EXPLORING THE HIGH MATERNAL MORTALITY RATE IN UGANDA

A SYSTEM DYNAMICS SIMULATION APPROACH

THESIS SUBMITTED TO IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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Abbreviations and Acronyms

MMR	Maternal Mortality Ratio
UBOS	Uganda bureau of statistics
UNFPA	United Nations Population Fund.
UDHS	Uganda Demographic health survey
UNICEF	United nations international children's Emergency Fund
SDG	Sustainable development goals.
UN	United nations.
EMOC	Emergency obstetric care
WHO	World health organization.
PHC	Primary health care.
DSM	Dynamic synthesis methodology
CLD	Causal loop Diagram.
MoH	Ministry of Health

Abstract

The purpose of this thesis is to investigate the maternal mortality rate in Uganda, especially that they never decrease till now yet there have been efforts initiated by government and its partners, generally maternal deaths have remained obstinate in Uganda. With all the statistics showing shows downward trend in the last twenty years since 2000, the lives of women are still at a risk when they get pregnant and deliver a baby. Various approaches have been employed to thoroughly comprehend the root cause of this problematic dynamic pattern but still with registered and acknowledged deficiencies. The System Dynamics methodology was employed to capture the complex dynamic nature of maternal healthcare in Uganda with the aim of understanding the problems towards improved decision making. A descriptive framework showing the variables, relationships and feedback loops involved in maternal health demand and healthcare service provision was developed. The framework provides insight into the system thus enhancing the decision-making process and the development of relevant health information systems which could substantially improve maternal healthcare demand and the effectiveness of the health system. The model developed provides a policy tool that can be used by policy makers and health managers in Uganda for improved decision-making. The model replicates reasonably the problematic dynamic behavior and recommends identifying synergies between investments in various sectors, such health infrastructure. Even so the study recognizes that problem can be delt with comprehensively by synergizing different strategies are employed because causes are multilayered. And by investing in education, you reduce child pregnancies and open up opportunities for health education. Moreover, by strengthening health for both grandparents and the mother, lays the foundation for the mother/women to stay longer and do better in school.

1 Thessalonians 5:16-18

Rejoice always, pray continually, give thanks in all circumstances; for this is God's will for you in Christ Jesus

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Chapter 1: Introduction

1.1 Background

Between 2000 and 2017, the subregion of Southern Asia achieved the greatest overall percentage reduction in MMR: 59% (from 384 to 157). This equates to an average ARR of 5.3%. Four other subregions roughly halved their MMRs during this period: Central Asia (52%), Eastern Asia (50%), Europe (53%) and Northern Africa (54%). MMR in LDCs also declined by 46%. Despite its very high MMR in 2017, sub-Saharan Africa as a region also achieved a substantial reduction in MMR of roughly 38% since 2000. Notably, one subregion with very low MMR (12) in 2000 – Northern America – had an increase in MMR of almost 52% during this period, rising to 18 in 2017. This is likely related to already low levels of MMR, as well as improvements in data collection, changes in life expectancy and/or changes in disparities between subpopulations. (WHO et al., 2019)

Maternal Mortality Rate is the number of resident maternal deaths within 42 days of pregnancy termination due to complications of pregnancy, childbirth, and the puerperium in a specified geographic area (country, state, county, etc.) divided by total resident live births for the same geographic area for a specified time period, usually a calendar year, multiplied by 100,000. (Maternal Mortality and Concepts, 2007)

Calculation:

$$(Number\ of\ resident\ maternal\ deaths / Number\ of\ resident\ live\ births)\ X\ 100{,}000$$

Maternal mortality is unacceptably high. About 295 000 women died during and following pregnancy and childbirth in 2017. The vast majority of these deaths (94%) occurred in low-resource settings, and most could have been prevented.

Sub-Saharan Africa and Southern Asia accounted for approximately 86% (254000) of the estimated global maternal deaths in 2017, with sub-Saharan Africa alone accounting for roughly 66% (196000), while Southern Asia accounted for nearly 20% (58000). South-Eastern Asia, in addition, accounted for over 5% of global maternal deaths (16000) (WHO, 2000-2017)

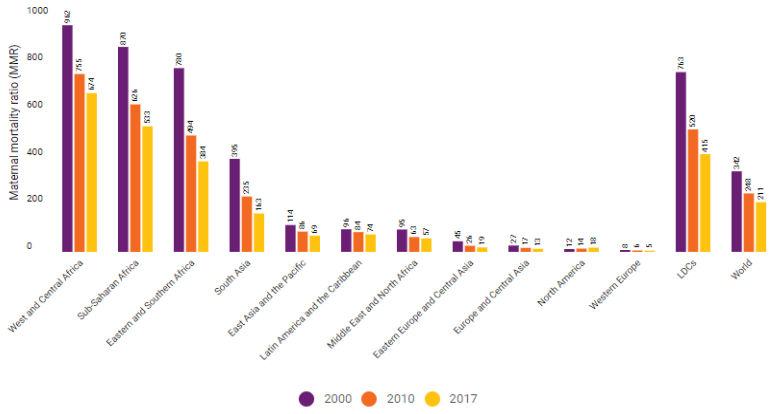
Estimates of the number of girls and women who die of pregnancy-related causes vary, because much uncertainty surrounds the numbers, especially in countries that have no civil registration systems for recording births, deaths, and causes of death. Most global estimates tend to hover around 300,000 per year, and the numbers have been declining over recent decades.

Pregnancy-related deaths are often expressed as a ratio of maternal deaths per 100,000 live births, allowing for comparison among countries and regions. The World Health Organization's global estimate for 2017 is 211 maternal deaths per 100,000 live births. (UNFPA) (WHO) .

The maternal mortality ratio varies widely by region; for every 100,000 live births in Western Europe five women die, while in sub-Saharan Africa 533 in figure 1.

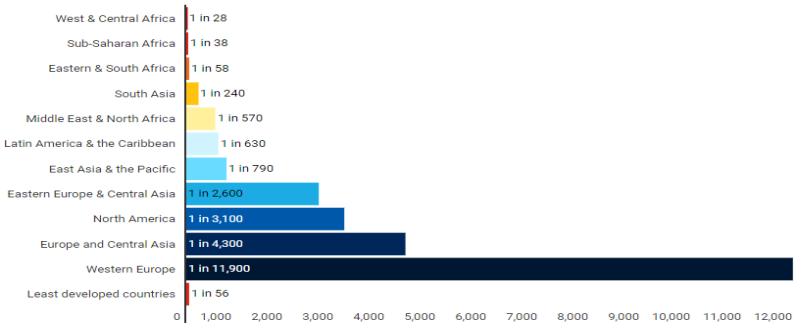
Women in less developed countries have, on average, many more pregnancies than women in developed countries, and their lifetime risk of death due to pregnancy is higher. A woman's lifetime risk of maternal death is the probability that a 15-year-old woman will eventually die from a maternal cause. In high income countries, this is 1 in 5400, versus 1 in 38 in low-income countries. (UNICEF, n.d.) in *figure*

Figure 1.1: maternal mortality trends in world:



Source: (UNICEF, 2000)

Figure 1.2: Maternal deaths probability in different regions in the world



Source*:* (UNICEF, 2000)

1.1.2 Why is it important to measure maternal mortality?

The incorporation of maternal mortality reduction into the goals of the international community reflect its importance as a measure of human and social development. Maternal mortality is a particularly sensitive indicator of inequity. Of all the indicators commonly used to com- pare levels of development between countries and regions, levels of maternal mortality show the widest disparities. Maternal mortality offers a litmus test of the status of women, their access to health care and the adequacy of the health care system in responding to their needs. Information about the levels and trends of maternal mortality is needed, therefore, not only for what it tells us about the risks of pregnancy and childbirth, but also for what it implies about women's health in general and, by extension, their social and economic status.(World Health Organization (WHO), 1996)

In this project we will focus on understanding and identifying why maternal deaths are still alarming using a system dynamics approach. The process involves creating an explanatory model and policy model whose main aim is to comprehend the maternal health challenges in Uganda and design polices to improve.

