ministry of Health prepares an annual Human Resource plans which gives the full details of the annual recruitment plans as per the available budget. These recruitments are done by Public Service Commission based on the available budget to fill the vacancies (PSC, 2016).

The Hiring Sector is a simple stock and flow; with the hiring budget stock affected by increase in budget which is the annual hiring budget. This is obtained as a percentage of expenditure set for additional recruitment from the Health Development Budget. With a hiring budget and the medical personnel salary, we can estimate the number of medical personnel that can be accommodated given the allocated budgetary provisions. The medical personnel salary is based on Ministry of Health guidelines (MOH, 2015).Figure 32 represents the hiring policy sector which is activated and works intandem with recruitment in the skilled Birth Attendants Module. We use the budgeted medical personnel in recruitment of medical personnel.

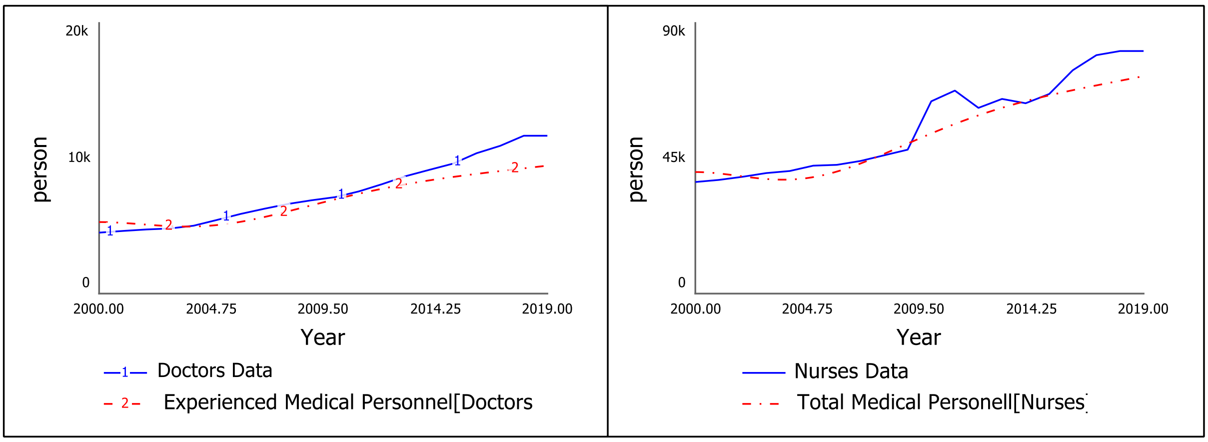
Figure 31: Hiring Policy Sector



A study supported by WHO showed that the shortage of health-care personnel in developing countries was further strained by low motivation and retention of existing personnel and on the other hand unemployment of many more qualified. This was occasioned by existing fiscal constraints on the public sector hiring. The macroeconomic policies capped public servants' salaries, froze employment and offered minimal human resource development interms of education and training. With prolonged application of such hard stance policies; the outcomes were severe erosion of the human health infrastructure. The public sector employment freeze began in 1994 saw to it many unemployed trained medical personnel. The rapid further increase thereafter could be attributed to Public–private partnerships (PPPs), such as 'The Clinton Foundation' facilitated hiring of trained unemployed medical personnel while the government was mandated to create the requisite budgetary allocations required to hire the medical personnel (Gross, et al., 2010). An estimate by The Clinton Foundation on the cost of absorbing nurses into the public service showed approximately US$ 4292.50 per annum which included the basic salary, retention bonuses and uniform allowances (Gross, et al., 2010).

Development of the model gives us an almost close to reference mode results. Figure 33 shows the modelled sector data and a representation of the sector.

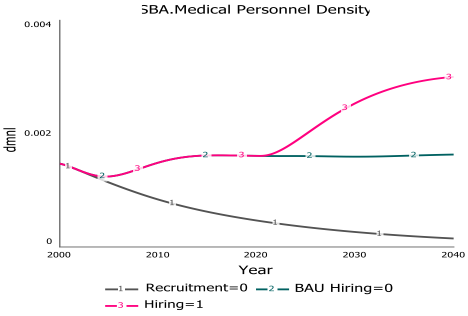
Figure 32: Medical personnel capacity (modelled and reference data)



5.2.3.2 Policy Analysis

Figures 34 shows the effect of hiring policy on the medical personnel density, the indicated share of women using the SBA and the maternal mortality. Hiring and its potential benefits on the different sectors differed depending on the scenarios.

Figure 33: Medical Personnel Density



Worst case scenario, without Policy occurs when the hiring does not happen. The total medical personnel decline away with an exponential decay pattern that is more severe as shown in figure 34. The medical personnel are not hired so there is no replacement after promotion or with departure; this depletes the stock of medical personnel.

In contrast, introducing hiring policy increases the total density of the medical personnel in proportion of the allocated budget though, the policy come to effect in 2020. In the BAU scenario, the recruitment is based on the system in an effort to replace the deficits. With the policy switch, hiring is done based on the budget and as such the increase in the medical personnel density exponentially from 2020. The policy increased the medical personnel stocks and costs the health sector Kshs.21.6 billion per year.

Though the policy introduces the positive results in towards higher share of skilled births, it does not get the system to policy target in 2030 as we get. We are able to record 68.6 percent, 80.8 percent,85 percent adoption of skilled birth with 613,420 and 347 maternal deaths per 100,000 live births for the no recruitment, 'business as usual' and hiring policy scenarios respectively.

Figure 34: Hiring policy

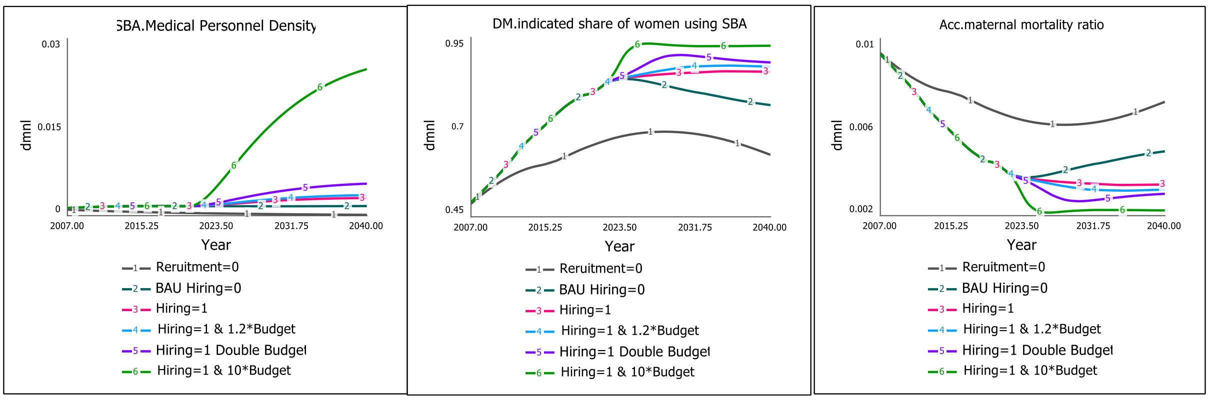


Table 6: Hiring Policy Scenario Analysis

Scenario	Budgetary Allocation @ (KShs.Billion)	Medical Personnel Density (x/10,000)	% share using skilled Birth	Maternal Mortality ratio (x/100,000)
No recruitment	Nil	2.64	68.6%	614
Hiring Policy off	Nil	15.9	80.9%	420
Hiring Policy=1	21.6Billion	25.4	85%	347
Hiring Policy=1 & 20% extra budget	25.92Billion	28	86.4%	322

Hiring Policy=1 & Double budget	43.2 Billion	40.5	90.1%	265
Hiring Policy=1 & 10fold 20% extra budget	216 Billion	162	92.8%	223

Figure 35 and Table 6 illustrates the different scenarios based on the budgetary allocations. From this we can deduce that any amount of additional extra budget leads in positive results regardless of the amount.

For the Best-Case scenario, 10-fold investment enabled the mitigation of almost all the potential costs posed by inadequate medical personnel. With this budgetary allocation, it was possible to achieve a significant spike in women and maternal mortality due to the sudden net gain in medical personnel. The costs were highest with at least Kshs.216Billion investment; this ensured progressive recruitment from 2020 over the years. It results in a 92.8 per cent share of adoptees to skilled birth and lowers maternal mortality at 223 to 100,000live births

This resulted in positive results for all the extra budgetary allocation as shown in figure 29 and table 6. The assumption here is that with adequate medical personnel the functionality of health facilities is at full capacity and 100% functional with staff; and that this works on the attractiveness of the skilled birth as more women chose delivery in hospitals and inturn their share increases and this influences the rest of their peers into skilled births. In the long run the effect on this adversely affects the traditional birth sector by reducing the recruitment levels and their functionality in home births, there are nil recruitments as the number of medical personnel increases, those available are only serving the few remaining non-adoptee.

In dynamic terms, the reinforcing loops R1 (access loop) and R3(attractiveness loop) exert enough influence despite the decisive action of the balancing mechanisms of B1 (social loop) (Figure 2). The overall maternal mortality ratio does not get to the target of at least 70 maternal deaths to 100000 live births. This is because the medical personnel and health facilities cannot build to sufficiently high levels within the ten years at the rate of investment being applied and the balancing mechanism of B1.

In subsequent cases, the overall investment was higher and resulted in positive results also. The overall results are presented in Table 6. Despite improvements, however, the policy goal of at least 70 maternal deaths was not achieved. According to WHO, the reference medical personnel should at least be 23 medical personnel to 10,000 persons; with that, the medical personnel switch ensures we get to the medical personnel seamlessly.

5.2.4 Free Maternity Programme

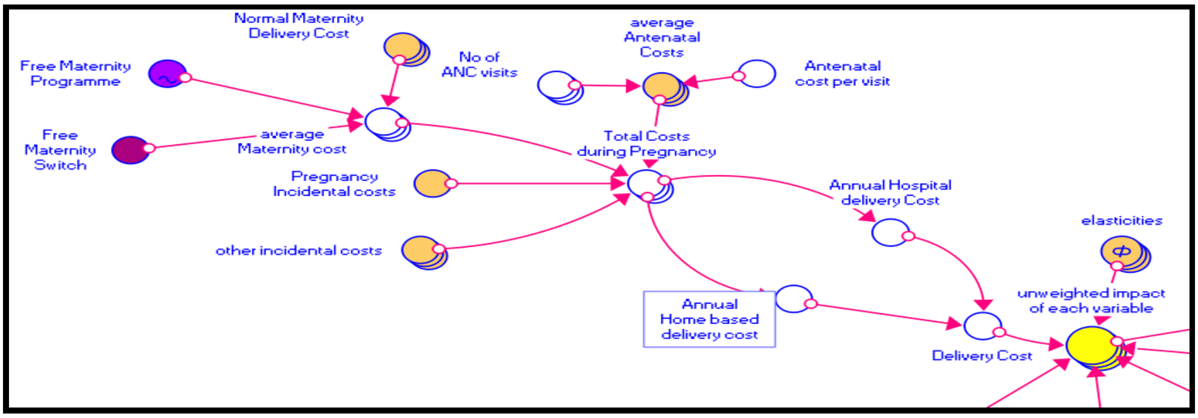
5.2.4.1 Policy Design

In 2013, the government of Kenya launched a 'free maternity service programme' commonly referred to as 'Linda Mama Program'. (MOH,2015). Maternity health services are provided free in public health facilities to women of reproductive age with the program. The program seeks to eradicate financial barriers to during delivery in public health facilities, thereby encouraging more women to opt for skilled delivery. This initiative would, in turn, contribute to improved pregnancy outcomes, reduced maternal and neonatal mortality, provide a cost-saving from delivery costs for other economic activities, especially in low-income households; supplement " budgetary provisions for public health facilities; hence effectively address quality gaps in the maternity services.

Each public health facilities offering free maternity services get a reimbursement of KSh.5,000 and KSh.2,500 for general hospitals and other health facilities, respectively. In model figure 36, we use Kshs.5000 as the base average maternity delivery cost. This parameter is arrayed to capture home birth and hospital birth.

The Ministry progressive budget of KSh.4.2 billion for this programme ensures that all health facilities are reimbursed for the maternity services. The project outcome has increased from 925,716 deliveries (2014/15), 995,905 (2015/16) and 982,122 deliveries (2016/17against Kshs 3.54 billion) deliveries in health facilities, and a total allocation of KSh.12.2 billion disbursed to public health facilities offering the service. Overtime change has been necessitated in how the project is implemented to ensure increased coverage and benefits to pregnant mothers. (MOH,2018).

Figure 35: Free maternity programme



5.2.4.2 Policy Analysis

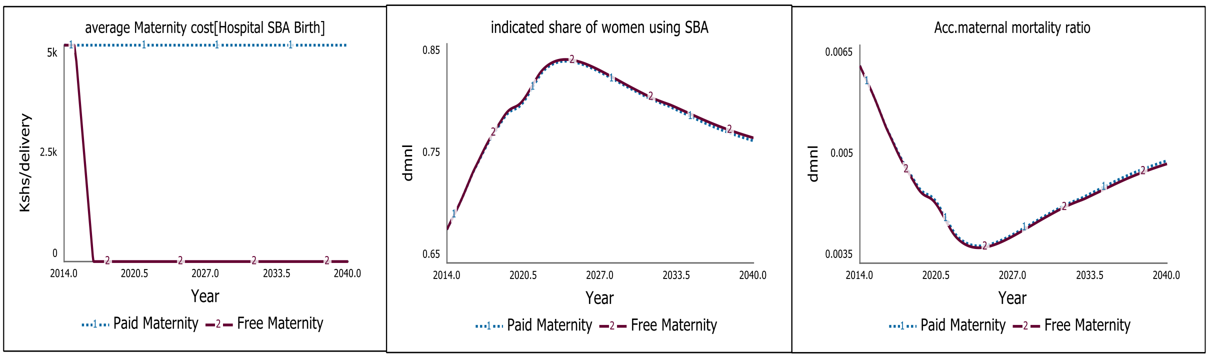
With paid maternity, without policy the access is quite low and usual, women pay for delivery service.

With free maternity programme and the policy switch on and delivery service is subsidised by the government. This policy addresses the issue of the delivery cost in public health Centres so that it waives the delivery cost. As such the worst-case scenario occurs with the payment of delivery cost which is priced at Kshs.5,000 per delivery and the subsidy cost by the government in free maternity programme.

As shown in Figures 37, the effect of free maternity service on the delivery costs, and the uptake of skilled births as measured through the ‘indicated share of women who opt skilled birth’ and in turn its influence on the maternal mortality differ depending on the scenario (worst case and business as usual (BAU scenario).

In the worst-case scenario, women pay for delivery service; the indicated share of women is 2 percent lower than with free maternity at 83.5 percent which accounts for an additional 30,000 women using the service due to the subsidy programme. An addition of extra one woman means less death; with free maternity the deaths are lower at 379 compared to 382 deaths in paid Maternity.

Figure 36: Free maternity service.



5.3 Main Insights

5.3.1 Policy Mix

In 2013/14, the government introduced free maternity service; from simulation not so much, difference can be seen; when coupled with other policies, the benefits can be seen from the graphical interpretation. The government is implementing free maternity programme currently. We look at the policy response of the different policy in relation to free maternity as this is an existing policy and it relieves the mothers the financial burden during birth.

Figure 38 shows interaction between the different policies; and we can deduce that combination of all the four policies gives the best results; free maternity, hiring, advocacy and mobile clinics give best results of approximately 286 deaths against an SDG target of 70 death in 2035. All the policies implementations are done and have delayed response as seen in the results, which could be the case especially where uptake takes time. For 10-year period it would cost the government approximately Kshs.339 billion to implement all the policies with an output of at least of 87.6 percent of women using skilled birth and approximately 306 maternal deaths. The policies continue working even after end of target policy period of 2030.

Mobile clinics, serve its function of providing additional coverage; this is a huge capital investment the health sector must undertake. For the 10-year period approximately Kshs.78. billion is required. If the budget is increased 10-fold to Kshs. 780 Billion budget, it gets an additional 94 percent use of skilled attendants with a 209 Maternal deaths.

From the graph below, we can deduce that we can achieve more with advocacy which is missing among pregnant women and as such this would be a good policy to invest as it only requires at least Kshs. 2.24 billion per year to undertake the advocacy campaigns and Kshs.24.7 billion for the 10-year period.

Hiring of medical personnel attracts more skilled births; This results 85.6 percent women opting for skilled birth in 2036 also being its peak year though results to 341 maternal deaths to 100,000 live births. This requires approximately Kshs.21.6 billion per year to fill the medical personnel gap. For the 10-year period the health sector would require Kshs.236 billion. This provides the best scenario and is government invests more into hiring, the results produced are favourable as seen in figure 38. From the analysis, increasing the budget by 10-fold for both the mobile clinics and hiring, increases the share of women opting for skilled birth. Increasing the recruitment budget gives responsive results in 2025 with 93.2 percent women using skilled birth attendants and reduced maternal death of 215 to 100,000 live births whereas increased mobile clinic budget gives delayed results at 2033 with better response rate at 93.9 percent skilled births and lower maternal deaths at 203 to 100,000 live births.