1.1.3 Why do women die?

According to Women die as a result of complications during and following pregnancy and childbirth. Most of these complications develop during pregnancy and most are preventable or treatable. Other complications may exist before pregnancy but are worsened during pregnancy, especially if not managed as part of the woman's care. The major complications that account for nearly 75% of all maternal deaths are shown below.

- severe bleeding (mostly bleeding after childbirth)
- infections (usually after childbirth)
- high blood pressure during pregnancy (pre-eclampsia and eclampsia)
- complications from delivery
- unsafe abortion.

1.1.4 Maternal deaths can be categorized as describes as below.

Pregnancy-related deaths occur during pregnancy, delivery, and puerperium. Maternal deaths are defined as those occurring during pregnancy or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, where the cause of death is related to or aggravated by pregnancy or its management, not from coincidental or accidental causes(WHO, 2012) .Direct deaths are due to obstetric complications, while indirect deaths result from non-obstetric pre-existing diseases, or diseases developing during pregnancy, that is aggravated by the physiologic effects of pregnancy. If the underlying cause is unknown or undetermined, the death is classified as unspecified. Coincidental deaths are deaths that occur during pregnancy, childbirth and puerperium due to external causes that are not related to the pregnancy.

Categories of underlying causes of death during pregnancy, childbirth and the puerperium in mutually exclusive, totally inclusive groups(WHO, 2012)

1.2 Maternal Health in Uganda

In the post MDG era, ending preventable maternal mortality remains an unfinished agenda and one of the world's most critical challenge despite significant progress over the past decades. Under the Sustainable Development Goals (SDG) agenda, each country has been given a maternal and newborn mortality reduction goal to contribute to the global target of reducing maternal mortality to 70/100.000 live births. Uganda has made progress towards reduction of maternal and perinatal mortality. The 2016 Uganda Demographic Health Survey (UDHS 2016) indicated a decline of Maternal Mortality Ratio (MMR) from 438 (UDHS 2011) to 336 per 100,000 live births.

Maternal mortality in sub-Saharan Africa remains such a big burden to deal with, and Uganda has one of the highest maternal mortality ratios in the world. World Health Organization revised estimates of 1990 figures for Uganda were as high as 1,200 maternal deaths per 100,000 live births.(World Health Organization (WHO), 1996) More recent estimates of 500–600 per 100,000 in 2000 and 2001 are mostly based on small-scale, hospital-based studies.(Survey, 1997). Given that the vast majority of Ugandan women live in rural areas and do not deliver in a health facility, the figures are likely to be much higher, with marked variation between districts**.**

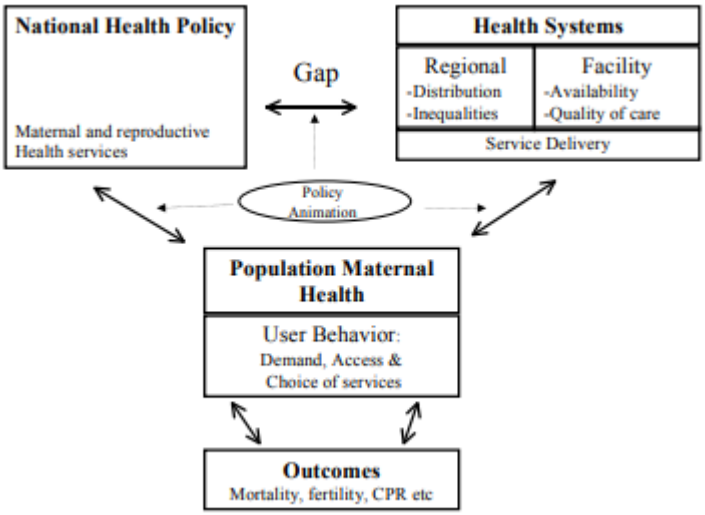
Uganda had a total fertility rate of 6.9 and a contraceptive prevalence rate of only 23%. The average age at first sexual intercourse was 16, the adolescent pregnancy rate was high at 43% and the average age at first birth 18.7. Only some 38% of births were attended by trained attendants.(UBOS, 2018) Compared to a decade before, apart from a rise in the contraceptive prevalence rate (which was 5% in 1991) and a large fall in the HIV prevalence rate, these indicators have barely changed in the past ten years.(Survey, 1989). In Uganda the major causes of maternal deaths include direct deaths and indirect deaths as described below:

In the past, maternal mortality and morbidity in Uganda were largely and justifiably blamed on the country's socio-economic and political instability, characterized by the destruction of the health infrastructure, chronic shortages of both staff and material supplies, poor remuneration of health workers, low accessibility to health services and erosion of medical ethics.

A number of studies have been undertaken in Uganda to understand the dimensions of maternal health performance and the broader reproductive rights and health issues. In many cases the available literature has been fragmented with little effort to bring it together for policy and health systems learning.

To undertake this review, a framework was adopted that looks at policy, health systems, and the level of population (*figure 1.3*). The policy level perspective seeks to understand the attempted 2 policies, their implementation and where possible, policy outcomes. At the system level, the review sought to understand the system capacity to deliver services at national and regional or district level. Issues of service delivery inputs, quality and distribution are included. At the population level we analyzed information pertaining to user behavior, service demand and access, as well as client choice for reproductive health and maternal services. (Neema, Freddie Ssengooba & Stella, 2003)

Figure 1.3 Conceptual framework of maternal health review

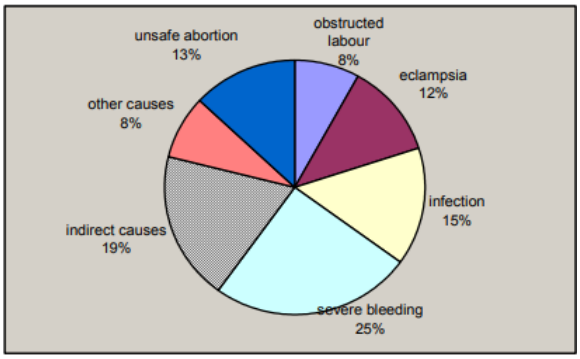


Source: (Sentubwe, Freddie Ssengooba&Stella Neema&Olive, 2003)

Today, there is a favorable and enabling policy environment, including good policies on gender equity, universal primary education, reproductive health, and decentralization of health services. These contain measures to be taken by both government and NGOs to increase health facilities, improve quality of services and care, and increase the numbers of professional health workers, equipment, and supplies.

Finally, though we aren't including covid19 in this thesis, but since we were in these unprecedented times, I believe it is a good thing to mention it. During the lockdown, over 2300 schoolgirls conceived, 128 married off during lockdown, according to this article that was published by one of the newspapers so one can only imagine what the outcome will be nine months later, not getting that most of the young girls who have conceived are situated in very rural areas and they either can't afford antenatal or have no to access the medical facilities. This is based on an article published by a newspaper known as the monitor. (Daily Monitor, 2020).