Figure 37: Policy Mix

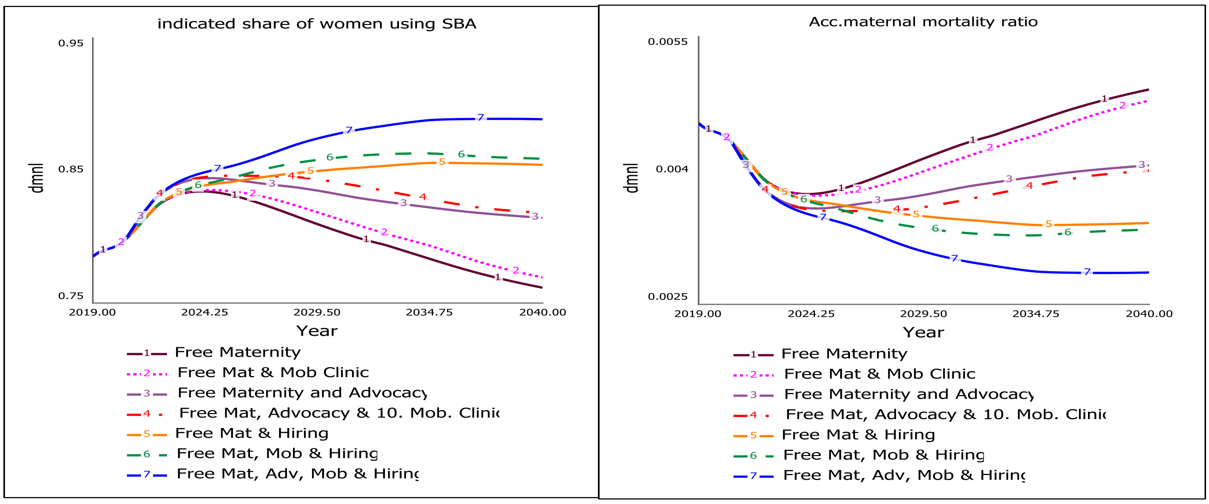


Table 7: Policy Mix summary results

Policy Scenario	Total Budget (kshs. Billion)	indicated share of women using SBA %	Maternal mortality ratio (x/100000)
Free Mat & Mob Clinic:	99.98	81.6%	403
Free Maternity and Advocacy	28.16	83.3%	375
Free Mat, Advocacy & 10. Mob. Clinic	99.99	84.6%	361
Free Mat, Advocacy &Mob clinic	108.34	84.4%	358
Free Mat & Hiring	28.16	85.03%	348
Free Mat, Mob & Hiring	99.28	85.9%	334
Free Mat Double Hiring, Adv	109.59	92.97%	219
Free Mat,Adv, 100Mob & Hiring	377.34	93.2%	215
Free Mat,Double hiring& advocacy,10* Mobile	101.47	93.6%	210

From the analysis we can deduce that increased budget yield higher results with highest results recorded with double hiring and advocacy budget and 10-fold mobile clinic budget. With introduction of road density for example 0.5 then we get better results using a budget of Kshs. 110 billion to achieve complete adoption of skilled birth as shown in figure 39 and table 8.

Figure 38: Best Policy Mix with Road density

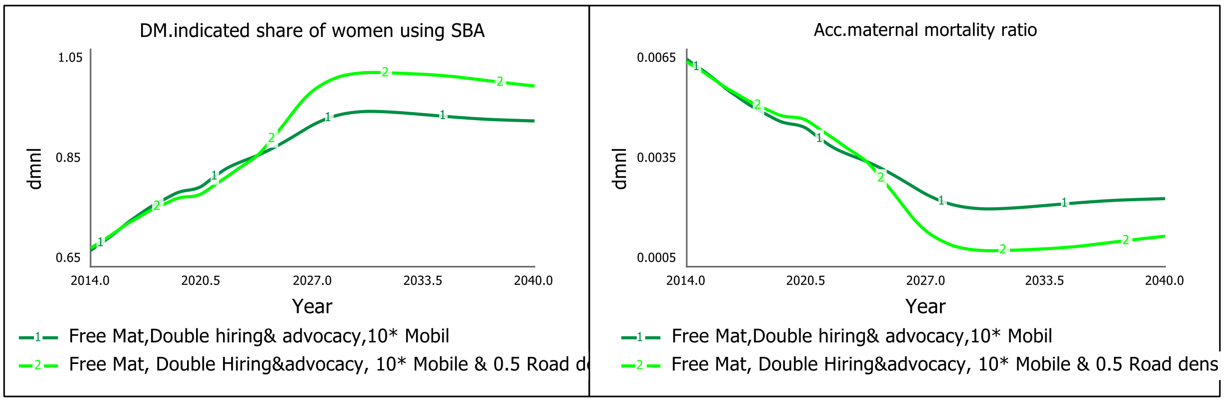


Table 8: Best Policy Mix with Road density

Policy Scenario	Total Budget (kshs. Billion)	indicated share of women using SBA %	Maternal mortality ratio (x/100000)

Free Mat,Double hiring& advocacy,10* Mobile	101.47	93.6%	210
Free Mat,Double hiring& advocacy,10* Mobile	110.09	100%	95

5.3.2 Strengths and Opportunities

In Chapter 4, the analysis indicated that financial investments in the various policies would help create and strengthen feedback mechanisms relating to the indicated share of women. Extra budgetary support to mobile clinics policy is designed to introduce such a more robust feedback mechanism through additional coverage and hence influence decision-making. The strength of this type of policy is that massive investment in mobile clinics could ensure optimal coverage within the shortest time possible, and as such, almost a 'one off 'kind of investment as it takes 40 years replacement.

The scenario on road density shows the importance of road networks and would hugely benefit investment in the health sector.

5.3.3 Model Limitation

While the model can offer interesting insights, it had its fair share of limitations, just like any work. Understanding the factors behind the choice of birthplaces and their implication on maternal mortality is quite extensive and extremely important. The degree of importance of the variables varies for everyone. Many could not be covered due to time constraints and captured under the 'other factors' variable. Hence, the policies developed and simulated improved the situation though other policies would enable us even to surpass the target.

The substantial financial investments required may not be in tandem with the slow and minimal improvement in the sector, which may not be in line with Cost-benefit analysis from an economic point of view. The health sector is a social sector where no amount of life lost could be measured, and no woman should lose life while giving life, especially for avoidable situations (UNICEF, 2019). This sector has its ripple effects on other sectors of the economy as a healthy and living population is a productive population and hence a healthy economy (Bloom & Canning, 2008).

The historic data spans back to even earlier than the 1980s; this would provide better insight into growth over time of various parameters, and the decision making, the trend in maternal mortality over the years. This could provide better knowledge on the trend and how decision-making could have changed over time and look at the significance of the decision factors. Therefore, the simulation model presents a dilemma in that it is too general, and some crucial variables could be left out. The model analyzes only a few decision-making variables, where several other parameters are likely at play, giving a simplified version of real-world dynamics.

Decision-making is an extensive subject to cover within the timelines; this required more time due to its extensive nature; there remain vital parameters that could be captured further, like income levels and literacy. Therefore, as much as some policies have been introduced that improve the share of women opting for skilled birth. In this field, it would be imperative to note other policies that could generate better results in combination with these.

The road density is relatively low compared to any ideal standard, like France having almost the same land area, making any little investment in mobile clinics look almost insignificant. Primarily since this is being focused in rural areas where the roads can be impassable in the rainy season as they are not tarmacked. The means of transport is mostly 'bodaboda motorbikes' due to poor infrastructure, which can be challenging, especially for the women due to delivery. This translates to a low number of women who would prefer hospital delivery which translates to a slightly higher mortality rate.

5.4 Findings

5.4.1 Overview

This projects' primary hypothesis is to develop a simulation model that can adequately explain the historically observed behavior patterns of maternal mortality at an aggregate level; by looking into the different relevant issues raised during the research and further understand the mechanisms pregnant women use in decision making as to whether to choose traditional birth attendants or opt for skilled birth.

The simulation model has been developed supported by existing literature that captures the causal relation of the various parameters identified in the study. This tries to explain the aggregated-individual behavior pattern pregnant women face when deciding where to give birth and whether to opt for a home birth or skilled birth. After several simulations runs, the model and its results were tested under several policy scenarios.

From the simulations, some policies are developed (advocacy, expansion of mobile clinics, and hiring of medical personnel). This section looks at the implications of the model findings, the limitations review, and the areas for further research. The last chapter's conclusion; will summarize the answers to the original research questions in section 1.3.

5.4.2 Summary of findings

These changes reflect in the model simulations as pregnant women shift their decisions to suit such policy introductions. These changes are reflected in the subcategories, i.e., yearly costs, convenience, socio-economic factors, and attractiveness. Therefore, the model should be applicable in explaining different birth choices (home/skilled) due to policy changes. The subcategories in the decision-making module use many specific effects which are vital in policy development.

After extensive simulations, some of the key findings include;

1. The 'business as usual' scenario confirms that the 'limits to growth' archetype in that the reinforcing loop (R1, R2, and R3; figure 2) enable the exponential growth in the indicated share of women using skilled birth while accelerating the exponential decay in maternal mortality these are countered by the strength posed by the balancing loop (B1 and B2), i.e., social and convenience loop respectively. The government efforts to promote skilled birth are successful initial by the investment in the health sector through construction and equipping of health facilities and recruitment of health personnel, though these efforts reach their point of diminishing returns as seen in the recent past with the stagnated maternal mortality. The effectiveness of the existing strategies and infrastructure has 'lost its former glory, and the growth begins to flatten as its effectiveness is lost.
2. In 2013/14, the free maternity programme was introduced, and it offered free delivery service; this has yielded positive results. The analysis shows minimalist positive results so that with this free delivery service, more opted for hospital birth at least 0.15% additional women and at least reducing maternal mortality by 3 to 100000 live births.
3. The Advocacy Policy is the most powerful of the three policies and can affect stability and growth in the various parameters in all scenarios. When combined with the other policies, much can be achieved within a shorter time frame. Little investment is required of Kshs. 33.7 billion compared for the 10 years compared to other policies which require massive. Advocacy works to reinforce the attractiveness loop R3 and counter the B1 social loop.
4. All these policies are dependent on the proportion of budgetary allocation; In all scenarios, and all three policies are switched on, positive results of different

magnitudes were reported. However, 100% budget is at its saturation point and has little difference in output with 50% for acquisition of mobile clinics.

5. A budgetary allocation increase and good road density result in better outcomes (figure 39 and table 8). This shows the need for proper access roads to increase access to the health centers and mobile clinics.

5.4.3 Implications of Findings

This research assumes that decisions at an individual level can be replicated collectively to get the aggregate national level; this changes each time new policies are introduced depending on their effect on specific traits/parameters of the decision. Hence, such a model can help better understand the decision-making generally and adjust with the introduction of the different policies.

5.4.4 Implications for policy makers

According to WHO, maternal mortality is extensively used as a critical health indicator that shows wide gaps between high-income, developed, and low-income countries (WHO, 2019). As such, policymakers try to develop policies that they hope that its adoption is almost 100%. Hence policymakers can benefit from this model insights as they develop policies to increase uptake of skilled birth. The policies show a policy mix will lower maternal mortality with more emphasis on advocacy as it gets more responses with lower budgetary implications.

The simulation model could test how future developments of the health sector, precisely maternal-related issues, are likely to affect decision-making. The model can be used to predict future behaviors after policies are introduced.

The model could be used for future projections as policymakers try to develop appropriate policy in the ever-dynamic health sector, and if the structure is valid with adjustment to fit situations, it should produce appropriate output for future scenarios. It could, for example, estimate how big an additional financial investment would require getting the share of women using skilled birth towards 100% and reduce maternal mortality to at least the SDG level. Policymakers or health sector investors could also use this to achieve the desired results and reduce maternal mortality with an estimated budgetary allocation and social and infrastructural investments.

5.4.5 Use in other Areas/ projects

This section answers research question 4, which asks, 'What other areas could such a model be customised for use in other areas beyond maternal mortality?' The thesis objective was to develop a simulation model that can be applied to different relevant issues. This model can be incorporated in other areas where decision-making is critical, such as child nutrition and investment at the household level, as some of the parameters apply to both cases. The model could also be used in estimating other sections where decision-making is paramount at an individual level and aggregated nationally.

The model can track how different policies affect decision-making; these additional feedback loops can be drawn through the model structure extension.

Some alterations and parameter modifications need to be done for the model to be used beyond decision making. If the model is to be used together with other models, it must be customized to suit the intended objective, validity tests conducted when combined with other model structures. For instance, if used with other models to estimate mortality in Kenya, the critical indicator 'maternal mortality can be used and added to other mortality, e.g., child mortality may not require much modification. The model could be adapted to other sectors such as education.

Decision-making at an individual level, e.g., deciding whether to undertake additional schooling years after introducing a free primary education programme; this kind of structure can be used with some modifications. The access sector where health facilities are simulated can be adapted as the schools and learning facilities as all require financial investment for construction; the medical personnel could be adapted to the teaching personnel e.t.c.

5.5 Future Research Opportunities

Decision-making cuts across many sectors both at the individual and aggregate national level. Therefore, it has the potential to be applied to more areas. Decision-making and its influence on the choice of birth attendants apply to all countries. As such, it can be customized or modified to capture the different country realities.

Hence there exists a vast opportunity for further application and testing. Its complexity can vary based on the needs of the project. This simulation provides a simplified version, and its complexity could vary depending on the basis. The model can be adopted in other aspects since decision-making applies to almost all spheres of life and varies in magnitude.

With the current model, it would be interesting to capture the COVID crisis to see its effects on decision-making on birthplace choice. During this COVID time, home births were preferred, especially for those pregnant women who had a low risk of complications (Bourgeois, et al., 2021), (Daviss, et al., 2021). Given the current Covid situation, Home births cases could be replicated in many countries, and it would be interesting to simulate such a crisis and see its implications to maternal mortality. In Kenya, a study recommended the need to have strengthened community midwifery to meet the current shortfall of medical personnel due to COVID constraints and the disruption of the essential services resulting in higher maternal and child mortality (Kimani, et al., 2020).

Finally, future research should include endogenous generation of specific parameters that are exogenously represented and empirical testing of the assumptions made in this model. This would give a better representation of the existing historical data. For example, one key parameter/sector that would give a better fit is the road network. Good road networks can only heighten the accessibility of both health facilities and mobile clinics. It would be good to model this and find out how much more roads can give us that accessibility with ease and make emergency services optimized (Rao, 2018).

Health e-innovation emerging sectors that need tapping to get its full effect in more opting for skilled birth. In Malawi, the adoption of ‘health centers by phone provides essential primary health care service through messaging to rural populations. This has been applied in prenatal and postnatal care messaging to women. With information, e.g., mosquito nets use to prevent malaria, tips for preventing mother-to-child HIV transmission, among others. Modeling this would an interesting emerging area to see its effects on maternal mortality and decision making (Oyaro, 2017).

Finally, future research should include endogenous generation of specific parameters that are exogenously represented, and empirical testing of the assumptions made in this model. This would give a better representation of the existing historical data.

6.Conclusions

This research project has looked at how existing literature can be utilized with system dynamics methodology to prepare simulation models. These simulations help one better understand decision attributes key to birthplace choices and how it would influence their policies decisions in existing policies and new policies. The stock and flow structure capture the accumulating cause and effect relationships vital in developing the historical representation of the reference modes under the different sectors that feed into maternal mortality. A summary of the research questions is documented below.

Research question 1 on 'What factors are responsible for determining the choice of birthplace among pregnant women in Kenya?' has been looked into through the literature reviewed concerning the choice of birthplace identifies some of the critical parameters which are further discussed in an earlier chapter. Several issues are highlighted as convenience-related, social and economic factors, financial, human, and capital infrastructure, discussed in chapter 2.

Research Question 2 on 'What are the causal feedback mechanisms influencing decision making of birthplace in Kenya?' seeks to look at the casual relations between the various parameters. These are extensively shown in the causal loop diagram in figure 2, which captures the main reinforcing loops R1 (access loop), R2 (TBA loop), R3 (Attractiveness loop), and the balancing loop B1 (social loop), B2 (convenience loop). Feedback mechanisms between decision-making and existing policies could be absent; so that even with free maternity services, some women opt for a home birth. This model hence, therefore, highlights some of the limitations. The model is developed to capture feedback mechanisms activated with the mobile clinics, advocacy, and hiring policy.

Research question 3 'Can a generic simulation model be developed and utilized that approximates from variety of factors to influence decision making?'

The simulation model has been developed supported by existing literature that captures the causal relation of the various parameters identified in the study.

The simulation model has been tested, calibrated, and validated using the historical reference modes (medical personnel data, hospital facility data, and maternal mortality data). The behavioral results of the model developed in this research suggest that the generic model can be used to show how behavior in various scenarios influenced decisions making that impacted maternal mortality. The model, under different parameterizations, can reproduce a wide variety of behavior modes across several different types of domains.

Research question 4 on 'What are the potential policies that can influence decision making processes of pregnant women when choosing birthplaces in Kenya? How can these policies be cost effectively implemented?'

The dynamic structures translate decision changes into the vital indicator of maternal mortality through the different parameters in the modules. These insights have helped inform the design of policy interventions. The policies developed were advocacy, mobile clinic policy, and hiring policy. These policies give different results when tested under different scenarios. The government can best cost-effectively implement these policies through a policy mix.

The advocacy policy gives better results with a lesser budget from the simulations since it requires lesser financial requirements. All these policies play a very critical role which gives better results from policy combination.

Different policies are developed, and different policy scenarios are undertaken to gain a better understanding. The different policy scenarios show each policy's effectiveness and would be a guiding point for the various stakeholders and policymakers. It also reveals the expected behavior patterns when specific shocks are introduced.

In dynamic terms, the reinforcing loops R1 (access loop) and R3(attractiveness loop) exert enough influence despite the intense action of the balancing mechanisms of B1 (social loop) (Figure 2). Despite policy introduction, the overall value of maternal mortality does not get to the target of at least 70 maternal deaths to 100000 live births. One of the reasons is that the medical personnel and health facilities cannot build up to sufficiently high levels within the 10 years at the rate of investment being applied and the balancing mechanism of B1.

Investment in these policies (hiring, advocacy, and mobile clinics) would result in good results with better adoption of skilled birth and lower maternal mortality. A government budgetary allocation of Kshs. 110 billion could see that there is full adoption of skilled birth with approximately 95 maternal deaths to 100,000 live births. These are pretty good positive results.

This model can be used to test the different scenarios towards which the government could use when investing in the health sector.

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Annex 1: Model documentation

	Equation	Units	Documentation
Acc.desired_maternal_mortality_ratio	70/100000	dmnl	The Kenyan government to align its national development targets to get to the global maternal mortality ratio. SDG 3.1 targets that by 2030 the global maternal mortality ratio will be reduced to less than 70deaths per 100,000 live births. (https://sustainabledevelopment.un.org/sdg3)
SBA.Average_Duration_of_Employment	30	year	The average tenure of a medical personnel given that retirement is at 60 years so we assume they work for 30 years. www.wikipedia/Kenya/retirementage
SBA.Average_review_for_intermediate_MP[MedicalPersonnel]	Intermediate_Medical_Personnel/Review_time_for_MP	person/year	This is the adjustment for intermediate Medical Personnel for review time for MP
SBA.Average_review_for_recruit[MedicalPersonnel]	Medical_Personnel_Recruit/Review_time_for_New_recruits	person/year	This is the adjustment for Medical Personnel recruit for review time for MP
SBA.Birth_1	Birth_rate*TOTAL_POP	person/year	
SBA.Birth_rate	GRAPH(TIME) Points: (2008.00, 0.03668), (2009.00, 0.03594), (2010.00, 0.03513), (2011.00, 0.03425), (2012.00, 0.03333), (2013.00, 0.03242), (2014.00, 0.03152), (2015.00, 0.03069), (2016.00, 0.02994), (2017.00, 0.0293), (2018.00, 0.02875)	dmnl/year	https://www.indexmundi.com/kenya/demographics_profile.html
SBA.Departure[MedicalPersonnel]	Experienced_Medical_Personnel/Average_Duration_of_Employment	person/year	
SBA.Departure_Intermediate[MedicalPersonnel]	Average_review_for_intermediate_MP*(1-Promotion_Fraction)	person/year	
SBA.Desired_Experienced_MP[Doctors]	WHO_MP_reference[Doctors]*TOTAL_POP {((STEP(Fractional_Change_in_MP, Time_to_Change_Medical_Personnel)))}	person	The WHO reference is multiplied the total population to get the desired experienced medical personnel
SBA.Desired_Experienced_MP[Nurses]	WHO_MP_reference[Nurses]*TOTAL_POP		
SBA.Desired_Intermediate_MP[MedicalPersonnel]	Desired_Intermediate_Promotion*Review_time_for_MP	person	
SBA.Desired_Intermediate_Promotion[MedicalPersonnel]	Departure+Experienced_MP_Correction	person/year	
SBA.Desired_MP_Recruit	Desired_Recruit_Promotion*Review_time_for_New_recruits	person	

s[MedicalPersonnel]			
SBA.Desired_Recruit_Promotion[MedicalPersonnel]	Intermediate_Medical_Personnel_Correction+Departure_Intermediate	person/year	
SBA.Desired_recruits_Start[MedicalPersonnel]	Recruits_MP_correction+Recruits_departure	person/year	
SBA.Effect_of_Relative_Gap_on_the_required_MP	GRAPH(Relative_access) Points: (0.000, 1.98996072361), (0.200, 1.97302068506), (0.400, 1.92886119023), (0.600, 1.82119561697), (0.800, 1.59658786795), (1.000, 1.2500), (1.200, 0.903412132055), (1.400, 0.678804383033), (1.600, 0.571138809766), (1.800, 0.526979314943), (2.000, 0.510039276386)	dmnl	
SBA.Experienced_Medical_Personnel[MedicalPersonnel](t)	Experienced_Medical_Personnel[MedicalPersonnel](t - dt) + (Intermediate_Promotion[MedicalPersonnel] - Departure[MedicalPersonnel]) * dt	person	This is initialized at the experienced medical personnel level. INIT SBA.Experienced_Medical_Personnel[MedicalPersonnel] = Required_Experienced_Medical_Personnel
SBA.Experienced_MP_Correction[MedicalPersonnel]	(Required_Experienced_Medical_Personnel-Experienced_Medical_Personnel)//Time_to_Correct_Experienced_MP	person/year	This is the gap function between required experienced and experienced medical personnel adjusted for time.
SBA.Hiring_Policy_Switch	1	Dimensionless	Policy switch off=0; Policy switch on=1
SBA.Intermediate_Medical_Personnel[MedicalPersonnel](t)	Intermediate_Medical_Personnel[MedicalPersonnel](t - dt) + (New_recruits_promotion[MedicalPersonnel] - Intermediate_Promotion[MedicalPersonnel] - Departure_Intermediate[MedicalPersonnel]) * dt	person	This is initialized at the intermediate medical personnel. INIT SBA.Intermediate_Medical_Personnel[MedicalPersonnel] = Desired_Intermediate_MP
SBA.Intermediate_Medical_Personnel_Correction[MedicalPersonnel]	(Desired_Intermediate_MP-Intermediate_Medical_Personnel)//Time_to_Correct_Intermediate_TBA	person/year	This is the gap function between desired intermediate medical personnel and intermediate medical personnel recruit adjusted for time.
SBA.Intermediate_Promotion[MedicalPersonnel]	Promotion_Fraction*Average_review_for_intermediate_MP	person/year	this is multiplication average review for intermediate MP by promotion fraction
SBA.Medical_Personnel_Recruit[MedicalPersonnel](t)	Medical_Personnel_Recruit[MedicalPersonnel](t - dt) + (Recruitment_rate[MedicalPersonnel] - New_recruits_promotion[MedicalPersonnel] - Recruits_departure[MedicalPersonnel]) * dt	person	This is initialized at the desired level of recruits level. INIT SBA.Medical_Personnel_Recruit[MedicalPersonnel] = Desired_MP_Recruits

SBA.Migration_rate	GRAPH(TIME) Points: (2000.00, -0.000027), (2001.00, 0.0000311), (2002.00, 0.0000892), (2003.00, 0.0001473), (2004.00, -0.0000754), (2005.00, -0.0002975), (2006.00, -0.0005196), (2007.00, -0.0007417), (2008.00, -0.0009638), (2009.00, -0.0008159), (2010.00, -0.000667), (2011.00, -0.000518), (2012.00, -0.00037), (2013.00, -0.000022), (2014.00, -0.000217), (2015.00, -0.000212), (2016.00, -0.000207), (2017.00, -0.000202), (2018.00, -0.000197), (2019.00, -0.000193), (2020.00, -0.000189), (2021.00, -0.000184)	dmnl/year	Net migration rate: -0.2 migrant(s)/1,000 population (2020 est.) Definition: This entry includes the figure for the difference between the number of persons entering and leaving a country during the year per 1,000 persons (based on midyear population).Nov 27, 2020
SBA.Mortality	TOTAL_POP*Mortality_rate	person/year	
SBA.Mortality_rate	GRAPH(TIME) Points: (2000.00, 0.012251), (2001.00, 0.012217), (2002.00, 0.012182), (2003.00, 0.012147), (2004.00, 0.011448), (2005.00, 0.010749), (2006.00, 0.01005), (2007.00, 0.009351), (2008.00, 0.008652), (2009.00, 0.008248), (2010.00, 0.007844), (2011.00, 0.00744), (2012.00, 0.007036), (2013.00, 0.006632), (2014.00, 0.006409), (2015.00, 0.006186), (2016.00, 0.005964), (2017.00, 0.005741), (2018.00, 0.005518), (2019.00, 0.005483), (2020.00, 0.005448), (2021.00, 0.005414)	dmnl/year	https://www.macrotrends.net/countries/KEN/kenya/death-rate 5.2 deaths/ Death rate: 5.2 deaths/1,000 population (2020 est.)Nov 27, 2020
SBA.Net_Migration	TOTAL_POP*Migration_rate	person/year	KNBS https://www.indexmundi.com/kenya/demographics_profile.html
SBA.New_recruits_promotion[Medical Personnel]	Average_review_for_recruit*Promotion_Fraction	person/year	this is multiplication average review for recruit by promotion fraction
SBA.Promotion_Fraction	0.995	dmnl	We assume 99.5% promotion fraction; In Public service almost all civil servants get promoted we assume 0.5 percent departure.
SBA.Recruitment_rate[MedicalPersonnel]	IF (Hiring_Policy_Switch=1) AND TIME>=2020 THEN DELAY3(MAX(Desired_recruits_Start, (Hire.Budgeted_Medical_Personnel/Time_to_recruit)), 3) ELSE (DELAY3(Desired_recruits_Start,3))	person/year	Recruitment rate has a third order delay; recruitment is done every 3 years when there is a promotion to the next cardre. The recruitment takes into consideration the minimum between budgeted medical personnel and the desired recruit promotion.
SBA.Recruits_departure[MedicalPersonnel]	Average_review_for_recruit*(1-Promotion_Fraction)	person/year	

SBA.Recruits_MP_correction[Medical Personnel]	(Desired_MP_Recruits-Medical_Personnel_Recruit)//Time_to_recruit	person/year	This is the gap function between desired medical personnel recruit and medical personnel recruit adjusted for time.
SBA.Reference_Access	SDG_Reference_Access*(1+STEP (Step_in_Reference_Access, 0))	dmnl	The required level of output. Set by the user; begins at the reference value, and can be increased by a certain amount, or follow a linear ramp with a user-determined slope.
SBA.Relative_access	DELAY1(Acc.Access_to_basic_health_care, 1, 0.8)/Reference_Access	dmnl	There is a delay n response of Access to basic information; to get the relative access we get the ratio of the delayed function of the annual access to health care and the reference access that's 80 percent.
SBA.Required_Experienced_Medical_Personnel[MedicalPersonnel]	(Required_Medical_Personnel * ((1+Review_time_for_MP)))/Review_time_for_MP	person	This is a function of the required medical personnel and the Required Medical Personnel (MP) increases with the Access shortfall. The sensitivity of MP to the shortfall determines how many MP are sought in response to a given Access gap. Required MP will also increase to provide services to boost capacity, according to the Sensitivity of MP to Acess.
SBA.Required_Medical_Personnel[Doctors]	Desired_Experienced_MP[Doctors]*Effect_of_Relative_Gap_on_the_required_MP*STTEPP[Doctors]	person	Required medical personnel increases with the access shortfall. The effect of relative gap on the required MP determines how many people are sought in response to a given access gap. Required Medical personnel will also increase to provide resources to boost capabilities, the gap in access. The step function capture the recruitment of additional MP
SBA.Required_Medical_Personnel[Nurses]	Desired_Experienced_MP[Nurses]*Effect_of_Relative_Gap_on_the_required_MP*STTEPP[Nurses]		
SBA.Review_time_for_MP	1	year	We assume that the review time for the intermediate personnel is 1 years.
SBA.Review_time_for_New_recruits	1	year	The review time is assumed to be 1 year.
SBA.SDG_Reference_Access	.8	dmnl	The initial value for required Access. Defined as atleast 80 percent can be thought of as an index value (100% of the initial level of required output).
SBA.Step_in_Reference_Access	0	Dmnl	The fractional step increase in required Access. Set by the govt.
SBA.STTEPP[Doctors]	0.068	dmnl	
SBA.STTEPP[Nurses]	0.26		
SBA.Time_to_Correct_Experienced_MP	1	year	We assume 1 year is required to correct experienced MP.
SBA.Time_to_Correct_Intermediate_TBA	1	year	We assume that 1 year is required to correct intermediate medical personnel
SBA.Time_to_recruit	5	year	This is five year. we assume it takes 5 years to make the decision, undertake the recruitment process and set budget after undertaking the gap analysis. Recruitment into Civil Service is quite a lengthy process in Kenya.

SBA.Total_Medical_Personnell[MedicalPersonnel]	Experienced_Medical_Personnel	person	This is the sum of the intermediate and experienced medical personnel. This is arrayed into doctors and nurses. So the same of each category of array. The medical personnel recruits are not included as they are in internship and work under supervision of intermediate and experienced personnel.
SBA.TOTAL_POP(t)	TOTAL_POP(t - dt) + (Birth_1 - Mortality - Net_Migration) * dt INIT SBA.TOTAL_POP = 31098751	person	http://ghdx.healthdata.org/record/kenya-population-and-housing-census-1999
SBA.WHO_doctors_reference	0.001	dmnl	Considering the number of registered medical practitioners of both modern medicine (MBBS) and traditional medicine (AYUSH), India has already achieved the World Health Organization recommended doctor to population ratio of 1:1,000 the "Golden Finishing Line" in the year 2018 by most conservative estimates. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6259525/
SBA.WHO_MP_reference[Doctors]	WHO_doctors_reference	dmnl	WHO nurse to population recommendation 1:500; WHO doctor 1:1000 https://www.slideshare.net/sivanandareddy52/nabhnursing-resource-management
SBA.WHO_MP_reference[Nurses]	WHO_nurses_reference		
SBA.WHO_nurses_reference	1/500	dmnl	WHO nurse to population recommendation 1:500 https://www.slideshare.net/sivanandareddy52/nabhnursing-resource-management With optimization we managed to get a value 0.00198999999768 as opposed to 1/500(0.002)
	Variable_Color_Scheme:		
Budget_Variables	1	dmnl	
Exogenous_Variables	1	dmnl	
Key_indicator_of_sector	1	dmnl	
Policy_Switch	1	dmnl	
	Acc.Data:		
Acc.annual_gap_adj_rate	1/(policy_time_period/3)	per year	YEARLY GAP ADJUSTMENT FRACTION. EACH YEAR WE CLOSE 15%
Acc.Births_Data	GRAPH(TIME) Points: (2000.00, 1281850), (2001.00, 1309153), (2002.00, 1333599), (2003.00, 1361604), (2004.00, 1386812), (2005.00, 1410418), (2006.00, 1431398), (2007.00, 1448943), (2008.00, 1462571), (2009.00, 1472217), (2010.00, 1477759), (2011.00, 1479292), (2012.00, 1477823), (2013.00, 1474654), (2014.00, 1470991), (2015.00, 1468429), (2016.00, 1468510), (2017.00, 1472012), (2018.00,	Dimensionless	Total - births (thousands) - total - estimates of Kenya increased from 599.65 thousands in 1971 to 1,505.63 thousands in 2020 growing at an average annual rate of 1.90%. https://knoema.com/UNWPP2019/world-population-prospects-2019

	1479343), (2019.00, 1490648), (2020.00, 1505629)		
Acc.Current_Mortality_rate	GRAPH(TIME) Points: (2000.00, 0.00708), (2001.00, 0.00702), (2002.00, 0.00692), (2003.00, 0.00678), (2004.00, 0.00653), (2005.00, 0.00618), (2006.00, 0.00583), (2007.00, 0.00545), (2008.00, 0.00513), (2009.00, 0.00472), (2010.00, 0.00432), (2011.00, 0.00398), (2012.00, 0.00373), (2013.00, 0.00364), (2014.00, 0.00358), (2015.00, 0.00353), (2016.00, 0.00346), (2017.00, 0.00342)	dmnl	Economic Survey by Kenya National Bureau of Statistics (Various issues)
Acc.Desired_Mortality_Rate	70/100000	dmnl	By 2030, Target 3.2 aims to "end preventable deaths of newborns and children under 5 years of age," and Target 3.1 is to "reduce the global maternal mortality ratio to less than 70 per 100,000 live births." Other targets reflect the universal nature of the SDGs (WHO 2016)
Acc.Health_centres_Data	GRAPH(TIME) Points: (2000.00, 1679), (2001.00, 3203), (2002.00, 5300), (2003.00, 6000), (2004.00, 6600), (2005.00, 7000), (2006.00, 6800), (2007.00, 6800), (2008.00, 6700), (2009.00, 9100), (2010.00, 9200), (2011.00, 9200), (2012.00, 9200), (2013.00, 9600), (2014.00, 10400), (2015.00, 11300)	health center	Economic Survey by Kenya National Bureau of Statistics (Various issues)
Acc.Maternal_death_ratio	Maternal_Deaths_Data/Births_Data	persons	
Acc.Maternal_Deaths_Data	GRAPH(TIME) Points: (2000.00, 9100.0), (2001.00, 9200.0), (2002.00, 9200.0), (2003.00, 9200.0), (2004.00, 9100.0), (2005.00, 8700.0), (2006.00, 8300.0), (2007.00, 7900.0), (2008.00, 7500.0), (2009.00, 6900.0), (2010.00, 6400.0), (2011.00, 5900.0), (2012.00, 5500.0), (2013.00, 5400.0), (2014.00, 5300.0), (2015.00, 5200.0), (2016.00, 5100.0), (2017.00, 5000.0)	persons	Economic Survey by Kenya National Bureau of Statistics (Various issues)
Acc.policy_deadline	2030	Year	Period for policy test and fit within the Kenya Vision 2030
Acc.policy_start_time	2014	Year	Policy introduced in 2014
Acc.policy_status	IF policy_switch = 1 AND TIME > policy_start_time THEN 1 ELSE 0	dmnl	
Acc.policy_switch	0	dmnl	
Acc.policy_time_period	policy_deadline-policy_start_time	Year	this is the period when the policy is expected to work with the set targets
Acc.total_population_Data	GRAPH(TIME) Points: (2000.00, 32000000), (2019.00, 47000000)	Person	This variable represents the total population. Sources include: World Bank

Acc.Total_Weight_of_budget	Advocacy_Policy.Share_of_awareness_budget + Hire."%_of_Expenditure_To_Recruit_Additional" + Share_of_budget_for_Health_facility_development	dmnl	
Acc.Access_to_basic_health_care	(Proportion_of_area_covered_by_Health_Centres+Mob:.proportion_of_area_covered_by_mobile_clinic)	dmnl	By adding both proportion of the area covered by hospitals and that covered through mobile clinics we are able to actually get the total area covered and hence get how accessible the healthcare system is in Kenya This indicator measures how accessible the health care systems (health facilities and mobile clinics) are to the Kenyans especially those in the rural area.
Acc.area_covered_by_healh_centers	MIN(Total_Land_Area, area_covered_per_health_center*Functioning_Health_Centres)	ha	This is a minimum function which ensure that the coverage does not exceed the total land area. The function selects the minimum coverage either the total land area or the total land area covered by the health centers(area covered by health center multiplied by the functioning health centres)
Acc.area_covered_per_health_center	2827	ha/health center	we estimate health centers to cover atleast 5827 ha
Acc.cost_of_building_a_new_health_center	15e6	KShs/health center	We assume that the average cost of bulding and equiping a hospital is Kshs. 33,500,000.
Acc.effect_of_medical_personnel_gap_on_functioning_Health_centre	GRAPH(SMTH3(SBA.Relative_Medical_Personnel_gap, 3)) Points: (0.000, 0.000), (0.200, 0.33583091167), (0.400, 0.560945103841), (0.600, 0.7118436595), (0.800, 0.812993986277), (1.000, 0.880797077978), (1.200, 0.926246849528), (1.400, 0.956712742486), (1.600, 0.977134641257), (1.800, 0.99082384938), (2.000, 1.000)	dmnl	This captures the effect of medical personnel adequacy to the health facilities. We assume that for a medical center to be considered functional it should be adequately staffed with doctors and nurses as per the WHO reference of 23 births to 100000 live births.
Acc.elasticity_of_MP_to_Health_Facility[Doctors]	0	dmnl	
Acc.elasticity_of_MP_to_Health_Facility[Nurses]	-0.5		
Acc.Functioning_Health_Centres	working_health_centers*effect_of_medical_personnel_gap_on_functioning_Health_centre	health center	This is a minimum function between the working health centers and the actual operational health centers
Acc.Health_Budget	GRAPH((IF TIME	Kshs/year	This is the health development budget in nominal terms (MTEF REPORT 2019/2020)
Acc.health_budget_for_health_centers_construction	MAX(real_Development_health_expenditure-health_centers_running_cost, 0)	Kshs/year	This is the remainder of the real development expenditure after deduction of the health center running cost. The remainder is what is left for health center construction
Acc.health_center_average_construction_time	4	year	We assume that it takes 4 years to construct and equip health centers.