Figure 1.3 Causes of maternal deaths in Uganda



Adapted from (Freddie Ssengooba)

Furthermore, the ICD provides a comprehensive coding system for diseases and health conditions to be used on death certificates, hospital, and other vital records. ICD-10 defines a maternal death as: the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes. (Graham, Wendy J., p. 428)

This definition requires cause-of-death information so that incidental causes can be excluded, and maternal deaths can be subdivided into two groups: direct obstetric deaths and indirect obstetric deaths. A direct obstetric death is defined as one: resulting from obstetric complications of the pregnant state (pregnancy, labour and the puerperium), from interventions, omissions, incorrect treatment, or from a chain of events resulting from any of the above. (Graham, Wendy J., p. 428)

An indirect obstetric death is defined as one: Resulting from previous existing disease or disease that developed during pregnancy, and which was not due to direct obstetric causes, but was aggravated by physiologic effects of pregnancy. (Graham, Wendy J., p. 428)

• Poor fertility regulation of early pregnancy in adolescents, short pregnancy intervals and a generally high total fertility level. This has been in part due to an overall low use of contraceptives (Uganda Demographic and Health Survey, 1995) (Ministry of Health, 2000)

• Limited capacity of health facilities to manage abortion/miscarriage complications, despite it being a major contribution to maternal morbidity and mortality. According to Mbonye, of the 97 health units studied, only 40% were able to manage the complications of abortion. There was also poor service availability for post abortion care, ranging from inadequate skills to lack of equipment, supplies and drugs in most health units (Mbonye, 2000)

• Prevalence of HIV/AIDS among pregnant women has also been a factor in poor maternal outcomes. It is presumed that the prevalence of HIV infection peaked in 1992 for many areas, then declined to its

current level, estimated in 2001 to be 6.1% of Ugandan pregnant mothers (Survillence report, 2001). According to one study, 26.5% are assumed to transmit the infection to their babies (Miiro, 2001). Although AIDS continues to be a major health problem in Uganda, HIV incidence (new infections per year) does seem to be declining in parts of the country [13]. (Mbulaiteye SM, 2002)

• Malaria is one of the leading causes of morbidity in pregnant women, but prevention and prophylaxis services are not well established (Lutalo SKK, 2001)

1.3 Terms and definitions

Maternal mortality ratio (MMR) is the number of resident maternal deaths within 42 days of pregnancy termination due to complications of pregnancy, childbirth, and the puerperium in a specified geographic area (country, state, county, etc.) divided by total resident live births for the same geographic area for a specified time period, usually a calendar year, multiplied by 100,000.

Maternal deaths: The annual number of female deaths from any cause related to or aggravated by pregnancy or its management (excluding accidental or incidental causes) during pregnancy and childbirth or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy. (WHO, n.d.)

Life risk: The lifetime risk of maternal death is the probability that a 15-year-old girl will die from complications of pregnancy or childbirth over her lifetime; it takes into account both the maternal mortality ratio and the total fertility rate (average number of births per woman during her reproductive years under current age-specific fertility rates). (UNICEF, n.d.)

Skilled birth attendance: Has only recently been defined explicitly as “the process by which a woman is provided with adequate care during labor, delivery and the early postpartum period” (Susan Munabi-Babigumira, , n.d.)

Skilled health/birth personnel, as referenced by SDG indicator 3.1.2, are competent maternal and newborn health (MNH) professionals educated, trained and regulated to national and international standards.(World Health Organization et al., 2018)

Maternal health Maternal health refers to the health of women during pregnancy, childbirth and the postnatal period. Each stage should be a positive experience, ensuring women and their babies reach their full potential for health and well-being. (WHO, n.d.)

Literacy rate: The literacy rate is defined by the percentage of the population of a given age group that can read and write. The adult literacy rate corresponds to ages 15 and above, the youth literacy rate to

ages 15 to 24, and the elderly to ages 65 and above. It is typically measured according to the ability to comprehend a short simple statement on everyday life. (UNESCO, n.d.)

Net migration: Net migration is the number of immigrants minus the number of emigrants, including citizens and noncitizens, for the five-year period.

Total fertility rate: The average number of children that would be born alive to a woman (or group of women) during her lifetime if she were to pass through her childbearing years conforming to the age specific fertility rates of a given period.

Emergency obstetric care (EmOC): refers to the care of women and newborns during pregnancy, delivery, and the time after delivery.

Health center IV: A mini hospital that provides the kind of services found at Health Centre III, but in addition has separate wards for men, women, and children in which to admit patients. It should have a senior medical officer and another doctor as well as a theatre for carrying out emergency operations. According to the Ugandan government's health policy, every county or parliamentary constituency is supposed to have a Health Centre IV.

1.4 Statement of the problem

Figure 1.4: graph representing trends maternal mortality rate

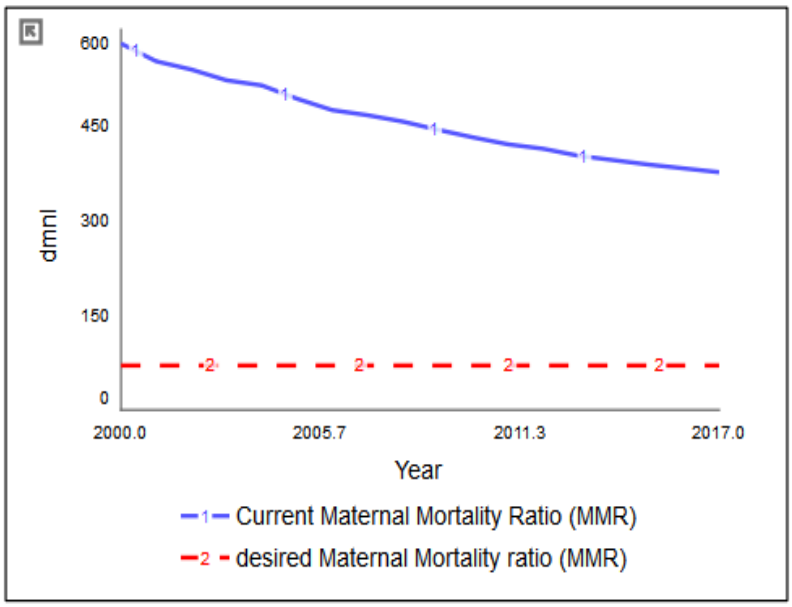


Figure 1.4 shows the dynamic pattern/ Behavior over Time (BOT) of the Ugandan maternal mortality rate for a period of about 17 years which requires to be managed or controlled. These patterns are often by BOT graphs, popularly known as reference modes. These are system thinking tools used to highlight important insights into the underlying dynamics present in a system (Maani, 2000). The BOT of the dynamic variables demonstrate how problems come into existence and how they are likely to manifest in the future (Sterman, 2000). Some of the dynamic patterns in health care system that

need to be understood and therefore need to be managed well are population and maternal mortality rate. Fig. 1.4 reveals a decline in MMR for the last 17 years from 578 to 375deaths per 100,000 women. It is clear that the decline has been very slow and therefore presents an urgent need to explore the challenges of maternal health in order to further lower the rates to minimal levels that the current maternal mortality rate in Uganda has been decreasing since the year 2000 but not the desired maternal mortality rate of seventy deaths per livelihoods a target that has been set by UN SDG.

This clearly shows complex when it comes to maternal health in Uganda, to be able to reduce, many systems and polices have to be synergized to a come to a goal.

Coverage of skilled attendance at birth is 53 percent in rural areas, compared to 89 percent in urban areas. (UNICEF, Maternal and Newborn Health Disparities in Uganda)

For instance, the local governments are struggling to cope with patient demands amidst lack of proper infrastructure. For instance, Muterere HCIII in Bugiri district lacked an adequate maternity ward. In addition, on lack of accommodation on facilities at the health centers affected service delivery. Nationally, only 12% (3,590) staff have accommodation on facilities, with majority of them having to travel long distances to the health facility. This means that they are not able to attend to mothers at the time of obstetric complications which result in maternal deaths. (Reducing maternal mortality in Uganda:, 2014, July)

Not forgetting to mention that healthcare infrastructure and/or facilities are a central facet of the health system; they are a requisite for health service delivery and an ultimate driver of progress towards universal access and coverage. Generating evidence on the availability of health facilities and their readiness to deliver health services is thus a fundamental aspect of the evidence base needed to assess universal access to health services as a precondition for attaining milestones towards UHC. (Kathryn O'Neill, 2013)

1.5 Research Objectives

The main objective is to understand why women in Uganda still die or suffer life-long disability owing to pregnancy or childbirth. This further explores the following research questions.

1. Why are the maternal mortality deaths still high in Uganda?
2. What are the causal feedback mechanisms influencing of women choosing skilled births attendance in Uganda?
3. What is the effect of health access on proportion of women seeking skilled birth attendance and maternal mortality?

Chapter 2: Literature review and hypothesis

This chapter generally gives a review of the previous approaches used to understand the dynamic problematic behavior that leads to maternal deaths. This thesis employs both qualitative and quantitative methodological approaches. The main aim of these approaches was to provide insights and deeper understanding into maternal health care challenges in Uganda. Moving forward, they even propose interventions aimed at improving maternal health care systems in Uganda generally. Some of the investigations undertaken relevant to our study are further discussed below:

2.1 Skilled births attendance

As defined earlier, Skilled birth attendance is the process by which women are provided with adequate care during labour, delivery, and the postpartum period. Furthermore, explain in detail such attendance requires both an enabling environment, characterized by supportive regulation, policies and infrastructure, communication, referral, and the necessary logistics and supplies and skilled attendant (Gaynor D.Maclean, 2003)

The Ministry of Health in Uganda has implemented several strategies to improve the infrastructure, equipment, and distribution of supplies. Uganda's investment in the expansion of health infrastructure dates back to the 1990s when health services were decentralized and continued with the MDGs. With funding from development partners e.g., the World Bank, USAID's Baylor Project and UNFPA, Level IV Health centers were constructed, and maternity wards and staff houses built or renovated. In addition, the Uganda government equipped Level III Health centers, and provided ambulances for hospitals. Despite the achievements made, the respondents noted that the physical environments of health facilities are not adequate. The quality of care, they suggested, is poor and facility delivery remains unattractive to some women. Level IV and III Health Centers in some districts are not fully functional due to a lack of electricity and other essential equipment. Some theatres are not utilized because they are poorly designed and lack equipment and anesthetists. Inadequate number of beds, limited space in the labour wards, and unreliable water supplies, also affects the quality of care at some facilities. (Susan Munabi-Babigumira & Harriet Nabudere, 2019)

According to (van den Broek, 2020) , Only 38 percent of mothers with no education had a skilled attendant at birth, compared to 55 percent with primary education and 93 percent for mothers with higher education.

There is a strong relationship between mother's education and delivery by a skilled provider. The percentage of births to highly educated women (those with at least some secondary education) attended by a skilled provider

was 81 percent, which compares favorably with 38 percent of births to women with no education. Similarly, assistance during delivery by a skilled provider varies by women's economic status: births to women in the highest wealth quintile are much more likely to be assisted by a skilled provider (88 percent) than births to women in the lowest wealth quintile (44 percent).(Bureau of Statistics & International, 2011)

Table 2.1: represents the skilled birth attendance by level of education and institutional delivery

		Coverage – care for mothers					
		Demand for family planning satisfied by modern methods (%)	Antenatal care coverage at least 4 times (%)*	Skilled attendant at birth (%)	Institutional delivery (%)	Delivered by caesarean section (%)	Postnatal care of mothers within 2 days (%)
Residence	Urban	57.2	57.0	89.1	89.5	13.7	55.9
	Rural	36.9	45.8	52.8	52.0	3.9	29.1
Residence ratio (urban to rural)		1.6	1.2	1.7	1.7	3.5	1.9
Household Wealth	Richest	56.7	58.8	88.4	87.7	12.6	56.3
	Poorest	22.3	42.6	43.5	42.2	2.2	25.1
Household wealth ratio (richest to poorest)		2.5	1.4	2.0	2.1	5.7	2.2
Mother's age	Less than 20		50.9	67.1	65.8	6.5	32.4
	20-34		47.2	57.1	56.5	5.1	33.7
	35-49		46.7	51.3	51.1	4.6	30.5
Mother's education	No education	29.7	44.7	37.7	36.1	2.6	20.5
	Primary	37.2	45.3	54.8	54.0	4.0	29.0
	Secondary	52.9		78.5	78.8	8.5	47.8
	Higher	63.3		93.3	94.9	23.6	68.7
Mother's education ratio (highest to lowest)		2.1		2.5	2.6	9.1	3.4

Source: Disparities in key maternal and newborn health interventions, Uganda, 2011.

2.3 Maternal Health infrastructure

There have been several government policy interventions in Uganda aimed at specifically improving access and quality of maternal services. The national health policy has set maternal and reproductive health care as one of the priority areas. Reduction of maternal morbidity and mortality are key outcomes expected. Safe motherhood is among the key elements of the minimum health package.

Forty nine percent of the Ugandan population lives within 5 km of a health facility. (Safe Motherhood Needs Assessment Survey, 1995-1996) However, even within this group, geographical access to health facilities does not translate into access to required services. For example, a baseline survey done for the SMP showed that 33% of health8 facilities in the country did not provide maternity services, and only 57% of hospitals were equipped to administer general anaesthesia (Uganda Demographic and Health Survey , 1995)

The Public health infrastructure is organized in a hierarchical manner on the basis of both catchment population and administrative boundaries. Table 2 shows the organizational layout of the infrastructure

Table 2.2 shows number breakdown of health facility

Region	Hospitals	Health Centre IV	Health Centre III	Total Beds	Population Per Bed
Northern	23	98	194	5894	658
Eastern	19	210	237	5499	935
Central	37	210	182	8606	670
Western	23	153	261	5587	1011
Total	102	671	874	25586	799

Adapted from: (MINISTRY OF HEALTH , 2002)

Generally, it is felt that there is more infrastructure capacity in the Central and Eastern parts of the country as compared to the Northern and Western regions. Table 3 illustrates the numbers of facilities in each region, but it should be noted that it is primarily the different population densities in these regions that affect how well the population is served by these facilities. While the Northern region has the lowest population per bed, for example, it has a small population spread

over a very large area.

Table 2.3 Distribution of health facilities by population

Facility Level	Population Served	Public	Private Not For Profit	Private For Profit*
National teaching hospital	22,000,000	2	0	0
Regional referral	2,000,000	11	0	0
District hospital	500,000	42	49	5
Health centre IV	100,000	143	13	3
Health centre III	20,000	614	147	26
Health centre II	5,000	781	365	879
Total		1593	574	913

Source: Ministry of Health 2002 Statistical Abstract

According to research paper *Uganda 2016 Demographic and Health Survey - Key Findings* (Survey & Findings, 2016) Nearly 3 in 5 women report at least one problem accessing health care for themselves. Forty-five percent of women are concerned about getting money for treatment, while 37% are concerned about the distance to the health facility. One in five women do not want to go alone to the health facility, while 5% are worried about getting permission to go for treatment. This is evidenced already, where geographical location is hinderance to access to health services the biggest hindrance is money funds, not all the women both in urban and rural areas are able to afford. One in ten women and 4% of men aged 15-49 have no education. More than half of women (57%) and men have attended primary school, while one quarter of women and 29% of men have attended some secondary education.