Acc.health_center_Lifetime	100	year	We assume Health Centers have a life time of approximately 80 years
Acc.health_centers_construction	DELAYN(((health_budget_for_health_centers_construction/cost_of_building_a_new_health_center)+health_centers_depreciation), health_center_average_construction_time,1, 1679)	health center/year	This is a first order material delay. It takes approximately 4 years to construct a health center and have it fully operational. the number of health centers constructed is obtained by dividing the cost of building a new health center and the health construction budget.
Acc.health_centers_depreciation	health_facility/health_center_Lifetime	health center/year	this is a function of the number of health centers to the average lifetime of the health centers
Acc.health_centers_running_cost	health_facility*Running_cost_per_health_center*relative_population_per_health_center	Kshs/year	To get the total running expenditures, we multiply the running costs per health center multiplied by the number of health centers
Acc.health_facility(t)	health_facility(t - dt) + (health_centers_construction - health_centers_depreciation) * dt INIT Acc.health_facility = INIT(Health_centres_Data)	health center	the initial number of health centers in 2000 was 1679. The massive development over time has been largely due to high budgetary allocation to the health sector
Acc.Inflation_Rate	GRAPH(TIME) Points: (2000.00, 0.061), (2001.00, 0.016), (2002.00, 0.009), (2003.00, 0.062), (2004.00, 0.071), (2005.00, 0.049), (2006.00, 0.235), (2007.00, 0.081), (2008.00, 0.152), (2009.00, 0.116), (2010.00, 0.021), (2011.00, 0.108), (2012.00, 0.094), (2013.00, 0.052), (2014.00, 0.081), (2015.00, 0.100), (2016.00, 0.056), (2017.00, 0.109), (2018.00, 0.024), (2019.00, 0.040)	dmnl	In 2019, inflation rate (GDP deflator) for Kenya was 4 %. Though Kenya inflation rate (GDP deflator) fluctuated substantially in recent years, it tended to decrease through 1970 - 2019 period ending at 4 % in 2019. Inflation in Kenya is erractic and hence the need to factor it (KNBS 2020-Economic survey) Inflation as measured by the annual growth rate of the GDP implicit deflator shows the rate of price change in the economy as a whole. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency. GDP deflator=Nominal GDP/Real GDP *100 https://knoema.com/atlas/Kenya/topics/Economy/Inflation-and-Prices/Inflation-rate-GDP-deflator
Acc.population_covered_by_health_services	proportion_of_Population_covered_by_health_centers*SBA.TOTAL_POP	person	This is a function of the proportion of population covered by health centers and the total population.
Acc.population_per_health_center	population_covered_by_health_services//working_health_centers	person/health center	this is the ratio of the population covered by health center and the number of working heath centers
Acc.Proportion_of_area_covered_by_Health_Centres	area_covered_by_health_centers/Total_Land_Area	dmnl	This is a ratio of the area covered by health centers to the total land area
Acc.proportion_of_Population_covered_by_health_centers	GRAPH(Proportion_of_area_covered_by_Health_Centres) Points: (0.000, 0.000), (0.030, 0.100), (0.100, 0.225), (0.250, 0.450), (0.500, 0.700), (1.000, 1.000)	dmnl	This is a graphical function of the area covered by health centers. It shows the proportion of coverage.
Acc.proportion_of_running_cost_covered	MIN(real_Development_health_expenditure//health_centers_running_cost, 1)	dmnl	This captures how much of the real health expenditure covers the health running cost. This proportion seeks to find the extent to which the health Center running cost is covered. So that if the running expenditure is nil then the proportion covered is nil, and when the real expenditure is greater than ambulance running cost, the Min function ensures that the lesser is picked and that is health centre running cost. This shows that 100% of

			the health center running cost is covered with the remainder left for purchase.
Acc.proportion_of_working_health_centers	SMTHN(proportion_of_running_cost_covered, time_for_expenditure_to_affect_functioning_health_services, 1, 1)	dmnl	We use an information delay to capture how the funding will have a direct effect on the functioning of the Health centers. We assume it takes 0.5 year for money set to function for health centers. So that if money the proportion of running cost covered is decreased, the effect of this reduction is not normally felt immediately but it takes some time before the health centers are grounded due to the low running cost coverage
Acc.real_Development_health_expenditure	(Health_Budget*(1-Inflation_Rate))*Share_of_budget_for_Health_facility_development	Kshs/year	this is the health development budget in nominal terms multiplied by the inflation rate.
Acc.Reference_Basic_Health_Access	0.8	dmnl	The 2006 World health report identified a minimum health worker density of 2.3 skilled health workers (physicians and nurses/ midwives) per 1000 population, which was considered generally necessary to attain high coverage of atleast 80 percent https://apps.who.int/iris/bitstream/handle/10665/250330/9789241511407-eng.pdf;sequence=1
Acc.Relative_Acces_to_basic_Health_Care	Access_to_basic_health_care/Reference_Basic_Health_Access	dmnl	
Acc.relative_population_per_health_center	population_per_health_center//INIT(population_per_health_center)	dmnl	Normalized by getting the dividing the population per health center by its initial number of health centers.
Acc.Running_cost_per_health_center	200000*12	Kshs/health center/year	we assume that it costs approximately Kshs.300,000 per month to run a health facility. This is with exclusion of salaries and medication. The costs is for general routine maintenance and operational costs i.e electricity bills, water bill
Acc.Share_of_budget_for_Health_facility_development	0.616	dmnl	
Acc.sim_time	TIME	year	
Acc.sim_time_dmnl	sim_time/year	dmnl	
Acc.time_for_expenditure_to_affect_functioning_health_services	0.5	year	we assume that it takes approximately 6 months for expenditure to affect functioning of health centers. The procurement process of various materials and equipments and medical supplies takes time approx. 6 months.
Acc.Total_Land_Area	569140*100	ha	580 367 sq km 1sq km is equivalent to 100ha At 580,367 square kilometres (224,081 sq mi), Kenya is the world's 48th largest country by total area. the inland water area occupies 1123000 square kilometres. The total land area is the difference between the total area and total water area. Total Land area is 569,140sq km

			Kenya - Wikipedia
Acc.working_health_centers	MAX(0, health_facility*proportion_of_working_health_centers)	health center	This is a function of proportion of working health centers multiplied to the number of health centers
Acc.year	1	year	
Acc.Maternal_Mortality_Sector:			
Acc.Adjustment_Time	1	year	This is the births that take place annually, its calculated annually. The time it takes to record the statistics which are collected annually.
Acc.Becoming_Pregnant	Pregnant_Women//Duration_of_Pregnancy	person/year	This is a function of pregnant women annually
Acc.Births	Births_Rate	person/year	
Acc.births_attended_by_skilled_health_personnel	Pregnant*DM.indicated_share_of_women_using_SBA	person	This is a function of births in population sector with the proportion of those births attended by skilled health personnel
Acc.births_attended_by_Traditional_Birth_Attendants	(Pregnant-births_attended_by_skilled_health_personnel)	person	This is determined by the births less those attended by skilled health personnel and the remainder of the effect of medical personnel adequacy on hospital birth
Acc.Births_Rate	Pregnant/Adjustment_Time	person/year	This is a function of of the pregnant women and the time adjustment
Acc.Current_Maternal_Mortality_Ratio	Maternal_Deaths_Data/Pregnant_Women	Dimensionless	This is calculated based on existing statistics. which is the ratio between maternal death and number of pregnant women. This is data from various sources of economic Survey (KNBS, 2000-2019)
Acc.Duration_of_Pregnancy	0.75	year	This is the time it takes to record the statistics which are collected annually
Acc.maternal_mortality_ratio	(women_dying_during_birth_under_TBA +women_dying_during_birth_under_SBA)//(births_attended_by_Traditional_Birth_Attendants+births_attended_by_skilled_health_personnel)	dmnl	This is a function of maternal deaths to total births. The maternal deaths is a sum of women dying with and without assistance from skilled health personnel. The Total births is a function of all births those attended and those without skilled health personnel in attendance.
Acc.maternal_mortality_ratio_gap	maternal_mortality_ratio-desired_maternal_mortality_ratio	dmnl	This is the difference between maternal mortality rate and the desired maternal ratio. With this gap we are able to measure how we are closing the gap
Acc.Pregnant(t)	Pregnant(t - dt) + (Becoming_Pregnant - Births_Rate) * dt INIT Acc.Pregnant = INIT(Pregnant_Women)	person	This is the stock of the accumulates the total number of pregnant women in Kenya This is a function of the birth rate. We assume that the 1:1 ratio in mother to child and minimal almost negligible multiple pregnancies
Acc.Pregnant_Women	GRAPH(TIME) Points: (2012.000, 801815.0), (2013.000, 870599.0), (2014.000, 954254.0), (2015.000, 950224.0), (2016.000, 948351.0), (2017.000, 923487.0), (2018.000, 1135378.0)	person	This is data from various sources of economic Survey (KNBS, 2000-2019)
Acc.Probability_of_death_from_TBA	0.0172 {1/55} {0.0012}	dmnl	In most african countries, traditional birth attendants (TBA's) have provided maternity care for women despite having no formal training. Unicef figures show 1 in every

			126 Tanzanian women dying due to maternity complications, and the story is the same in Ghana. https://www.worktheworld.co.uk/blog/traditional-birth-attendants-%E2%80%93-do-they-put-african-women-risk The average lifetime risk of a woman dying of maternal causes in these countries is approximately 1 in 55 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3126980/
Acc.Probability_of_death_under_SBA	0.00106 {130/100000) {0.0158	dmnl	Maternal mortality: Every day in 2017, about 808 women died due to complications of pregnancy and child birth. Almost all of these deaths occurred in low-resource settings, and most could have been prevented. The primary causes of death are haemorrhage, hypertension, infections, and indirect causes, mostly due to interaction between pre-existing medical conditions and pregnancy. The risk of a woman in a low income country dying from a maternal-related cause during her lifetime is about 130 times higher compared to a woman living in a high income country. Maternal mortality is a health indicator that shows very wide gaps between rich and poor and between countries. https://www.who.int/data/gho/data/themes/maternal-and-reproductive-health
Acc.women_dying_during_birth_under_SBA	births_attended_by_skilled_health_personnel*Probability_of_death_under_SBA	person	This is determined by the number of women giving birth, the proportion having skilled birth attendance, the proportion of risk of women dying while delivering under the help of skilled practioner and the effect of medical staff adequacy on having a successful birth.
Acc.women_dying_during_birth_under_TBA	births_attended_by_Traditional_Birth_Attendants*Probability_of_death_from_TBA	person	
Advocacy_Policy."Advocacy_Policy.":			
Advocacy_Policy."%_female_population"	GRAPH(TIME) Points: (2000.00, 0.503612517), (2001.00, 0.503721517), (2002.00, 0.503797137), (2003.00, 0.503839913), (2004.00, 0.503851339), (2005.00, 0.503834072), (2006.00, 0.503788689), (2007.00, 0.503719145), (2008.00, 0.503637114), (2009.00, 0.503556225), (2010.00, 0.503485549), (2011.00, 0.503428183), (2012.00, 0.503382088), (2013.00, 0.503343498), (2014.00, 0.503307308), (2015.00, 0.503269965), (2016.00, 0.503231591), (2017.00, 0.503194491), (2018.00, 0.503160204), (2019.00, 0.503130856)	dmnl	The proportion of female in the entire population range in almost 50 percent over the entire period. https://data.worldbank.org/indicator/SP.POP.TOTL.FE.ZS?end=2019&locations=KE&start=2000
Advocacy_Policy.Adopters(t)	Adopters(t - dt) + (Adoption_rate + Adoption_through_Awareness_campaign - Discard_Rate) * dt	person	The adopters represents number of women who give birth using skilled Birth attendants after undergoing awareness campaigns and adopt through word of Mouth.

	INIT Advocacy_Policy.Adopters = Total_Women_in_Reproductive_age		
Advocacy_Policy.Adoption_Density	((Adopters*Effectiveness_of_advocacy)/Total_Women_in_Reproductive_age)	dmnl	This captures the total number of adopters who have embraced skilled birth to the total women in the reproductive age.
Advocacy_Policy.Adoption_fraction	0.4	1/person	We assume that the adoption rate is atleast 40 percent using word of mouth
Advocacy_Policy.Adoption_from_word_of_mouth	(contact_rate*Adoption_fraction*Non_Adopters)*(Adopters/(Adopters+Non_Adopters))	person/year	Word of mouth and its adoption is generated by population of women who advocate for skilled birth attendants. The adoption from Advocacy works and is dependent on how effective the advocacy is; the more effective it is the more non-adopters are converted. It has a positive relationship. Adoption through awareness campaigns is strongly dependent on the awareness budget so that with a high budget more women can be reached; it works well with how effective the advocacy will be.
Advocacy_Policy.Adoption_rate	IF TIME < 2020 THEN 0 ELSE (Adoption_from_word_of_mouth)	person/Year	Advocacy-awareness and education This represents the total number of pregnant-women who adopt birth by skilled birth attendants following advocacy and word-of-mouth from fellow women. We assume advocacy starts in the year 2020 to be able to see the policy effect.
Advocacy_Policy.Adoption_through_Awareness_campaign	awareness_budget/awareness_cost_per_woman	person/year	Adoption through awareness campaigns is strongly dependent on the awareness budget so that with a high budget more women can be reached; it works well with how effective the advocacy will be. We obtain this by division of the awareness budget to the awareness cost per woman. This gives the number of women who can be reached through the campaigns.
Advocacy_Policy.awareness_budget	IF policy_Switch=1 AND TIME>=Policy_Start_year THEN (Share_of_awareness_budget*Acc. Health_Budget)*2 ELSE 0	Kshs/year	This represents the budget the government sets aside for advocacy and awareness creation campaigns on the raft of programmes and measures done to assist women use the health facilities while also giving them maternal education.
Advocacy_Policy.awareness_cost_per_woman	2000	Kshs/person	We assume that the cost per woman would be approximately Kshs. 2000 to undertake the sensitization and awareness campaigns.
Advocacy_Policy.contact_rate	10	person/year	We assume a contact rate of 5 women. During her pregnancy and even after her pregnancy.
Advocacy_Policy.Discard_Rate	IF TIME < 2020 THEN 0 ELSE Proportion_of_discard_rate*Adopters	person/Year	The discard rate captures the active women who have given birth by skilled births attendants but chose to give birth at home in subsequent births.
Advocacy_Policy.Effectiveness_of_advocacy	GRAPH(TIME) Points: (2020.00, 0.20267714037), (2020.42857143, 0.203554635488), (2020.85714286, 0.204716335946), (2021.28571429, 0.206251708019), (2021.71428571, 0.208276444908), (2022.14285714, 0.210938714718), (2022.57142857, 0.21442581524), (2023.00, 0.2190),	dmnl	The adoption from Advocacy works and is dependent on how effective the advocacy is; the more effective it is the more non-adopters are converted. It has a positive relationship.