Only 8% of women and 12% of men have more than secondary education. More than 2 in 3 women (68%) and 4 in 5 men (79%) are literate. (Survey & Findings, 2016)

Figure 2.4: Indicators Trends for Maternal and Reproductive Health, Uganda

	Past Trends			Future Policy Goals**
Outcome Indicators:	DHS 1988/89	DHS 1995	DHS 2000/01	(2004/05)
Maternal mortality ratio	700	506	505	Reduce 70%
Neonatal mortality rate *	-	27	33.2	Decrease by 30%
Total fertility rate	7.1	6.9	6.9	Reduce to 5.4
Infant mortality rate *	119	81.3	88.4	
Process Indicators:				
Proportion of Women delivering by skilled attendant (%)	38	37.8	39	Increase to 50
Antenatal Care (ANC) coverage (%)				
In first 6 months		48.6	55.4	
At least once		90.7	91.9	
At least 4 times		47.2	41.9	Increase by 15%
At least 2 doses of TT		53.7	41.7	Increase to 80%
At least 1 dose of TT	76	80	69.6	
Caesarean section rate (%)		2.6	2.5	
Contraceptive rate – married women (%)	4.9	14.8	22.8	Increase to 30

Source: Source: (Sentubwe, Freddie Ssengooba&Stella Neema&Olive, 2003)

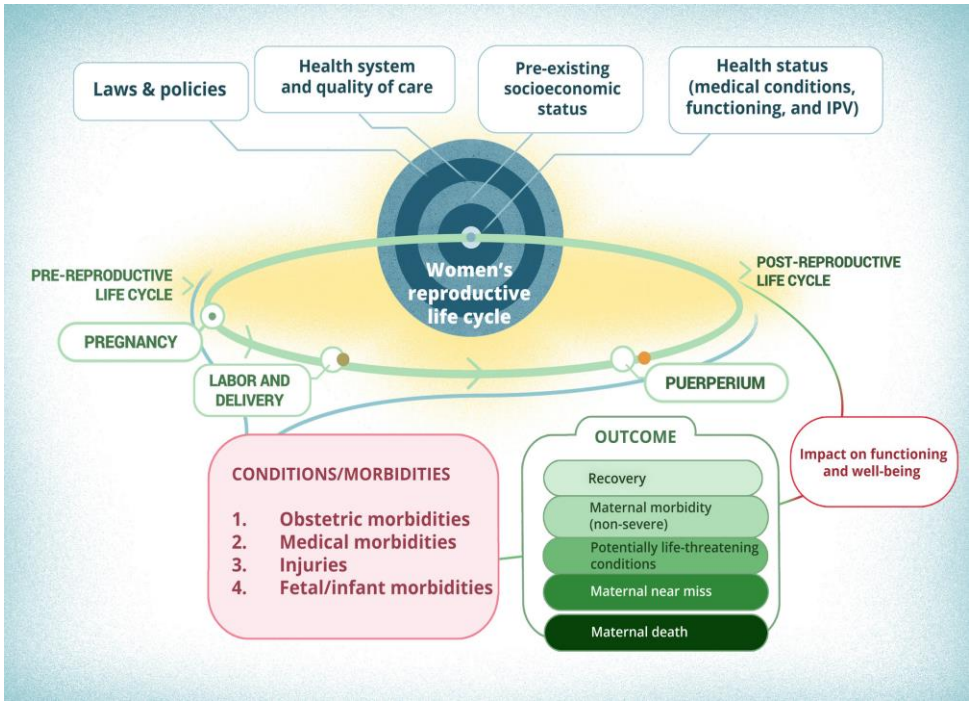
(Fonkam, July 2020) In his research paper *titled "understanding the dynamics of the uptake of maternal health services in kebbi state using system dynamics approach "used* system dynamics to understand maternal health services in Kebbi Nigeria. He focused on the dynamics of Maternal Health Services utilization in Kebbi State using a Systems Thinking approach. The broad objective was to understand the effect of interventions intended to promote utilization of Maternal Health Services. The study evolved a model to represent the causal interrelationship, interdependencies, and feedback influences of the multifactorial and multisectoral public health approach on utilization of public maternal health services using a Systems Thinking approach. This enabled us draw inferences on the effect on the mother, the intended end-beneficiary from these interventions. Using a Causal Loop Diagram, they to identified reinforcing and balancing feedback loops that could explain the behavior or outcomes being observed. The findings revealed that the feedback in the system is driven by limited resources at the household levels, technical quality of health care services, and knowledgeableness of women on maternal health services. Therefore, policies where ere able to recommend trying effectively address socio-economic inadequacies at the household level including Socio-cultural practices leading to low level of girl-child school enrolment, and several factors affecting motivation of health care workers.

2.5 Dynamic Hypothesis.

To be in position to come up with a solution to a dynamic problem and comprehend it behavior, it is very important to understand the underlying structure that cause the problem. The following section presents a tentative theory inform of a structure responsible for producing the dynamic behavior.

Wendy and Campbell scheme's scheme explains how a maternal death may occur as a result of many outcomes that end a maternal death. For a maternal death occurs, a teenage girl or woman must become pregnant, experience a problem associated with pregnancy and fail to have that problem solved hence resulting into maternal deaths. Thus, a woman/teenage girl must be in a pregnancy window, leading to due to copulation frequency, then pregnancy complications must arise, failure to manage those complications leads into deaths of a woman. As shown in the *figure 1.5* below, in 2012, WHO began a program of work on the definition, conceptualization, and assessment of maternal morbidity. The culmination of this work was a conceptual framework: the Maternal Morbidity Measurement (MMM) Framework (Veronique Filippi&Doris Chou&Maria Barreix2& Lale Say2, 2012)

Figure 1.5: Maternal morbidity measurement (MMM) framework.



Due to the poor on infrastructure especially in the rural areas, women were also concerned about birthing conditions, including hygiene, water supplies and privacy. In a study that looked at the birthing environments at the home and facilities found that only a third of women experienced child delivery in Uganda where the environment had 'improved water' (as defined by incidences constructed by study investigators) (Kyomuhendo, 2003) (Giorgia Gon, 2016). Moreover, across Uganda and Eastern Africa, less than 50% of birthing facilities had improved water and sanitation (Giorgia Gon, 2016).

A number of key documents have highlighted the need to increase resources in global maternity care, including the improved training of health professionals, the provision of suitable housing for those professionals and the building of adequate facilities to enable high quality care to be provided. (Flavia Bustreo & Say Lale, 2013),

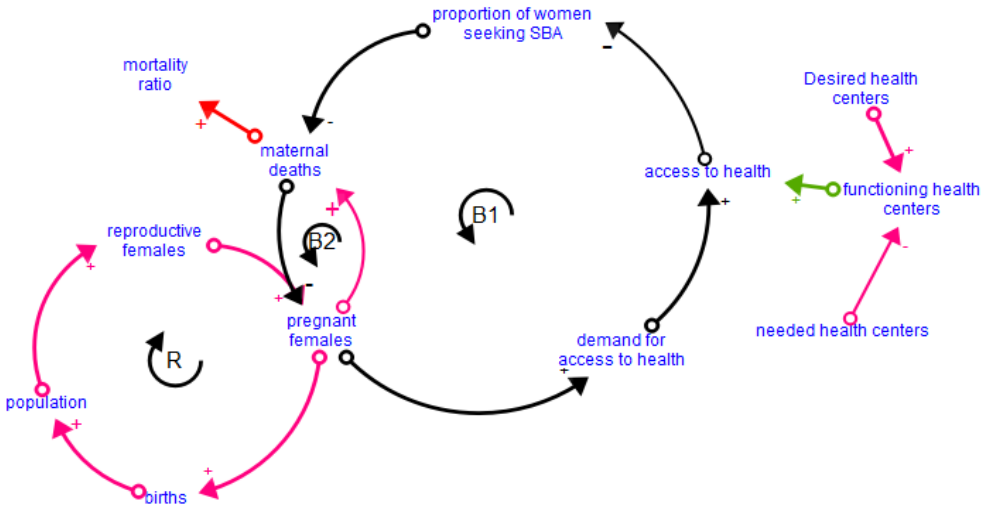
With this background, factors that impact a women's decision on where to deliver include cost and household barriers, poor health services and lack of education. Thus, making the *proportion of women seeking skilled birth attendance* still very low especially in the rural areas, and this definitely makes the maternal mortality ratio still very high in Uganda.

There the model, model suggests that larger stock of pregnant females increases higher chances of maternal risk of a woman. The larger stock of pregnant females increases higher chances of maternal risk because huge stock of mother's population strains the capacity of the health system (loop two, (B2) in Figure 2.4 reducing its effectiveness to deliver. An increase in the stock of pregnant females contributes to high population growth via high births. As births increases, the stock of non-pregnant females of reproductive age between 15 to 49 increases.

When the stock of non-pregnant females of reproductive age increases, women who are most likely to become pregnant increases too exacerbating growth of mother's population again, the process continues. (Reinforcing Loop, (R) in Figure 2.4. This is partly due to high fertility rate in Uganda that stands at around 6.9 births per woman.(Survey & Findings, 2016)

Basic causal loop diagram showing loops that constitute the dynamic problem.

Figure 2.4 causal loop diagram



With reference to the model ***maternal mortality ratio*** reduces if the ***proportion of women seeking skilled births*** increases in Uganda is higher enough to reduce any maternal related risk of the huge numbers of Ugandan ***pregnant females*** that flock health units for maternal services.

CLD in *figure 2.4*, thus briefly illustrates dynamic intricate and complex relationships associated with what the situation ought to be and what gap in terms of access to health. The diagram simplifies the tentative theory of a dynamic negative relationships between access to health and the proportion of women seeking skilled births in Uganda to deter such fatal outcome from happening.

The causal loop diagram represents one reinforcing loop (R) and a balancing/counteracting loop (B).

Loop R (***reinforcing loop***) shows that an increase in pregnant females increases births, this increases population growth increasing mature female population again in the long run (age -cohort of females between 15 to 49). This loop is most common in Sub -Saharan Africa, Uganda inclusive where total fertility rate is still high despite its slow decline. According to (2016 Demographic and Health Surve, 2016), Uganda has a total fertility of 7.2 births per woman. Such Loop(R) eventually increases the population of pregnant females exacerbating pressure onto maternal services making health units overburden appearing as if there is no service delivery (in loop two B *Figure 2.4*)

Loop B (balancing loop) shows the relationship between high numbers of pregnant mothers and skilled births attendance. The loop postulates that an increase in the numbers of pregnant females increases women who seeks maternal services. The huge numbers of pregnant females in the health units eventually increases demand for access to health.

Chapter 3: Model description and overview

3.1 Model Overview

This chapter provides a detailed description of the system dynamics modelling as a methodology adopted in this study. System Dynamics (SD) is a simulation technique that would assist decision makers to have a better comprehension of the behavior of complex systems over time and the implication of system intervention.

This chapter describes the simulation modelś structure and explains how the different literature theories applied are used in the model. In addition to these, it also describes the dynamics generated in the model during the simulation time frame. The three different sectors of the model in terms of stocks flows and how majors structure formulations are developed has been explained in detail and the interactions between them. The following the model's different sectors that were developed which generated the dynamics in the system:

- Population module
- Fertile module
- Access to Health sector

After this, causal loop diagram has been constructed for defining framework in less detailed perspective explaining the major feedback loops and their interactions. For more information see the appendix, there is more explanation on the further documentation of the model that explains the values and their sources too. A tentative policy has been introduced in the model to solve the problem stated. Furthermore, the relevant policy choice has been explained in Chapter 6. The time horizon for the explanatory model simulation is from 2000 till 2017. As stated by Generally, the modeler should back trace the data from historical trend in order to develop the reference mode of behavior. Time selected should be sufficiently long enough to allow the problematic dynamic behavior to be seen and described as well as extending the time horizon far away in future to be able to capture the indirect effects of policies designed. The time horizon used is 30 years (2000-2040).

3.1.1 Model assumptions

This section provides the explanation to the overall set of assumptions made throughout the modelling process. It defines the scope and boundary of the model. Below are the model basic assumptions made

throughout the modeling process. The following points highlights the basic assumptions made in the model:

3.1.2 Assumption 2: Aging chain population chain

We have assumed that females move along the aging chain through three stocks: young girls ages ranges 0-14, mature females ages ranges from 15-49, pre-elderly females (before menopause) and elderly females age range from menopause onwards. From this we obtain the main stock of interest is "the stock of mature females aged between 15 to 49". It is the stock of interest because this is the age cohort that is most in that reproductive age. The study shows that women in fertile age (15 to 49), die due either reasons related to pregnancy complications and death aggravated by pregnancy or death due to any other reason.

3.1.3 Assumption 3: probability of getting pregnant

This is the probability of a woman getting pregnant in case there is coitus (between a woman and man) The initial value is an assumed value

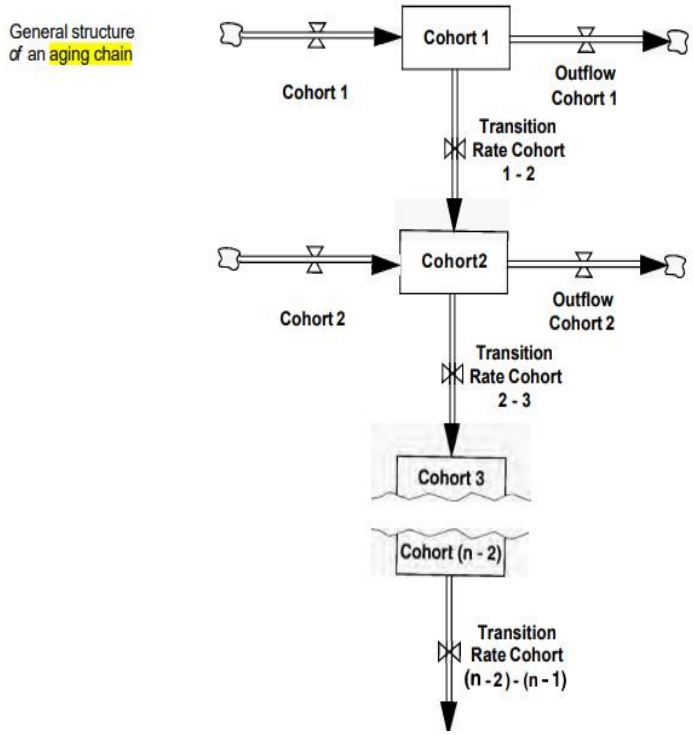
3.2 Model structure

This section explains a detailed discussion of each component of the simulation models' structure in align with different theories applied and gives an explanation to how dynamic problematic behavior could be replicated without a policy structure. The different sectors of the model structure and the interactions between them is explained in detail