	(2023.42857143, 0.2190), (2023.85714286, 0.2246), (2024.28571429, 0.2284), (2024.71428571, 0.2303), (2025.14285714, 0.2398), (2025.57142857, 0.2455), (2026.00, 0.2531), (2026.42857143, 0.2607), (2026.85714286, 0.2645), (2027.28571429, 0.2701), (2027.71428571, 0.2796), (2028.14285714, 0.2891), (2028.57142857, 0.2948), (2029.00, 0.3024), (2029.42857143, 0.3100), (2029.85714286, 0.3175), (2030.28571429, 0.3251), (2030.71428571, 0.3346), (2031.14285714, 0.3403), (2031.57142857, 0.3498), (2032.00, 0.3592), (2032.42857143, 0.3668), (2032.85714286, 0.3744), (2033.28571429, 0.3896), (2033.71428571, 0.4009), (2034.14285714, 0.4066), (2034.57142857, 0.4123), (2035.00, 0.4218)		
Advocacy_Policy.Non_Adopters(t)	Non_Adopters(t - dt) + (Discard_Rate - Adoption_rate) * dt INIT Advocacy_Policy.Non_Adopters = INIT(Total_Women_in_Reproductive_age)	person	The non-adopters represents the women still giving birth using the traditional Birth attendants before advocacy is done. Its initialized by the number of Births by TBA.
Advocacy_Policy.Policy_Start_year	2020	year	This represents the year the policy comes into operation.
Advocacy_Policy.policy_Switch	1	dmnl	Policy on=1 and policy switch off=0
Advocacy_Policy."Proportion_in_Reproductive_age_(15-49)"	0.56	dmnl	Women making their own informed decisions regarding sexual relations, contraceptive use and reproductive health care (% of women age 15-49) - Kenya https://data.worldbank.org/indicator/SG.DMK.SRCR.FN.ZS?locations=KE
Advocacy_Policy.Proportion_of_discard_rate	0.01	dmnl/year	This represents the number of women who after advocacy or those who have had early pregnancy and births in hospitals chose to give birth using traditional birth attendants in the subsequent births out of personal choice. We assume atleast 1 % chose to give birth using TBA after being adopters previously.
Advocacy_Policy.Share_of_awareness_budget	0.05	dmnl	We assume that the awareness Budget is 5 percent of the health Budget. This enables us to known the response level when the budget is low and what it could be if the budget is increased. This policy helps us to better understand the importance of adequate financial allocations.
Advocacy_Policy.Total_Women_in_	(SBA.TOTAL_POP*"%_female_population")*"Proportion_in_Reproductive_age_(15-49)"	person	This is a product of the female population and the proportion of women in the reproductive age.

Reproductive_age			
DM.Decision_Criteria_Sector:			
DM.Annual_Home_based_delivery_cost	Total_Costs_during_Pregnancy[Home_birthTBA]	Kshs/delivery	This captures the approximate cost for home delivery
DM.Annual_Hospital_delivery_Cost	Total_Costs_during_Pregnancy[Hospital_SBA_Birth]	Kshs/delivery	This captures the approximate cost for hosptial delivery
DM.Antenatal_cost_per_visit	2650	kshs/clinicvisit	2650*No_of_ANC_visits In most governemnet hospitals the antenatal visists are free of charge with exception where you maay pay for some additional costs which will be less than Kshs. 500 {Hospital Rates - Avenue Healthcare - Affordable, Quality and ...www.avenuehealthcare.com › hospitalrates Ante-Natal Clinic Consultation, Kshs. 2,650.00. Well Baby Clinic ... Normal Dispensing fees - outpatient pharmacy fee per prescription, Kshs. 40.00. Admission }
DM.Attractiveness	Effect_of_accessibility_on_attractiveness+effect_of_medical_staff_adequacy_on_attractiveness+Perception_in_Availability_of_TBA+effect_of_advocacy_on_shifting_to_SBA	dmnl	When the health sector that fall below the 23/10000 threshold they struggle to provide skilled care at birth to pregnant women, as well as attend to emergency and specialized services for newborn and young children. This has direct consequences on the numbers of deaths of women and children. it becomes less attractive for women to deliver in the hospitals. This is calculated based on perception of availability of TBA, effect of access to health care and effect of adequacy of the medical personnel in the health centers.
DM.average_Antenatal_Costs[Birth]	No_of_ANC_visits*Antenatal_cost_per_visit	Kshs/delivery	This is a function of the number of ANC visits to the total cost per visit. Results Utilisation of maternal health care services Number of deliveries • 511,721 deliveries occurred in public health care facilities in the 12 months prior to the removal of deliveries fees. Of these, 90.5 percent were normal deliveries and 9.5 percent were through Caesarean section. https://www.healthpolicyproject.com/pubs/400_KenyaUserFeesBaselineReportFINAL.pdf
DM.average_distance_to_be_covered	IF TIME>= 2020 THEN (initial_distance_to_be_covered*(effect_of_Mobile_clinic_on_area_covered*multiplier_of_coverage_to_distance)) ELSE initial_distance_to_be_covered	Km	This shows the initial distance to be covered if a pregnant was to chose health facility delivery. With a multiplier of one this shows the effect after introduction of mobile clinics to increase access by reducing distance to be covered; the multiplier enhances the effect after this introduction.
DM.average_Maternity_cost[Hospital_SBA_Birth]	IF TIME>=2015 AND Free_Maternity_Switch=1 THEN Normal_Maternity_Delivery_Cost[Hospital_SBA_Birth]*Free_Maternity_Programme ELSE (Normal_Maternity_Delivery_Cost[Hospital_SBA_Birth])	Kshs/delivery	This variable calculates the total average cost paid during child birth

DM.average_Maternity_cost[Home_birthTBA]	Normal_Maternity_Delivery_Cost		
DM.convenience	(effect_of_density_on_convinience+effect_of_distance_on_convenience)	dmnl	This variable factors in all major variables associated with the convenience of home vs hospital delivery. It sums the effect of health center density and the effect of distance on convenience.
DM.Delivery_Cost	((Annual_Home_based_delivery_cost//(Annual_Hospital_delivery_Cost))//(((Annual_Hospital_delivery_Cost//Annual_Home_based_delivery_cost))+((Annual_Home_based_delivery_cost//Annual_Hospital_delivery_Cost))))	dmnl	This calculates the home cost in comparison to the hospital cost.
DM.Effect_of_accessibility_on_attractiveness	GRAPH(SMTH3(Acc.Relative_Acces_to_basic_Health_Care, 3)) Points: (0.000, 0.0133857018486), (0.200, 0.0359724199242), (0.400, 0.0948517463551), (0.600, 0.238405844044), (0.800, 0.53788284274), (1.000, 1.000), (1.200, 1.46211715726), (1.400, 1.76159415596), (1.600, 1.90514825364), (1.800, 1.96402758008), (2.000, 1.98661429815)	dmnl	This has a third order information delay represented by smooth function. The more accessible the health facilities are, the more attractive they are to the pregnant women and vice versa. Introduction of mobile clinic programme is meant to boost access in the rural area and hence increase the number of women using skilled birth attendants.
DM.effect_of_adult_literacy_on_social_pressure	GRAPH(SMTHN(Relative_female_literacy_rate, 3,1, 1.16)) Points: (0.500, 0.795984289445), (0.700, 0.789208274023), (0.900, 0.771544476093), (1.100, 0.728478246787), (1.300, 0.638635147178), (1.500, 0.5000), (1.700, 0.361364852822), (1.900, 0.271521753213), (2.100, 0.228455523907), (2.300, 0.210791725977), (2.500, 0.204015710555)	dmnl	This has an information delay and captures the effect of adult literacy on how social presuures from society, family and friends influence once decisions
DM.effect_of_advocacy_on_shifting_to_SBA	GRAPH({SMTHN((Advocacy_Policy.Adoption_Density), 3, 0.5)} {SMTH1((Advocacy_Policy.Adoption_Density), 2)} Advocacy_Policy.Adoption_Density) Points: (0.000, 0.0190), (0.100, 0.0545), (0.200, 0.0853), (0.300, 0.1137), (0.400, 0.1517), (0.500, 0.1896), (0.600, 0.2062), (0.700, 0.2156), (0.800, 0.2322), (0.900, 0.2512), (1.000, 0.2559)	dmnl	We assume that with advocacy, the uptake initially will be low before it picks up.
DM.effect_of_density_on_convinience	GRAPH(SMTH3(Health_Centres_density, 1)) Points: (0.0000, 0.3000), (0.0800, 0.324482809824), (0.1600, 0.351540499234), (0.2400, 0.381443870681), (0.3200, 0.414492207156), (0.4000, 0.451016267519), (0.4800, 0.491381596843), (0.5600, 0.535992184909), (0.6400, 0.585294509479), (0.7200, 0.639782004787), (0.8000, 0.7000)	dmnl	This variable assumes what the impact is on convenience of the distance covered to nearest health center. If the distance is high then this would be less convenient and highly affects the decision of pregnant women. In Kenya, the delivery culture is that women go to hospital just when they start experiencing signs of labor. Since this reduces the chances and cost attributed to admission to hospital longer.

DM.effect_of_distance_on_convenience	GRAPH(SMTH1(Relative_distance, 1)) Points: (0.000, 0.4602), (0.100, 0.4237), (0.200, 0.3872), (0.300, 0.3507), (0.400, 0.2972), (0.500, 0.2782), (0.600, 0.2668), (0.700, 0.2517), (0.800, 0.2384), (0.900, 0.2251), (1.000, 0.2137)	dmnl	The table function captures the effect of distance on the convenience;
DM.effect_of_medical_staff_adequacy_on_attractiveness	GRAPH(SMTH1(SBA.Relative_Medical_Personnel_gap, 1)) Points: (0.000, 0.104684995647), (0.200, 0.112590346973), (0.400, 0.133198111224), (0.600, 0.183442045415), (0.800, 0.288258994959), (1.000, 0.4500), (1.200, 0.611741005041), (1.400, 0.716557954585), (1.600, 0.766801888776), (1.800, 0.787409653027), (2.000, 0.795315004353)	dmnl	When the medical personnel adequacy is low, the attractiveness to skilled birth is low and when its adequate then hospital delivery is attractive. The government should try to ensure adequacy in health centers to at least increase its attractiveness to the pregnant women and the community. this has information delay and takes a year for its effect to be felt. This is represented by Smooth function
DM.effect_of_Mobile_clinic_on_area_covered	GRAPH(IF TIME>=2014 THEN Mob:.proportion_of_area_covered_by_mobile_clinic ELSE 0) Points: (0.000, 1.000), (0.100, 0.99082384938), (0.200, 0.977134641257), (0.300, 0.956712742486), (0.400, 0.926246849528), (0.500, 0.880797077978), (0.600, 0.812993986277), (0.700, 0.7118436595), (0.800, 0.560945103841), (0.900, 0.33583091167), (1.000, 0.000)	dmnl	This captures how introduction of mobile clinics affects the area coverage for the mothers and thereby influencing their decisions
DM.effect_of_peer_pressure	GRAPH(Proportion_of_Women_Doing_Home_delivery) Points: (0.000, 0.00535428073943), (0.100, 0.0143889679697), (0.200, 0.0379406985421), (0.300, 0.0953623376177), (0.400, 0.215153137096), (0.500, 0.4000), (0.600, 0.584846862904), (0.700, 0.704637662382), (0.800, 0.762059301458), (0.900, 0.78561103203), (1.000, 0.794645719261)	dmnl	This is a graphical variable to show an assumption about family expectation and will decrease over time. Family expectation and friends in the rural setup plays huge role in decision making especially for young mothers This just uses percentage of population using TBA as a proxy for peer pressure effect.
DM.Effect_of_poverty_on_choice	GRAPH(SMTHN(relative_poverty_rate, 3, 1,1.02)) Points: (0.000, 0.004684995647), (0.150, 0.0125903469735), (0.300, 0.0331981112243), (0.450, 0.1074), (0.600, 0.1758), (0.750, 0.2833), (0.900, 0.3907), (1.050, 0.4330), (1.200, 0.4819), (1.350, 0.5274), (1.500, 0.5567)	dmnl	This effects captures the role of once income level on the decision they make on choice of birth attendant
DM.Effect_on_number_of_children_on_decision	GRAPH(SMTH3(Relative_Fertility_Rate,1)) Points: (0.000, 0.106023565832), (0.300, 0.116187588966), (0.600, 0.14268328586), (0.900, 0.20728262982), (1.200, 0.342047279233), (1.500, 0.5500), (1.800, 0.757952720767), (2.100, 0.89271737018), (2.400, 0.95731671414), (2.700,	dmnl	with the 1st birth, new mothers may chose hospital birth other factors held constant and if they dont experience any dificult and with knowledge of family history during child birth, they may chose home birth.

	0.983812411034), (3.000, 0.993976434168)		
DM.effects_of_other_factors_on_SBA	GRAPH(TIME) Points: (2000.00, 0.993307149076), (2000.50, 0.991422514586), (2001.00, 0.989013057369), (2001.50, 0.985936372957), (2002.00, 0.982013790038), (2002.50, 0.97702263009), (2003.00, 0.970687769249), (2003.50, 0.962673112656), (2004.00, 0.952574126822), (2004.50, 0.939913349826), (2005.00, 0.924141819979), (2005.50, 0.904650535101), (2006.00, 0.880797077978), (2006.50, 0.851952801968), (2007.00, 0.817574476194), (2007.50, 0.777299861175), (2008.00, 0.73105857863), (2008.50, 0.679178699175), (2009.00, 0.622459331202), (2009.50, 0.562176500886), (2010.00, 0.500), (2010.50, 0.437823499114), (2011.00, 0.377540668798), (2011.50, 0.320821300825), (2012.00, 0.26894142137), (2012.50, 0.222700138825), (2013.00, 0.182425523806), (2013.50, 0.148047198032), (2014.00, 0.119202922022), (2014.50, 0.0953494648991), (2015.00, 0.0758581800212), (2015.50, 0.060086650174), (2016.00, 0.0474258731776), (2016.50, 0.0373268873441), (2017.00, 0.0293122307514), (2017.50, 0.02297736991), (2018.00, 0.0179862099621), (2018.50, 0.0140636270432), (2019.00, 0.0109869426306), (2019.50, 0.00857748541371), (2020.00, 0.00669285092428)	dmnl	Good interpersonal relationships and practices by TBAs/perception were one of the reasons they preferred TBA. It has also been noted that most women have developed trust with the TBAs. (Sialubanje et al., 2015). This makes the woman more comfortable without services; hence they can freely discuss with the TBAs their personal feelings and fears as compared to health professionals. They were allowed to choose birth positions by TBA Adatara et al. (2019). The TBAs, was considered flexible and spoke the same language, lived in the same community, hence level of trust was higher to SBA's; they were always deemed available compared to SBA (Adatara et al., 2019). (Sarker et al., 2016). T SBAs were identified to mistreat women in verbal abuse, neglect, and abandonment during delivery hence a pivotal deterrent to accessing facility-based delivery compared to emotional support offered by their counterparts TBA (Bryne et al., 2016) (Balde et al., 2017).
DM.elasticities[yearly_cost]	3.82610248808	dmnl	Once model was built , calibration was done to determine the best fit value for the elasticities and initial values (SBA share and distance). The optimization gives a fair validated value for each parameter where there exists no documented data. Utilizing Stella Architect, these values were calibrated according to the following procedure. It was then optimized with the following criteria: Payoff = Maternal Mortality ratio Comparison Variable = Current Maternal mortality ratio Comparison Run = current run Comparison Type = Squared error Additional Starts = 5 Optimization Method = Powell Tolerance = 0.00001 Initial Step = 0.1
DM.elasticities[convenience]	5.24274942316		
DM.elasticities[other_factors]	0.264459673605		
DM.elasticities[social_factors]	-3.77531205585		
DM.elasticities[Attractiveness_Factor]	0.96617261873		

			Max Sims = 10000 Optimization of >elasticities >Initial Indicated share of SBA >Initial distance to be covered Detailed results in annex 3
DM.Female_literacy_rate	GRAPH(TIME) Points: (2000.00, 0.4550), (2007.00, 0.4780), (2014.00, 0.4860), (2015.00, 0.5260)	dmnl/year	The adult literacy rate estimates the proportion of persons (over 15yrs) who can read and write with some basic understanding of short, simple statements about their everyday lives. In 2015, youth female illiteracy was 47.4 % (2015), showing a gradually decline from 54.5 % (2000) We assume that the literate population is (100- illiterate female rate) https://knoema.com/atlas/Kenya/topics/Education/Literacy/Adult-literacy-rate https://knoema.com/atlas/Kenya/topics/Education/Literacy/Youth-female-illiteracy We assume that the literate population is (100- illerate female rate)
DM.Fertility_Rate	GRAPH(TIME) Points: (2000.00, 5.210), (2001.00, 5.140), (2002.00, 5.070), (2003.00, 5.000), (2004.00, 4.930), (2005.00, 4.860), (2006.00, 4.790), (2007.00, 4.720), (2008.00, 4.650), (2009.00, 4.532), (2010.00, 4.414), (2011.00, 4.296), (2012.00, 4.178), (2013.00, 4.060), (2014.00, 3.952), (2015.00, 3.844), (2016.00, 3.736), (2017.00, 3.628), (2018.00, 3.520), (2019.00, 3.468), (2020.00, 3.416), (2021.00, 3.363)	persons	This statistic shows the fertility rate from 2008 to 2018. The fertility rate is the average number of children born to one woman while being of child-bearing age. In 2018, the fertility rate in Kenya amounted to 3.49 children per woman. contraceptive use in Kenya, decreased the fertility rate from about 8 in the late 1970s to less than 5 children twenty years later, but it has plateaued at just over 3 children today https://www.statista.com/statistics/451135/fertility-rate-in-kenya/ The current fertility rate for Kenya in 2021 is 3.363 births per woman, a 1.55% decline from 2020. https://www.macrotrends.net/countries/KEN/kenya/fertility-rate
DM.Free_Maternity_Programme	GRAPH(TIME) Points: (2000.00, 1.000), (2001.66666667, 1.000), (2003.33333333, 1.000), (2005.00, 1.000), (2006.66666667, 1.000), (2008.33333333, 1.000), (2010.00, 1.000), (2011.66666667, 1.000), (2013.33333333, 1.000), (2015.00, 1.000), (2016.66666667, 0.000), (2018.33333333, 0.000), (2020.00, 0.000), (2021.66666667, 0.000), (2023.33333333, 0.000), (2025.00, 0.000), (2026.66666667, 0.000), (2028.33333333, 0.000), (2030.00, 0.000)	dmnl	The Kenyan government has made significant and purposeful efforts geared towards improving the lives of women over the years and more recently, in June of 2013, Kenya declared maternity services free of charge, in all public health institutions across the country, a move that makes access to quality maternal health Maternal and perinatal mortality remains a major public health concern globally with more than 289,000 maternal deaths, 2.6 million stillbirths and 2.7 million neonatal deaths occurring each year [1]. In Kenya the current Maternal Mortality Ratio (MMR) of 362 maternal deaths per 100,000 live births, and the still birth rate of 23 deaths per 1000 live births is far below the target of 147 maternal mortality per 100,000 live births and 12 stillbirths per 1000 live births respectively [2]. The Kenyan government has made significant and purposeful efforts geared towards improving the lives of women over the years and more recently, in June of 2013, Kenya declared maternity services free of charge, in all public health institutions across the country, a move that makes access to quality maternal health care possible for all women in the country [3].

			Delivery by skilled health personnel has been established as an effective approach in reducing the risk of maternal and perinatal morbidity and mortality [4] however its utilisation is much less common among the women in Kenya with only 61.8% of deliveries being attended by a skilled provider [5] https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-019-4462-x#:~:text=The%20Kenyan%20government%20has%20made,access%20to%20quality%20maternal%20health
DM.Free_Maternity_Switch	0	dmnl	
DM.Health_Centres_density	Acc.Proportion_of_area_covered_by_Health_Centres	dmnl	This variable calculates the average density of health centers by calculating on average how much area each health center cover. The lower the value its shows how dispersed the health facilities are and that pregnant and the local citizens have to cover much distance to get to the health centers.
DM.indicated_share_of_women_using_SBA	indicated_share_of_women_with_weights	dmnl	This is the Key proxy indicator in this sector that we use to measure decision making.
DM.indicated_share_of_women_using_TBA	1-indicated_share_of_women_with_weights	dmnl	This is the inverse of the indicated share of hospital-based skilled delivery A study assessed the determinants of home delivery among remote women in rural Zambia, showed that 42% of women deliver at home, suggesting persistent challenges for women in seeking, reaching, and receiving quality maternity care. From the study its imperatively noted that access to skilled birth with capacity to provide emergency obstetric and newborn care was critical to reducing maternal mortality. https://www.dovepress.com/factors-affecting-home-delivery-among-women-living-in-remote-areas-of--peer-reviewed-fulltext-article-IJWH
DM.indicated_share_of_women_with_weights	(initial_indicated_SBA_share*(SUM(weight_of_attribute*unweighted_perception_of_each_variable)))	dmnl	This multiplies the perception of each variable by the weights to return a weighted average of how all the various variables contribute to peoples decision from home based delivery to hospital based delivery. This represents the group of women who chose to go to the hospital as they may not have access to TBA or do not even cosider home birth as an option Delivery by skilled health personnel has been established as an effective approach in reducing the risk of maternal and perinatal morbidity and mortality [4] however its utilisation is much less common among the women in Kenya with only 61.8% of deliveries being attended by a skilled provider [5] https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-019-4462-x#:~:text=The%20Kenyan%20government%20has%20made,access%20to%20quality%20maternal%20health
DM.initial_distance_to_be_covered	97.5429254809	km	In the rural area we assume women cover at least over 50 km to get to nearest health facility for delivery. In Marsabit county, the distance ranged from 1-301 km, distance to nearest health facility (FAO, 2016) The callibrated figure gives approximately 97.5429254809km
DM.initial_indicated_SBA_share	0.43200768172	dmnl	In 2015, a study showed tat only 44 percent women delivered using skilled birth attendants in Kenya whereas 28% were assisted by traditional birth attendants with 21%

			being relatives and friends and 7% delivered alone without assistance (Calverton, 2010).
DM.multiplier_of_coverage_to_distance	1	dmnl	
DM.No_of_ANC_visits[Hospital_SBA_Birth]	4	clinicvisit/delivery	Every pregnant woman need to have atleast four antenatal check-ups. This is only a minimum requirement and that more visits may be necessary, depending on the woman's condition and needs (Bidhan, et al., 2020) We assume atheist 3 visits for home births
DM.No_of_ANC_visits[Home_birthTBA]	3		
DM.Normal_Maternity_Delivery_Cost[Hospital_SBA_Birth]	5000	Kshs/delivery	The majority of women interviewed reported paying out-of-pocket costs for facility-based deliveries. Out-of-pocket costs were highest in Kenya (a mean of US$18.4 for normal and complicated deliveries), where 98% of women who delivered in a health facility had to pay some fees. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2699243/
DM.Normal_Maternity_Delivery_Cost[Home_birthTBA]	1500		
DM.other_factors	SMTH1(effects_of_other_factors_on_SBA, 3)	dmnl	for the sake of this model, 'other factors' includes income level, partner's role, education and his income level. This is an opportunity for future model development. The study shows that home delivery by TBAs remain the first preference for pregnant women. Poverty is the most frequently cited reason for preferring home delivery with a TBA. Other major reasons include; traditional views, religious fallacy, poor road conditions, limited access of women to decision making in the family, lack of transportation to reach the nearest health facility. Apart from these, community people also prefer home delivery due to lack of knowledge and awareness about service delivery points, fear of increased chance of having a caesarean delivery at hospital, and lack of female doctors in the health care facilities.
DM.perception_delays[yearly_cost]	0.5	year	The perception delays used represent the time it takes for changes in the underlying criteria to affect peoples real time decision making. These variables were estimated according to intuition and should be subject to further research and validation in future models.
DM.perception_delays[convenience]	0.5		
DM.perception_delays[other_factors]	0.5		
DM.perception_delays[social_factors]	0.5		
DM.perception_delays[Attractiveness_Factor]	0.75		
DM.Perception_in_Availa	GRAPH(SMTH1(TBA.Relative_Total_TBA_density, 1, 0.0023))	dmnl	This is a third order information delay;

bility_of_TBA	Points: (0.000, 0.00535428073943), (0.200, 0.0143889679697), (0.400, 0.0379406985421), (0.600, 0.0953623376177), (0.800, 0.215153137096), (1.000, 0.4000), (1.200, 0.584846862904), (1.400, 0.704637662382), (1.600, 0.762059301458), (1.800, 0.78561103203), (2.000, 0.794645719261)		
DM.Perception_of_risk	GRAPH(SMTHN(Relative_risk_of_death_from_childbirth, 1, 1, INIT(Relative_risk_of_death_from_childbirth))) Points: (0.00, 0.004684995647), (2.00, 0.0125903469735), (4.00, 0.0331981112243), (6.00, 0.0834420454155), (8.00, 0.188258994959), (10.00, 0.3500), (12.00, 0.511741005041), (14.00, 0.616557954585), (16.00, 0.666801888776), (18.00, 0.687409653027), (20.00, 0.695315004353)	dmnl	In most african countries, traditional birth attendants (TBA's) have provided maternity care for women despite having no formal training. Unicef figures show 1 in every 126 Tanzanian women dying due to maternity complications, and the story is the same in Ghana. https://www.worktheworld.co.uk/blog/traditional-birth-attendants-%E2%80%93-do-they-put-african-women-risk
DM.Poverty	GRAPH(TIME) Points: (1992.00, 0.7620), (1994.00, 0.8450), (1997.00, 0.8330), (2005.00, 0.8830), (2015.00, 0.8660)	dmnl	A study titled 'Reasons for Preference of Home Delivery with Traditional Birth Attendants (TBAs) in Rural Bangladesh: A Qualitative Exploration' showed that home delivery by TBAs remain the first preference for pregnant women. and cited poverty as the main reason for home delivery preference. Poverty headcount ratio at $5.50 a day is the percentage of the population living on less than $5.50 a day at 2011 international prices. https://www.macrotrends.net/countries/KEN/kenya/poverty-rate#:~:text=Kenya%20poverty%20rate%20for%202015,a%208.3%25%20increase%20from%201992.
DM.Pregnancy_incidental_costs[Hospital_SBA_Birth]	9000	Kshs/delivery	This capture other extra costs that come by as result of pregnancy like the transport costs to the hospital during prenatal clinics and during delivery. This includes those extra costs that could be unforeseen during pregnancy. shopping during pregnancy, special diet and medical costs (supplements) during pregnancy.
DM.Pregnancy_incidental_costs[Home_birthTBA]	4000		
DM.Proportion_of_Women_Doing_Home_delivery	SMTH3((1-indicated_share_of_women_using_SBA), 1, 1) {Acc.births_attended_by_Traditional_Birth_Attendants//(Acc.births_attended_by_Traditional_Birth_Attendants+Acc.births_attended_by_skilled_health_personnel)} {Pregnant women TBA/Total number of Pregnant women}	dmnl	This study has documented the percentage of women who deliver at home in West Pokot County of Kenya. It found out that 66.7% of women in the County give birth at home (Otieno, 2015) https://www.hindawi.com/journals/aph/2015/493184/
DM.Relative_distance	average_distance_to_be_covered//INIT(average_distance_to_be_covered)	dmnl	The distance is normalised by division by its original value

DM.Relative_female_literacy_rate	Female_literacy_rate//INIT(Female_literacy_rate)	dmnl	The female literacy is normalised by division by its original value
DM.Relative_Fertility_Rate	Fertility_Rate//INIT(Fertility_Rate)	dmnl	Overtime as one has more births the subsequent births can take place at home especially if they didn’t have complications in prior births
DM.relative_poverty_rate	(Poverty//INIT(Poverty))*(SDG_Poverty_goal)	dmnl	The poverty is normalised by division by its original value
DM.Relative_risk_of_death_from_child birth	Acc.Probability_of_death_from_TBA//Acc.Probability_of_death_under_SBA	dmnl	This is obtained by division of risk from home birth to the risk from hospital birth
DM.SDG_Poverty_goal	0.5	dmnl	The SDG poverty Goal 1 aims to reduce poverty by at least 50% by 2030.
DM."socio-economic_factors"	(effect_of_adult_literacy_on_social_pressure+effect_of_adult_literacy_on_social_pressure+Effect_on_number_of_children_on_decision+effect_of_peer_pressure+Perception_of_risk+Effect_of_poverty_on_choice)*1+(test_input*0)	dmnl	Social factors is estimated by taking a multiplication of these characteristics: family expectation, perception of risk, peer pressure, TBA relations, literacy levels, which represents a general change over time in how much social aspects weighs into the choice of delivery place; and peer pressure represents the social conformity pressure to deliver using traditional birth attendants. With interaction of the factors, a higher value If all of these values interact with each other and the higher the value produced, the higher the pressure is todeliver at home This is a variable to show how home delivery is always a better choice as one has undivided attention during child birth. as compared to Hospital delivery This is variable how it would be easy to relate and the kind of care one gets while using TBA in home delivery as compared to hospital birth. Social Pressure (Hospital Birth)= (("TBA_Relation_during_birth_/friendliness")*Family_Expectation)*(1-peer_pressure)*(1-Effect_on_number_of_children_on_decision)*(1-Perception_of_risk)*(1-effect_of_adult_literacy_on_social_pressure) Social Pressure (Home Birth)= (1-TBA_friendliness_experiences)*Family_Expectation*(peer_pressure)*Effect_on_number_of_children_on_decision*Perception_of_risk*effect_of_adult_literacy_on_social_pressure
DM.sum_of_weights	SUM(weight_of_attribute)	dmnl	To ensure it does not exceed 1
DM.test_input	1+RAMP(.2)	dmnl	2.5(socail factors)
DM.Total_Costs_during_Pregnancy[Hospital_SBA_Birth]	average_Maternity_cost[Hospital_SBA_Birth]+Pregnancy_incidental_costs+(average_Antenatal_Costs)+Pregnancy_incidental_costs[Hospital_SBA_Birth]	Kshs/delivery	This variable calculates the total cost accruing during pregnancy. These are the total delivery related costs. This variable adds up all major costs associated with delivery cost and represents the 'price' components. It encompasses the average delivery cost, average antenatal costs, pregnancy incidental cots and other incidental costs
DM.Total_Costs_during_Pregnancy[Home_birthTBA]	average_Maternity_cost[Home_birthTBA]+Pregnancy_incidental_costs+Pregnancy_incidental_costs[Home_birthTBA]		

DM.unweighted_impact_of_each_variable[yearly_cost]	Delivery_Cost^elasticities[yearly_cost]	dmnl	This is an array variable, arrayed by attribute, that calculates how differences in the attribute affect the final estimated split between what proportion of people will choose TBA or SBA. The formula works in the following way: It first calculates compares the underlying value of home birth to the underlying value of hospital birth. Then it expresses that as a ratio. It then takes that ratio divided by the sum of the ratio of home to hospital birth (same as in the numerator) and the ratio of hospital to home birth The resulting ratio is then taken to an elasticity that is defined in the elasticities variable. What results is a sort of analytic S-shaped curve for each attribute so that if the values are equal between hospital and home birth, it would return an assumed 50-50 split between both. As the difference between the two values becomes greater and greater, a proportion approaching either one or zero will be returned depending on the polarity of the elasticity.
DM.unweighted_impact_of_each_variable[convenience]	(convenience/INIT(convenience))^elasticities[convenience]		
DM.unweighted_impact_of_each_variable[other_factors]	(other_factors/INIT(other_factors))^elasticities[other_factors]		
DM.unweighted_impact_of_each_variable[social_factors]	("socio-economic_factors"//INIT("socio-economic_factors"))^elasticities[social_factors]		
DM.unweighted_impact_of_each_variable[Attractiveness_Factor]	(Attractiveness//INIT(Attractiveness))^elasticities[Attractiveness_Factor]		
DM.unweighted_perception_of_each_variable[Decision_attribute]	SMTH3(unweighted_impact_of_each_variable, perception_delays)	dmnl	This calculates an information delay of the unweighted impact of each variable, since it is assumed to take time for changes in the underlying variables to be perceived and affect people's decision making.
DM.weight_of_attribute[yearly_cost]	0.3	dmnl	
DM.weight_of_attribute[convenience]	0.05		
DM.weight_of_attribute[other_factors]	0.25		
DM.weight_of_attribute[social_factors]	0.3		
DM.weight_of_attribute[Attractiveness_Factor]	0.1		
Hire.Hiring_Policy: This is a simplified Stock flow structure to capture the hiring budget and how many additional medical personnel it can support.			
Hire."%_of_Expenditure_To_Recruit_Additional"	1	dmnl	This represents the share of the budget used for recruitment of both doctors and the nurses. The current estimated cost for absorbing nurses into Kenya's civil service will account for approximately 1.5% of the government's health budget. https://www.who.int/bulletin/volumes/88/11/09-072678/en/ We assume doctors would account for 3.5% hence a total of 5%

Hire.Actual_Additional_Hired_Per_Budget[Medical Personnel]	((Hiring_Budget)*2/Medical_Personnel_Salary)	person	This is obtained as the division of Hiring Budget by the Medical personnel salary. This gives us the number of medical personnel that can be accommodated given the allocated budgetary provisions.
Hire.Annual_Adjustment_Rate	1	year	These adjustments are annual as per the financial year which is annual also. The government financial year begins in July until June the subsequent year.
Hire.annual_gap_adj_rate	1/(policy_time_period/3)	per year	Discuss with client what fraction of the gap we want to adjust each year ((/3 due to the adk. rate) YEARLY GAP ADJUSTMENT FRACTION. EACH YEAR WE CLOSE 15% make it as a rate so instead of devidingg we multiplu
Hire.Annual_Real_Hiring_Budget	Acc.Health_Budget*"%_of_Expenditure_To_Recruit_Additional"*(1-Acc.Inflation_Rate)	Kshs/year	This is a function of the health budget and share of expenditure used to recruit additional medical personnel. The budget is in nominal terms we multiply the inflation rate to get the budget in real terms.
Hire.Budgeted_Medical_Personnel[MedicalPersonnel]	Actual_Additional_Hired_Per_Budget	person	This represents the number of additional medical personnel that can be hired as per the budgetary allocations.
Hire.Decrease_in_Hiring_Budget	Hiring_Budget/Annual_Adjustment_Rate	Kshs/Year	
Hire.Hiring_Budget(t)	Hiring_Budget(t - dt) + (Increase_in_Hiring_Budget - Decrease_in_Hiring_Budget) * dt INIT Hire.Hiring_Budget = 0	Kshs	This shows the available recruitment budget of doctors and nurses which available every 3 years. In each Ministries/State Departments, the human resource department is required to develop annual recruitment plans which will be forwarded to the Public Service Commission at the beginning of each financial year to enable it plan to fill the vacancies. With these plans, the ministry can be able to know how many additional medical personnel can be recruited. (PSC 2016)
Hire.Increase_in_Hiring_Budget	Annual_Real_Hiring_Budget-(Hiring_Budget/Annual_Adjustment_Rate)	Kshs/Year	This is a gap function; which takes into account the difference between the annual real hiring budget and the hiring budget with consideration of the annual hiring adjustment time.
Hire.Medical_Personnel_Salary[Doctors]	68165*12	Kshs/person	The entry basic salary of a doctor was assumed at Kshs68, 165 per month which is close to job group M for doctors after internship; and also the proffessional entry level of doctors. https://www.fixusjobs.com/job-groups-and-salaries-in-kenya/ The cost of absorbing EHP nurses into the civil service is an important consideration. The Clinton Foundation estimated that US$ 4292.50 were required annually for each nurse to cover salary, retention bonuses and uniform allowances. https://www.who.int/bulletin/volumes/88/11/09-072678/en/ Doctors The minimum Entry of of Holders of Bachelor of Medicine and Surgery (MB,CHB), Bachelor of Dental Surgery (BDS) or their approved equivalents entry level in Public Service scheme is Job Group Level M https://www.health.go.ke/wp-
Hire.Medical_Personnel_Salary[Nurses]	4292.50*100 {US $4292.50; 1USD =Kshs.100}		