3.2.1 Population module

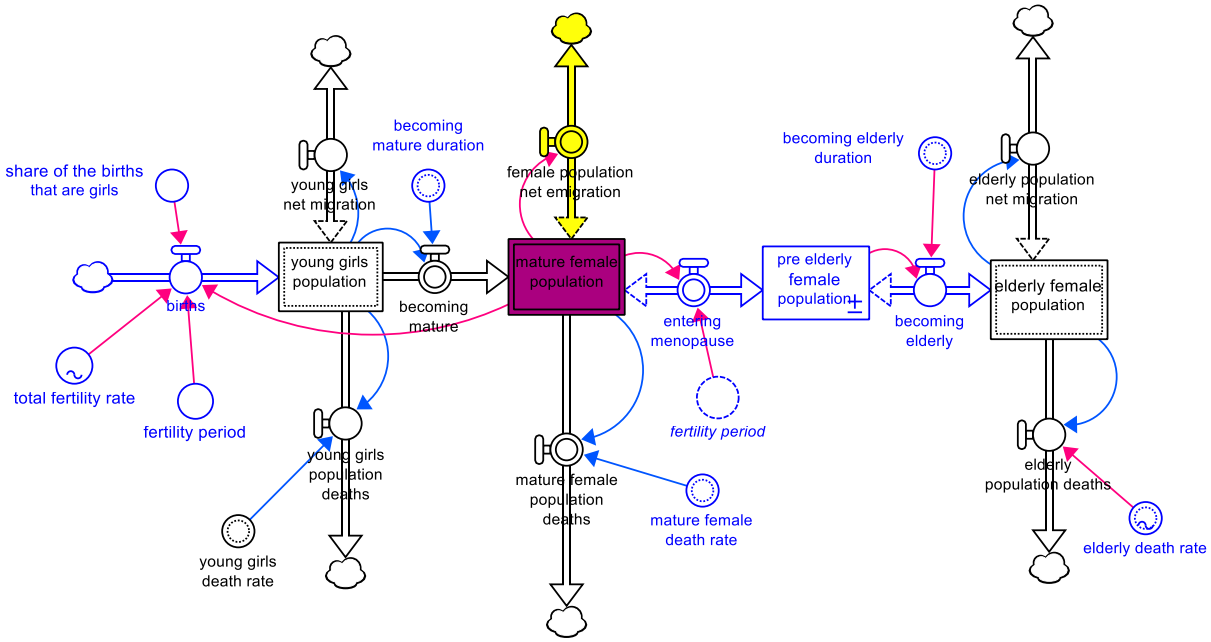
This sector is adapted from population aging chain (Sterman, 2000). The main stock (age cohort) of interest is "the stock of females aged between 15 to 49". It is the stock of interest because this is the age cohort that is most likely to conceive. The study acknowledges that women in reproductive age (15 to 49), the is the stock-colored violet in figure 3.1 below, they die due to either reasons related to pregnancy complications and death aggravated by pregnancy or death due to any other reason. This thesis solely focuses on the focuses deaths that are pregnancy related complications.

Figure 3.1: structure of an aging chain



Source: Adapted from (Sterman, 2000)

Figure 3.2 Stock and flow diagram showing the stock of interest



3.2.2 Fertile module

This is the main sector, and it indicates the core parameter, and it most crucial importance in relation to health performance indicator. The variable-colored red shows the estimated “maternal mortality ratio. The simulated maternal mortality is obtained as the ratio between sum of maternal deaths to the resident livebirths as shown in the equation above.

In Uganda, the leading causes of maternal death are hemorrhage, eclampsia (high blood pressure), unsafe abortion, and infection. (WHO, n.d.), (UNICEF, n.d.)

All pregnant women, face some level of maternal risk. According to the WHO, about 40% of pregnant women will experience delivery complications, while about 15% need obstetric care to manage complications which are potentially life threatening to the mother or infant. Despite the importance of antenatal care to predict and prevent some complications, many are sudden in onset and unpredictable

Some of the contributing factors to the high maternal mortality rate in Uganda have been found to include:

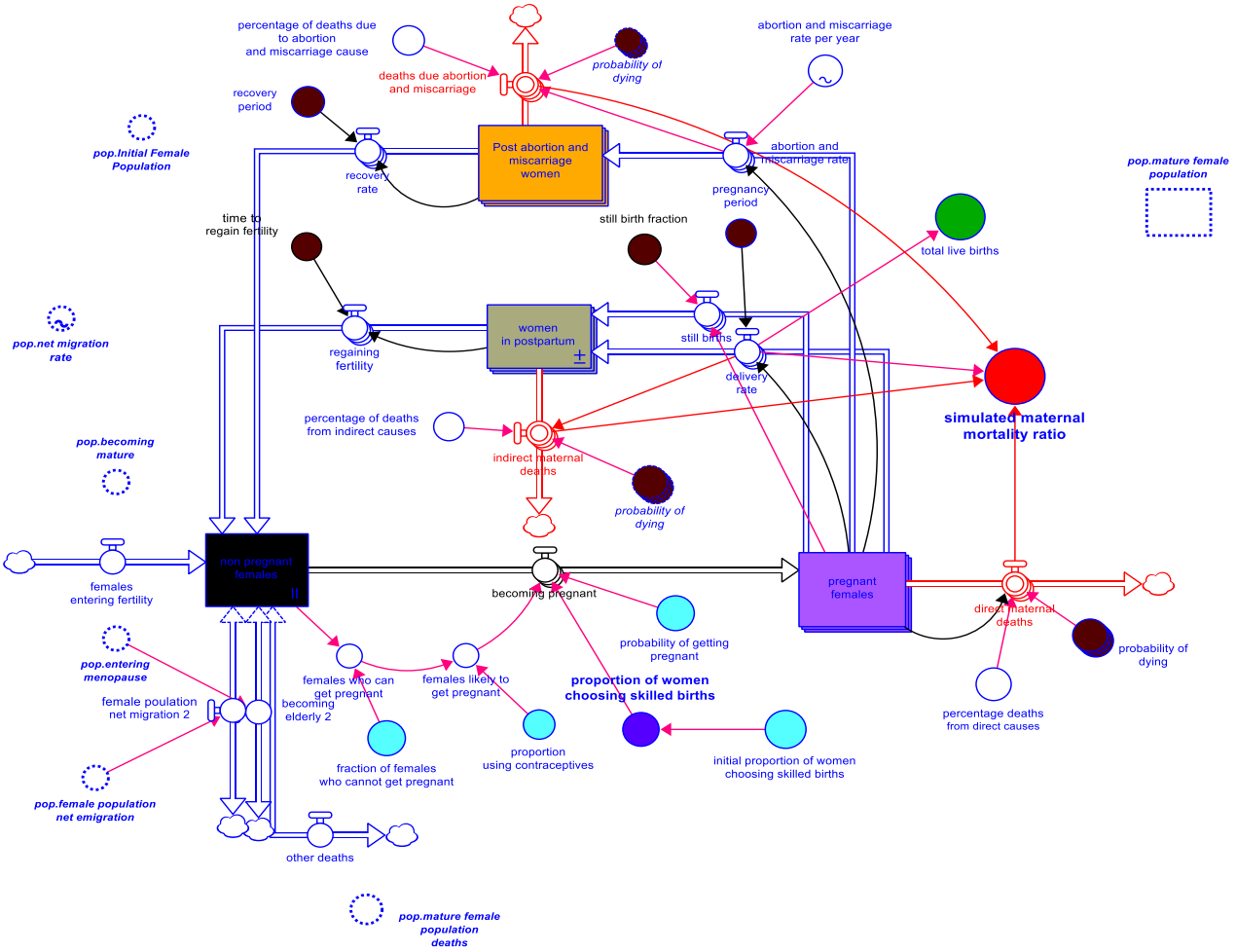
• Poor fertility regulation of early pregnancy in adolescents, short pregnancy intervals and a generally high total fertility level. This has been in part due to an overall low use of contraceptives.