			content/uploads/2015/11/Guidelines%20for%20Career%20Progression(1).pdf
	Mob:.Mobile_Clinic_Service:		
Mob:."%ASAL_Area"	.89	dmnl	This is the proportion of the Arid and Semi Arid lands which the programme is majorly focused. http://www.Kenya - Wikipedia
Mob:.area_covered_by_Mobile_Clinic	area_covered_per_Mobile_Clinic*functioning_Mobile_Clinics	ha	This is determined by functioning mobile clinics and the area covered per mobile clinic. with this we are able to estimate the total area covered by the mobile clinics in an effort to calculate its contribution to the health care access. This is captured in hectares.
Mob:.area_covered_per_Mobile_Clinic	effect_of_relative_road_density_per_Mobile_Clinic_coverage*area_covered_per_Mobile_clinic_with_optimal_road_density	ha/mobile clinic	This is a function of the effect of relative road density covered area per mobile clinic with the optimal area covered by mobile clinic with existence of optimal road density. Obtained by multiplication of the effect of road density on the area covered per mobile clinic ; this calculates how accessible the mobile clinics are by the road density.
Mob:.area_covered_per_Mobile_clinic_with_optimal_road_density	2000 {1km^2=100 hectares}	ha/Mobile Clinic	we assume the area covered is approximately 20 km^2 per mobile clinic. This captures as hectarage per mobile clinic. This when converted equals 2000ha (20*100) as 1km square equals 100 ha.
Mob:.ASAL_Area	Total_Land_Area*"%ASAL_Area"	ha	The ASALs make up to 89% of the Country with approximately 38% of Kenya's Population. These regions are home to more than 90% of the wildlife that supports the tourism industry, contributing to 12% of Kenya's Gross Domestic Product (GDP). The ASAL regions host 70% of the National Livestock herd with an estimated value of Ksh.70 billion. Further, they have enormous potential for renewable energy (both solar and wind) and other natural resources and are as well strategically positioned for cross-border trade and social cultural interaction with Ethiopia, Uganda, Tanzania, South Sudan and Somalia. Beyond Zero caimpaign is mainly focused in the ASAL rural areas where access is limited. https://www.asals.go.ke/
Mob:.Average_adjustment_time	1	year	This is the average time it takes to purchase and operationalize a mobile clinic. This is the estimated amount of time required to purchase and have it operationalized.
Mob:.Basic_Health_Access_Adjustment	MAX(0, (Reference_Basic_Health_Access-Acc.Access_to_basic_health_care))	dmnl	This gives the gap between the reference Health Access and the current Access. This obtained by the difference between the reference and the access to basic health care A wide gap shows the need for additional measures to cover the remaining area and hence increase the access.
Mob:.Beyond_Zero_Fund_Budget	GRAPH(TIME) Points: (2000.00, 0), (2013.00, 0), (2014.00, 5e+07), (2016.00, 7e+07), (2018.00, 8.5e+07), (2020.00, 1.2e+08)	ksh/year	This is purely a donor funded programme run by the First lady and has no government support. It depends on annual donations. This is the name of the programme ' Beyond Zero programme' https://www.beyondzero.or.ke/news/beyond-zero-campaign-corporate-donors/
Mob:.Budgetary_Requirements	IF TIME>=2020 THEN ((purchase_cost_per_mobile_clinic*Desired_mobile_clinics)/Average_adjustment_time) ELSE 0	Ksh/year	This represents the amount of funds required have the required access of atleast 80%; With the desired number of mobile clinics this is multiplied with the price per each and adjusted for time when this budget is available.
Mob:.Desired_Additional	(ASAL_Area*Basic_Health_Access_Adjustment)/0.8	ha	This is the obtained as the basic health access gap multiplied to the total land area to get the total additional coverage required. The additional gap area is measured in hectares.

Coverage Area			
Mob:.Desired_mobile_clinics	(Desired_Additional_Coverage_Area//area_covered_per_Mobile_clinic_with_optimal_road_density)	mobile clinic	This is a ratio between the desired additional coverage gap and area covered per mobile clinic. This represents the number of mobile clinics required
Mob:.effect_of_relative_road_density_per_Mobile_Clinic_coverage	GRAPH(Relative_Road_density) Points: (0.000, 0.0000), (0.100, 0.0428449171921), (0.200, 0.0901958736601), (0.300, 0.142526773692), (0.400, 0.200361362523), (0.500, 0.264278468159), (0.600, 0.334917794475), (0.700, 0.412986323591), (0.800, 0.499265391588), (0.900, 0.594618508377), (1.000, 0.7000)	dmnl	This shows the effect of relative road density is on the area covered by the mobile clinics. As these road density grows , the area covered increases and more and more area is covered per mobile clinic.
Mob:.France_Road_Density	GRAPH(TIME) Points: (2000.00, 180.40), (2005.00, 183.10), (2010.00, 191.10), (2015.00, 191.60)	dmnl	Macau is the top country by road density in the world. As of 2011, road density in Macau was 1,485.7 km per 100 sq.km. The top 5 countries also includes San Marino, Belgium, Singapore, and Netherlands. Road density is the ratio of the length of the country's total road network to the country's land area. The road network includes all roads in the country: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads. we use France as it has 547 557 sq.km almost same land area as Kenya. We use as the reference road density https://data.worldbank.org/indicator/AG.LND.TOTL.K2 https://knoema.com/atlas/ranks/Road-density
Mob:.functioning_Mobile_Clinics	(Mobile_Clinic*proportion_of_functioning_mobile_Clinics)	mobile clinic	This captures proportion of functioning mobile clinics of the existing mobile clinics. This determines the number of of mobile clinics having adequate running costs covered and hence considered as a fraction of the exiting mobile clinics. Calculated as proportion of functioning mobile clinics multiplied by the number of mobile clinics.
Mob:.health_budget_for_Mobile_Clinic_purchase	MAX(Mobile_Clinics_Budget-Mobile_Clinic_running_cost, 0)	Ksh/year	This is budget left for purchase after deduction of the running cost. When 0, there is no budget to purchase the mobile clinics. This is obtained by the difference between the Real health expenditure and the total running costs. This determines the number of mobile clinics can be purchased with the existing budget.
Mob:.Kenya_Road_Density	GRAPH(TIME) Points: (2000.00, 11.00), (2005.00, 11.00), (2010.00, 10.70), (2015.00, 27.70)	dmnl	
Mob:.Mobile_Clinic(t)	Mobile_Clinic(t - dt) + (Mobile_Clinic_purchases - Mobile_Clinic_depreciation) * dt INIT Mob:.Mobile_Clinic = 0	mobile clinic	We assume there are non existent mobile clinics prior to 2014. Initially the introduction of the mobile clinics may tend show negligible results but in the long run its impact would be increasing as the number of women choose to utilize them. This works well in combination with advocacy and hiring of additional medical personnel.
Mob:.Mobile_Clinic_depreciation	Mobile_Clinic/Mobile_Clinic_depreciation_time	mobile clinic/Years	This is the ratio between the existing number of mobile clinics with the lifetime of the mobile clinic. We assume mobile clinics have a life time of approximately 40 years. This gives us mobile clinics depreciating per year. This depreciation is reverted back through the purchases of their replacement for continuity.

Mob:.Mobile_Clinic_depreciation_time	60	year	we assume the lifetime of a mobile clinic is 40 years
Mob:.Mobile_Clinic_purchases	DELAY3(health_budget_for_Mobile_Clinic_purchase/purchase_cost_per_mobile_clinic,2)	mobile clinic/Years	This is a material delay function with the purchase dependant on the available budget over purchase cost per mobile clinic and replacement of the depreciation rate. After 2030, the purchase will mainly be influenced by the gap function of what is required to cover the remaining area so as to get the desired access to basic health as per the WHO requirements.
Mob:.Mobile_Clinic_running_cost	IF TIME<2016 THEN 0 ELSE (Mobile_Clinic*running_cost_per_Mobile_Clinic)	Ksh/Year	This is the total running cost budget used to operationalize the mobile clinics daily. They are a function of both the number of the mobile clinics and the cost it takes to run a clinic annually. we multiply the number of mobile clinics with the total number of clinics.
Mob:.Mobile_Clinics_Budget	IF TIME>=2020 AND Zero_Policy_Switch=1 THEN (Beyond_Zero_Fund_Budget+Budgetary_Requirements)*10 ELSE Beyond_Zero_Fund_Budget	ksh/year	Prior to 2014, Kenya had no mobile clinics service in the health sector, this initiative began in 2014. This combines the beyond Zero Budget and the budgetary requirements
Mob:.proportion_of_area_covered_by_mobile_clinic	(area_covered_by_Mobile_Clinic)/ ASAL_Area	dmnl	This is the ratio of the total estimated area covered by mobile clinics multiplied divided by total land area. This will give the proportional contribution of the mobile clinics to the total access to health care.
Mob:.proportion_of_functioning_mobile_Clinics	SMTHN(proportion_of_Mobile_Clinics_running_cost_covered, time_for_expenditure_to_affect_functioning_Mobile_Clinics, 1, 1)	dmnl	We use an information delay to capture how the funding will have a direct effect on the functioning of the mobile clinics. We assume it takes 0.5 year for money set to function for mobile clinics. So that if money the proportion of running cost covered is decreased, the effect of this reduction is not normally felt immediately but it takes some time before the mobile clinics are grounded due to the low running cost coverage
Mob:.proportion_of_Mobile_Clinics_running_cost_covered	IF Mobile_Clinic_running_cost =0 THEN 0 ELSE MIN(Mobile_Clinics_Budget, Mobile_Clinic_running_cost)/Mobile_Clinic_running_cost	dmnl	This proportion seeks to find the extent to which the mobile clinic running cost is covered. So that if the running expenditure is nil then the proportion covered is nil, and when the real expenditure is greater than running cost, the Min function ensures that the lesser is picked and that is Mobile clinic running cost. This shows that 100% of the running cost is covered with the remainder left for purchase.
Mob:.purchase_cost_per_mobile_clinic	5000000	Ksh/Mobile clinic	The mobile clinics cost are estimated to cost about Ksh:3,000,000. Many are run with the help of donations and grants. They are made from prefabricated metallic containers hence the relatively cheap cost. The cost includes the prefabrication and modification of the mobile clinic to suit the purpose.
Mob:.Reference_Basic_Health_Access	0.8	dmnl	The 2006 World health report identified a minimum health worker density of 2.3 skilled health workers (physicians and nurses/ midwives) per 1000 population, which was considered generally necessary to attain high coverage of atleast 80 percent https://apps.who.int/iris/bitstream/handle/10665/250330/9789241511407-eng.pdf;sequence=1
Mob:.Relative_Road_density	(Kenya_Road_Density/France_Road_Density)*0+0.5	dmnl	we normalize road density by dividing with a reference in this case we use France as it has almost same land size as Kenya and is among the top 10 countries with good road density.
Mob:.running_cost_per_	150000*12	Ksh/year/Mobile clinic	We assume that it costs the Kshs. 250,000 per month to run the mobile clinic.This is exclusive of salaries of the medical personnel and support services which is normally catered for

Mobile_Clinic			by the various county governments as the staff are deployed to these work stations. The medical supplies are also done centrally. These are the support interms of operational maintenance, lighting and minor expenses. This acts like the monthly budget for minor running costs.
Mob:.time_for_expenditure_to_affect_functioning_Mobile_Clinics	0.5	year	This we assume is 6 months before the functioning of mobile clinics is hampered
Mob:.Total_Land_Area	569140*100	ha	580 367 sq km 1sq km is equivalent to 100ha At 580,367 square kilometres (224,081 sq mi), Kenya is the world's 48th largest country by total area. the inland water area occupies 1123000 square kilometres. The total land area is the difference between the total area and total water area. Total Land area is 569,140sq km http://www.Kenya - Wikipedia
Mob:.Zero_Policy_Switch	1	dmnl	This is a policy switch when 0 its off and 1 its on
	SBA.Data:		
SBA.Doctors_Data	GRAPH(TIME) Points: (2000.00, 4506.0), (2001.00, 4630.0), (2002.00, 4740.0), (2003.00, 4813.0), (2004.00, 5016.0), (2005.00, 5446.0), (2006.00, 5889.0), (2007.00, 6271.0), (2008.00, 6623.0), (2009.00, 6897.0), (2010.00, 7129.0), (2011.00, 7549.0), (2012.00, 8092.0), (2013.00, 8682.0), (2014.00, 9149.0), (2015.00, 9605.0), (2016.00, 10376.0), (2017.00, 10921.0), (2018.00, 11667.0)	person	Capture the real time data for the doctors http://www.Kenya - Wikipedia
SBA.Medical_Personnel_Data[Doctors]	Doctors_Data	person	The initial labor force. Set by the user.
SBA.Medical_Personnel_Data[Nurses]	Nurses_Data		
SBA.Nurses_Data	GRAPH(TIME) Points: (2000.00, 37113.0), (2001.00, 37812.0), (2002.00, 38847.0), (2003.00, 40081.0), (2004.00, 40772.0), (2005.00, 42552.0), (2006.00, 42822.0), (2007.00, 44115.0), (2008.00, 45990.0), (2009.00, 47865.0), (2010.00, 63960.0), (2011.00, 67517.0), (2012.00, 61769.0), (2013.00, 64748.0), (2014.00, 63309.0), (2015.00, 66387.0), (2016.00, 74302.0), (2017.00, 79307.0), (2018.00, 80673.0)	person	Capture the real time data for the nurses http://www.Kenya - Wikipedia

SBA.Total_medical_Personnel	SUM(Experienced_Medical_Personnel[*]) + SUM(Intermediate_Medical_Personnel[*])	person	
SBA.total_population_Data	GRAPH(TIME) Points: (2000.00, 32000000), (2019.00, 47000000)	Person	This variable represents the total population. Sources include: World Bank http://ghdx.healthdata.org/record/kenya-population-and-housing-census-1999
	SBA.MP_gap:		
SBA.Medical_Personnel_Density	(Total_Medical_Personell[Doctors]+Total_Medical_Personell[Nurses])/TOTAL_POP	dmnl	This captures the relation of the medical personnel staffing levels to the total population to see their adequacy
SBA.Relative_Medical_Personnel_gap	Medical_Personnel_Density/Total_medical_personnel_reference	dmnl	Captures the ratio of the currents dctor density to the WHO refernce
SBA.Total_medical_personnel_reference	23/10000	dmnl	Only 5 of the 49 countries categorized as low-income economies by the World Bank meet the minimum threshold of 23 doctors, nurses and midwives per 10 000 population that was established by WHO as necessary to deliver essential maternal and child health services. https://www.who.int/hrh/workforce_mdgs/en/
SBA.Total_MP_density[MedicalPersonnel]	(Total_Medical_Personell[Doctors]+Total_Medical_Personell[Nurses])/TOTAL_POP	dmnl	This measures the total medical personnel density per total population. This is obtained by dividing the total number of doctors and nurses per total population. This will show their density per population in relation to the World Health Organisation reference guide. For our case, the same doctors and nurses will be used in the health centers during delivery. And more crucial in the Kenyan cases the nurses are usually critical during childbirth as they act as midwives and doctors are called in during complicated cases which require caesarean section. This is a scenario across board most hospitals in Kenya. (Otieno, 2015)
TBA.Sector_1:			
TBA.Attrition	Experienced_TBA//Service_Time_Experienced_TBA	person/Year	
TBA.Average_review_for_intermediate_TBA	Intermediate_TBA/Review_time_for_Intermediate_TBA	person/year	This is obtained as the ratio between the stock of the intermediate TBA and the review time for the intermediate TBA. From this calculation, we get the number of intermediate TBA available for promotion to next level (experienced). It measured as the person/year.
TBA.Average_review_for_New_TBA	Recruit_TBA/Review_time_for_New_recruits	person/year	This is obtained as the ratio between the stock of the recruits and the review time for the new recruits. From this calculation we get the number of new recruits available for promotion to next level. It measured as the person/year.
TBA.Departure_Intermediate	Average_review_for_intermediate_TBA*(1-Promotion_Fraction)	person/Year	This flow measures those TBA who leave the practice through natural attrition or just leaving the profession all together. This is obtained as the remainder of those not promoted after review of the intermediate TBA .
TBA.Desired_Experienced_TBA	Total_pregnant_women*Desired_Experienced_TBA_Density	person	This is the desired capacity of TBA that should fill the skilled medical personel gap. This is obtained as fraction of women seeking the traditional birth attendants by the desired experienced TBA density.
TBA.Desired_Experienced	DELAY3(SBA.Medical_Personnel_Density, 1)	dmnl	The ideal situation would be a traditional birth attends atleast one birth per day. Hence the assumption of 1/300.

_TBA_Density			This formulation is directly affected by the proportion of medical personnel gap; so that the larger the medical personnel gap the larger the number of traditional births attends recruitment is. They have an inverse relation with the skilled birth attendants sector. we use a material delay as the information of the delay takes time to translate the inadequacies in the medical sector into recruitment and training of the traditional birth attendants.
TBA.Desired_Intermediate_Promotion	Attrition+Experienced_TBA_Correction	person/year	This is the number of Intermediate TBA we require to bring the system in equilibrium. This originates from the correction gap function in the experienced TBA and its outflow. The total number gives the quantity required to bring the system in a steady state.
TBA.Desired_Intermediate_TBA	Desired_Intermediate_Promotion*Review_time_for_Intermediate_TBA	person	This gives the required desired intermediate promotions adjusted by the review time of five year.
TBA.Desired_Recruit_TBA_Promotion	Intermediate_TBA_Correction+Departure_Intermediate+Desired_Intermediate_Promotion	person/year	This is the desired number of recruit TBA promotions we require to bring the system in equilibrium. This originates from the correction gap function in the intermediate TBA and its outflow departures. The total number gives the quantity required to bring the system in a steady state hence a summation of the desired intermediate promotion, the intermediate TBA correction and the intermediate departure
TBA.Desired_recruits	Recruits_departure+Recruits_TBA_correction+Desired_Recruit_TBA_Promotion	person/year	This is the desired number of recruit TBA promotions we require to bring the system in equilibrium. This originates from the correction gap function in the intermediate TBA and its outflow departures. The total number gives the quantity required to bring the system in a steady state hence a summation of the recruits departure, recruits TBA correction, and the desired new TBA promotion
TBA.Desired_TBA_Recruits	Desired_Recruit_TBA_Promotion*Review_time_for_New_recruits	person	This gives the required desired recruits promotions adjusted by the review time of three years.
TBA.effect_of_Women_using_SBA_on_TBA_Recruitment	GRAPH(DELAY3((1-DM.indicated_share_of_women_using_SBA), 1)) Points: (0.000, 0.2000), (0.100, 0.134064009207), (0.200, 0.0898657928234), (0.300, 0.0602388423824), (0.400, 0.0403793035989), (0.500, 0.0270670566473), (0.600, 0.0181435906579), (0.700, 0.012162012525), (0.800, 0.00815244079567), (0.900, 0.00546474448946), (1.000, 0.00366312777775)	dmnl	This calculates the effect of the women using TBA from the proportion of those already using skilled birth. The effect directly affects the recruitment rate with a delay; so that when there are more women opting for skilled birth, then there is no gap to be filled by the additional TBA as less of there services are required.
TBA.Experienced_TBA(t)	Experienced_TBA(t - dt) + (Intermediate_Promotion - Attrition) * dt INIT TBA.Experienced_TBA = Desired_Experienced_TBA	person	The stock is initialized at the desired experienced TBA level which is the equilibrium level so that the inflow and the outflow is equal. We assume that the experienced work alone and have a 60 year service time period. The stock is affected by an inflow of intermediate promotions and the outflow of attrition through retirement or natural attrition.
TBA.Experienced_TBA_Correction	(Desired_Experienced_TBA-Experienced_TBA)//Time_to_Correct_Experienced_TBA	person/year	This is a gap function which calculates the difference between the desired experienced and the experienced TBA over the time required to correct this disparity which is one year. It is tracked annual by the number of persons.
TBA.Initial_Pregnant_women_data	801815	person	

TBA.Intermediate_Promotion	Promotion_Fraction*Average_review_for_intermediate_TBA	person/Year	This flow shows how many intermediate recruits are promoted as the experienced TBA stock. This calculated as a fraction of promotion on the number of reviewed intermediate TBA. Its measured as persons per year. The review is done every 5 years.
TBA.Intermediate_TBA(t)	Intermediate_TBA(t - dt) + (New_recruits_promotion - Intermediate_Promotion - Departure_Intermediate) * dt INIT TBA.Intermediate_TBA = Desired_Intermediate_TBA	person	The stock is initialized at the desired intermediate TBA level which is the equilibrium level so that the inflow and the outflow is equal. We assume that the intermediate work alone and have a 5 year review period. The stock is affected by an inflow of new recruits who are promoted and the outflow of intermediate TBA promoted and intermediate departures who leave the profession.
TBA.Intermediate_TBA_Correction	(Desired_Intermediate_TBA-Intermediate_TBA)//Time_to_Correct_Intermediate_TBA	person/year	This is a gap function which calculates the difference between the desired and the actual intermediate TBA over the time required to correct this disparity which is one year. It is tracked annual by the number of persons.
TBA.New_recruits_promotion	Promotion_Fraction*Average_review_for_New_TBA	person/Year	This flow shows how many new recruits are promoted as the intermediate TBA. This calculated as a fraction of promotion on the number of reviewed recruit TBA. Its measured as persons per year. The review is done every 3 years.
TBA.Promotion_Fraction	0.7	dmnl	This is estimated that seventy percent of the traditional birth attendants are considered for the next level. One is considered for next level after the TBA is able to conduct a series of births individual alone and successful mostly with positive response from the mothers and subsequent referrals of other deliveries through word of Mouth.
TBA.Recruit_TBA(t)	Recruit_TBA(t - dt) + (Recruitment_rate - New_recruits_promotion - Recruits_departure) * dt INIT TBA.Recruit_TBA = Desired_TBA_Recruits	person	The stock is initialized at the desired recruits TBA level which is the equilibrium level so that the inflow and the outflow is equal. We assume that the experienced work alone and have a 60 year service time period. The stock is affected by an inflow of new recruits and the outflow of new recruit promoted after their review and the departure of the recruits who leave the profession.
TBA.Recruitment_rate	(MAX(0, Desired_recruits))*effect_of_Women_using_SBA_on_TBA_Recruitment	person/Year	This is a function of the desired recruits. in the inflow we use a maximum function to prevent non negative inflow of the numbers to be recruited and maintain a positive number of recruits or nil recruits in a specific year when the system notices excess numbers.
TBA.Recruits_departure	Average_review_for_New_TBA*(1-Promotion_Fraction)	person/Year	This flow measures those TBA who leave the practice through natural attrition or just leaving the profession all together. This is obtained as the remainder of those not promoted after review of the new TBA .
TBA.Recruits_TBA_correction	(Desired_TBA_Recruits-Recruit_TBA)//Time_to_recruit	person/year	This is a gap function which calculates the difference between the desired and the actual recruits TBA over the time required to correct this disparity which is one year. It is tracked annual by the number of persons.
TBA.Relative_TBA_Density	Desired_Experienced_TBA_Density*Total_TBA_density	dmnl	
TBA.Relative_Total_TBA_density	Total_TBA_density/INIT(Total_TBA_density)	dmnl	This is normalized by dividing the total TBA density by its initial
TBA.Review_time_for_Intermediate_TBA	0.5	year	It takes 5 years for the intermediate recruits to be considered for the next level as experienced TBA. Most intermediate alone in close consultation with the experienced TBA.

TBA.Review_time_for_New_recruits	0.5	year	It takes 3 years for the new recruits to be considered for the next intermediate. Most recruits will work hand in hand with experienced TBA as their assistants as they learn from them. With time they are allowed to deliver alone under the supervision of the experienced TBA.
TBA.Service_Time_Experienced_TBA	50	year	This is the number of traditional birth attendants who leave due to retirement or natural attrition reasons; this is divided by the service time of 60 years; to get the annual attrition rate.
TBA.TBA_Births	Initial_Pregnant_women_data*DM.indicated_share_of_women_using_TBA	person	
TBA.Time_to_Correct_Experienced_TBA	10	year	We assume it takes a year correct the disparity between existing experienced TBA to the reach the desired level.
TBA.Time_to_Correct_Intermediate_TBA	5	year	We assume it takes a year correct the disparity between existing intermediate TBA to the reach the desired level.
TBA.Time_to_recruit	5	year	We assume it takes a year correct the disparity between existing recruits TBA to the reach the desired level.
TBA.Time_to_transition	1	year	
TBA.Total_pregnant_women	Women_Seeking_SBA + Women_Seeking_TBA	person	This is a summing converter showing the total number of women pregnant at any time. Those who deliver at home or in the heath centers.
TBA.Total_TBA	Intermediate_TBA+Experienced_TBA	person	This is the sum of both intermediate and experienced TBA. In most cases, the new TBA work hand in hand with experienced and intermediate traditional birth attendants before they can work alone.
TBA.Total_TBA_density	Total_pregnant_women/Total_TBA	1	This is the ratio of the total traditional birth attendants and the pregnant women.
TBA.Transition_rate	Women_Seeking_TBA/Time_to_transition	person/year	
TBA.Women_Seeking_SBA(t)	Women_Seeking_SBA(t - dt) + (Transition_rate) * dt INIT TBA.Women_Seeking_SBA = INIT(Acc.births_attended_by_skilled_health_personnel)	person	
TBA.Women_Seeking_TBA(t)	Women_Seeking_TBA(t - dt) + (- Transition_rate) * dt INIT TBA.Women_Seeking_TBA = INIT(TBA_Births)	person	

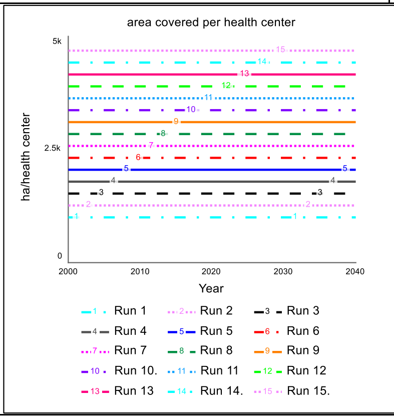
Annex 2: Sensitivity Analysis

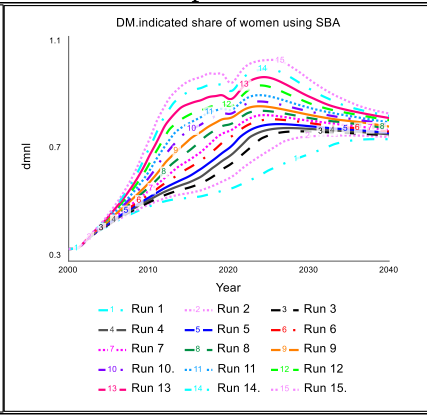
Sensitivity Testing

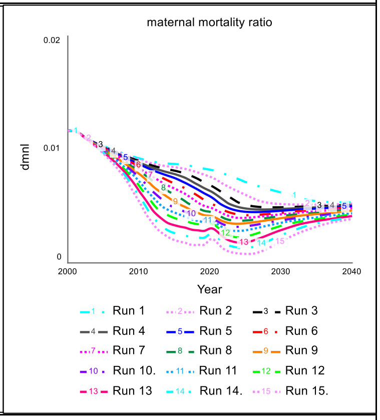
The model has been subjected to sensitivity testing for each of the key parameters used.

Sensitivity analysis shows the runs off exogenous parameters of the generic model. The Business-as-usual case is shown below. The parameters all change with an incremental varying range based on its current range as shown in the adjacent table.
A brief discussion about the insights of the sensitivity analysis will follow the results

Variable	Area covered per health center

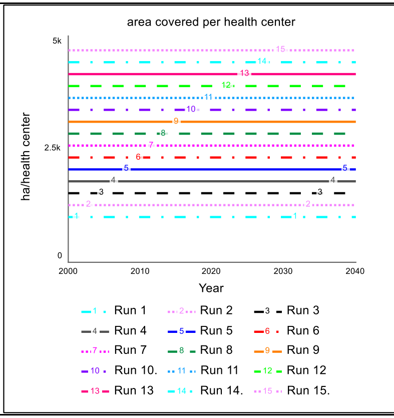


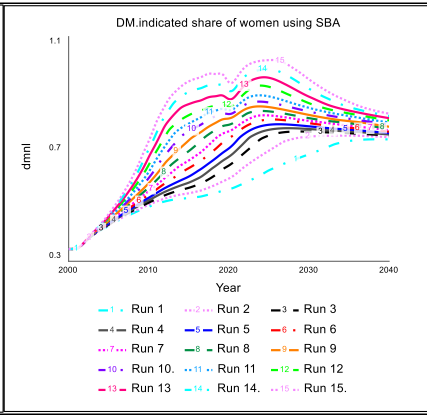


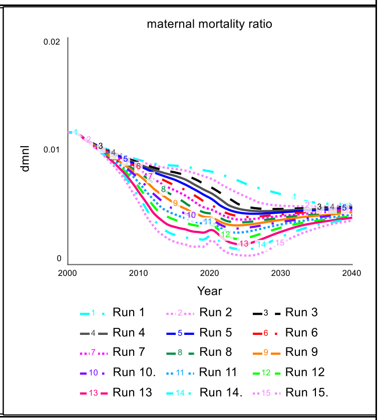


Area covered per health center

The follow are the results of the sensitivity analysis conduction on the 'area covered per health center' variable. The model was run in the business-as-usual scenario for all other variables and the area changed incrementally from 1000 to 6000. As the
Area covered increases, these changes are reflected in the model behavior. This variable is extremely sensitive, hence the need to have some good estimation of fit as uncertainty can affect the other sectors.

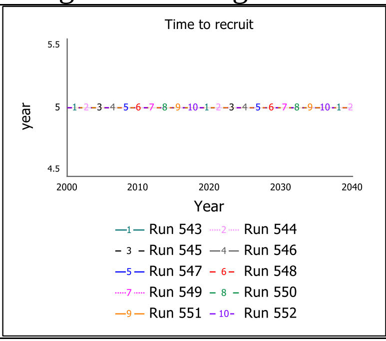


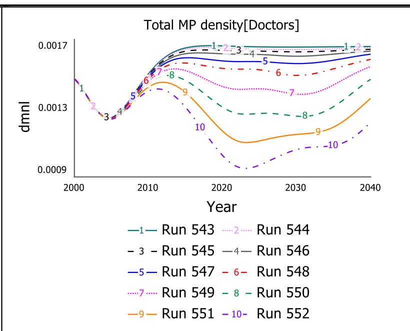


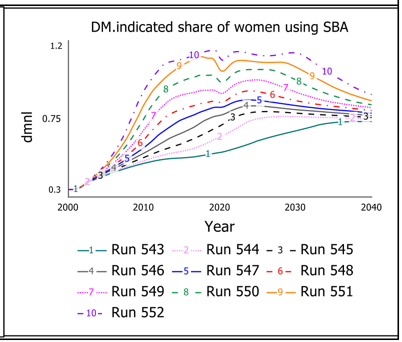


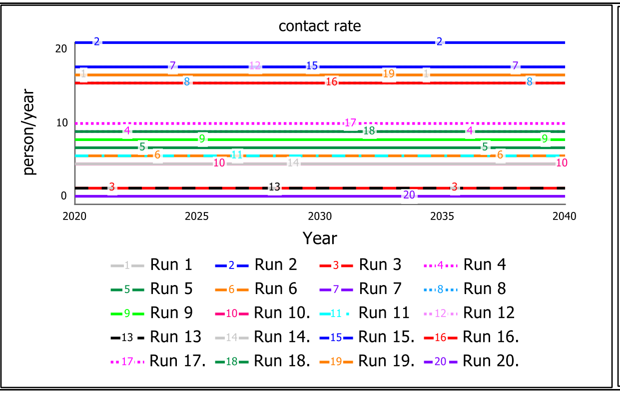
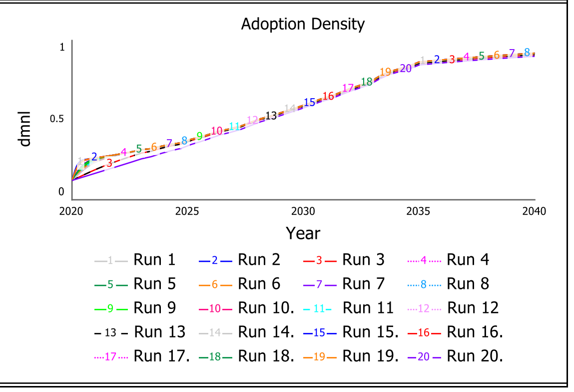
Time to Recruit (Medical Personnel)

The follow are the results of the sensitivity analysis conduction on the 'time to recruit' variable. The model was run in the business-as-usual scenario for all other variables and the area changed incrementally from 1 to 10. The time is not sensitive to any changes though these changes are reflected in the model behaviour.







Contact Rate	
The follow are the results of the sensitivity analysis conduction on the 'contact rate' variable. The model was run in the business-as-usual scenario for all other variables and the contact changed incrementally from 0 to 20. Changes in the contact causes change in the adoption density in minimal terms, these changes reflect in the model behavior.	
	

Annex 3: Optimization

The following Calibration procedure was used to determine the 'elasticities' parameter in the model.

Starting optimization "MMcalibration 2" at 2021-Jul-03 15:28:51

Method	additional starts	maxiter	init_step	tolerance
Powell	5	10000	0.00001	0.000001

Payoff:	**MMcalibrationrun 1**
Action	minimize
Kind	Calibration
Element	Acc.maternal mortality ratio
Weight	auto
Comparison Variable	Acc.Current Maternal Mortality Ratio
Comparison Run	-2
Comparison Type	Squared Error
Comparison Tolerance	0

Parameter:	DM.elasticities[yearly cost]	DM.elasticities[convenience]	DM.elasticities[social factors]	DM.elasticities[other factors]	DM.initial distance to be covered	DM.elasticities[Attractiveness Factor]	DM.initial indicated SBA share
min_value	-10	-15	-7	-10	0	-7	0
max_value	7	20	7	10	100	7	1
scaling	1	1	1	1	0.01	1	1

	DM.elasticities[yearly cost]	DM.elasticities[convenience]	DM.elasticities[social factors]	DM.elasticities[other factors]	DM.initial distance to be covered	DM.elasticities[Attractiveness Factor]	DM.initial indicated SBA share	**MMcalibrationrun 1**
Starting at	3.181179937	5.21316748372	-3.78031056096	0.264958897591	89.982495391	0.936714326202	0.433936922645	
This pass gave	3.4760523995	5.18672993537	-3.77292505254	0.263954014562	87.9503019442	0.967409432431	0.432352090359	637.970498233
Restarting at	-1.5	2.5	0	0	50	0	0.5	
This pass gave	1.71067239128	4.48104913032	-3.73339580923	0.258309455807	27.708170655	1.0158468684	0.432609672581	654.291351667
Restarting at	2.75	-6.25	3.5	-5	75	-3.5	0.75	
This pass gave	3.11259554508	-6.0289727191	3.10594446617	-4.65995432611	93.2651122758	-3.57282962136	0(min)	488196.007304
Restarting at	-5.75	11.25	-3.5	5	25	3.5	0.25	
This pass gave	-5.71370832397	11.1866216737	-3.51948152681	4.99831324872	24.2665447097	3.48457364235	9.90058178026e-7	279592.329878
Restarting at	-3.625	-1.875	1.75	-7.5	87.5	5.25	0.125	
This pass gave	-3.62518704644	-1.8749529415	1.75010761117	-7.49837502263	87.5025378574	5.24997720396	0.123881729688	1.78141725113e32
Restarting at	4.875	15.625	-5.25	2.5	37.5	-1.75	0.625	
This pass gave	3.82610187737	5.24274932344	-3.77531255867	0.264459338574	97.5429727813	0.966172458498	0.432007732807	637.960720306
After 5493 runs	3.82610248808	5.24274942316	-3.77531205585	0.264459673605	97.5429254809	0.96617261873	0.43200768172	637.960720306

Finishing optimization at 2021-Jul-03 15:40:34