• Limited capacity of health facilities to manage abortion/miscarriage complications, despite it being a major contribution to maternal morbidity and mortality. According to Mbonye, of the 97 health units studied, only 40% were able to manage the complications of abortion. There was also poor service availability for post abortion care, ranging from inadequate skills to lack of equipment, supplies and drugs in most health units (Mbonye, 2000)

• Prevalence of HIV/AIDS among pregnant women has also been a factor in poor maternal outcomes. It is presumed that the prevalence of HIV infection peaked in 1992 for many areas, then declined to its current level, estimated in 2001 to be 6.1% of Ugandan pregnant mothers (Survillence report, 2001). According to one study, 26.5% are assumed to transmit the infection to their babies (Miiro, 2001). Although AIDS continues to be a major health problem in Uganda, HIV incidence (new infections per year) does seem to be declining in parts of the country [13]. (Mbulaiteye SM, 2002)

• Malaria is one of the leading causes of morbidity in pregnant women, but prevention and prophylaxis services are not well established (Lutalo SKK, 2001)

Figure 3.3 Stock and flow diagram of the fertile sector

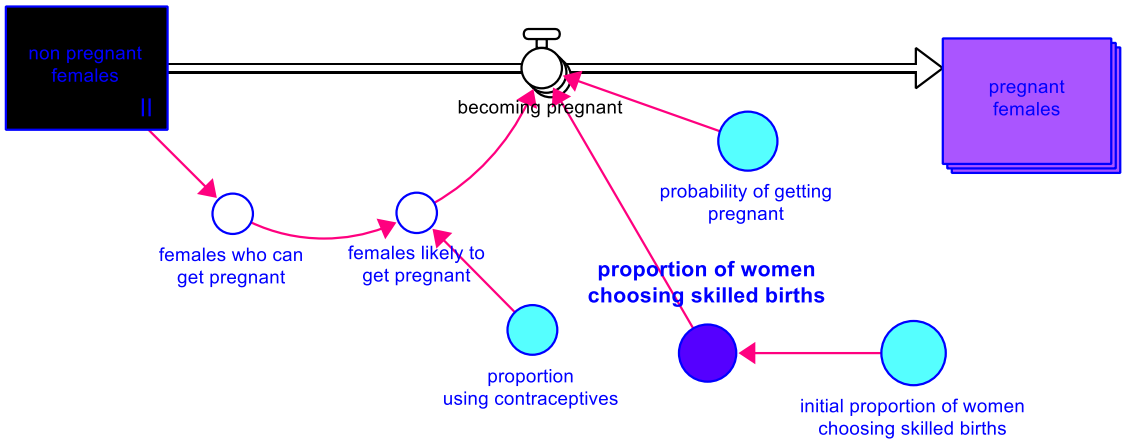


This figure 3.3 above shows a descriptive simulation of how maternal mortality occur, there are three outflows that contribute to the maternal deaths, they include flows from three stocks namely pregnant females, female in postpartum, and females in post abortion and miscarriage, The out flows are colored red in figure 3.3 above -these are then further divided into two which are define as direct deaths and indirect deaths.

As explained by above in *figure 4* above, a woman has to be in her fertile period and there has to be a man in the picture, then get pregnant and then either they have access to health access or not, before it ends into a maternal death, this shows how complex it is to measure maternal mortality.

We have a stock of non-pregnant female in age range of 15-49 colored black, these are also deemed to be fertile women then from them we are able to determine who are likely to get pregnant, this is determined by multiplying with a fraction of those using contraceptives. The proportion of females seeking skilled births attendance is modelled in a dynamic structure which affects the flow of becoming pregnant as shown in this figure 3.4 below:

Figure 3.4



The flow of becoming pregnant is calculated from the expression given below.

females_likely_to_get_pregnant*proportion_of_women_choosing_skilled_births*probability_of_getting_pregnant

As shown above from expression, the stock of pregnant females is determined by females who are like to get pregnant an initial proportion of women seeking skilled birth attendance. This value is till very low and it is why the maternal mortality ratio is still high in Uganda, due to less access to health services. A tentative policy to address this problem is well discussed in health sector below on how to increase to access to health from 0.39 to 0.80

This proportion of females seeking skilled birth attendance will then modelled in dynamic effect to of the access to HEALTH

Proportion of females seeking skilled birth attendance

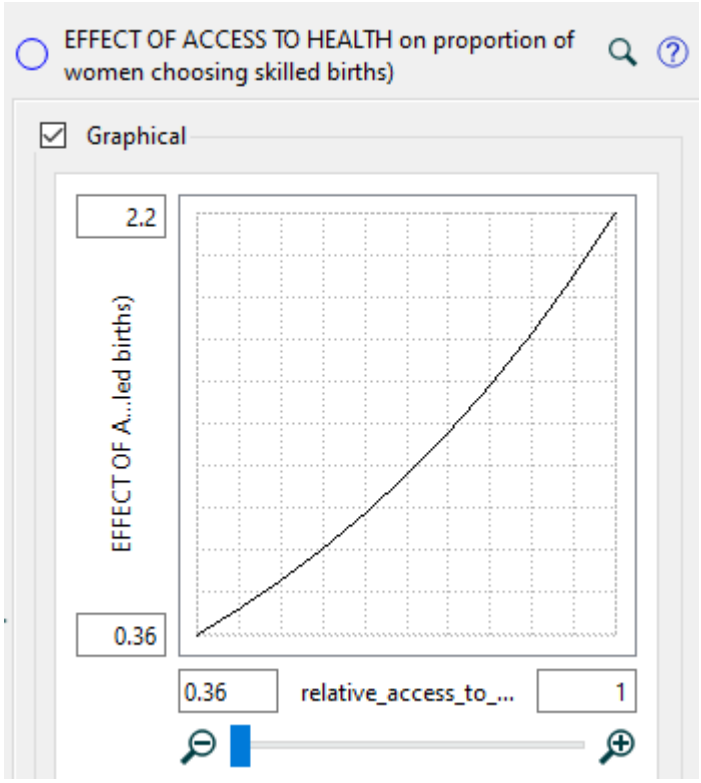
MIN(1,

*initial_proportion_of_women_choosing_skilled_births*effect_of_access_to_health_on_proportion_of_women_choosing_skilled_births*

In this part of the model, we initialized the proportion of females seeking skilled birth attendance as 0.28 especially in the rural areas. This is basically due to low level of level of education and health access being minimal where demand supersedes the supply. (UNICEF, 2000)

3.2.2.3 Effect of access to HEALTH to proportion of women seeking skilled births attendance

Figure 3.5 Table function



This table portrays how the proportion of women seeking skilled births increase with increase in the access to health especially in the urban areas.

Those residing in urban centers are 2.6 times more likely to deliver under skilled birth attendance than those in remote areas. (Östergren, 2012)

With further improvements in the health sector through policy intervention later in the next section a policy is model different policies and see their effect of on the 'proportion of females choosing skilled birth attendance. The introduction of this policy geared to ease increase the health access and increase the proportion of the females seeking skilled birth attendance which further leads to the decrease in the maternal mortality ratio.

The skilled birth attendance policy was an important priority on Uganda's maternal health agenda and received strong political commitment, and support from development partners and national stakeholders. Considerable effort was devoted to implementation of this policy through strategies to increase the availability of skilled health workers for instance through expanded midwifery training, and creation of the comprehensive nurse midwife cadre. In addition, access to emergency obstetric care improved to some extent, with expansion of the physical infrastructure, and improved distribution of medicines and supplies. (Susan Munabi-Babigumira &, n.d.)

3.3.3 Health Sector

This policy structure is to increase the proportion of females seeking skilled birth attendance increasing the number of desired health centers to a reasonable state to reduce the maternal deaths.

Some of the existing health facilities have been upgraded to provide for the new health policy strategy of Health Sub-Districts (HSD). The strategy of the HSD was incorporated into the health policy with the objective of improving access to the minimum health care package and decentralizing health service delivery further down to the community level. One of the key services to be provided at HSD is emergency obstetric care in the form of caesarean sections, blood transfusions and post abortion care.

Although Health Centre IVs (now also called HSDs) have not been fully equipped to function in these roles in the past, the recruitment of doctors and other personnel has been a major activity for the year 2000–2001. However, it should be noted that most Health Centre IVs are at early stages of establishment, and the health service referral system in most districts remains less than satisfactory

Nevertheless, the system of HSD and efforts to further decentralize service delivery and more financing closer to the community level points to a commitment by government to improve maternal health services in the country.

Figure 4.1 stock and flow diagram for construction of health centers

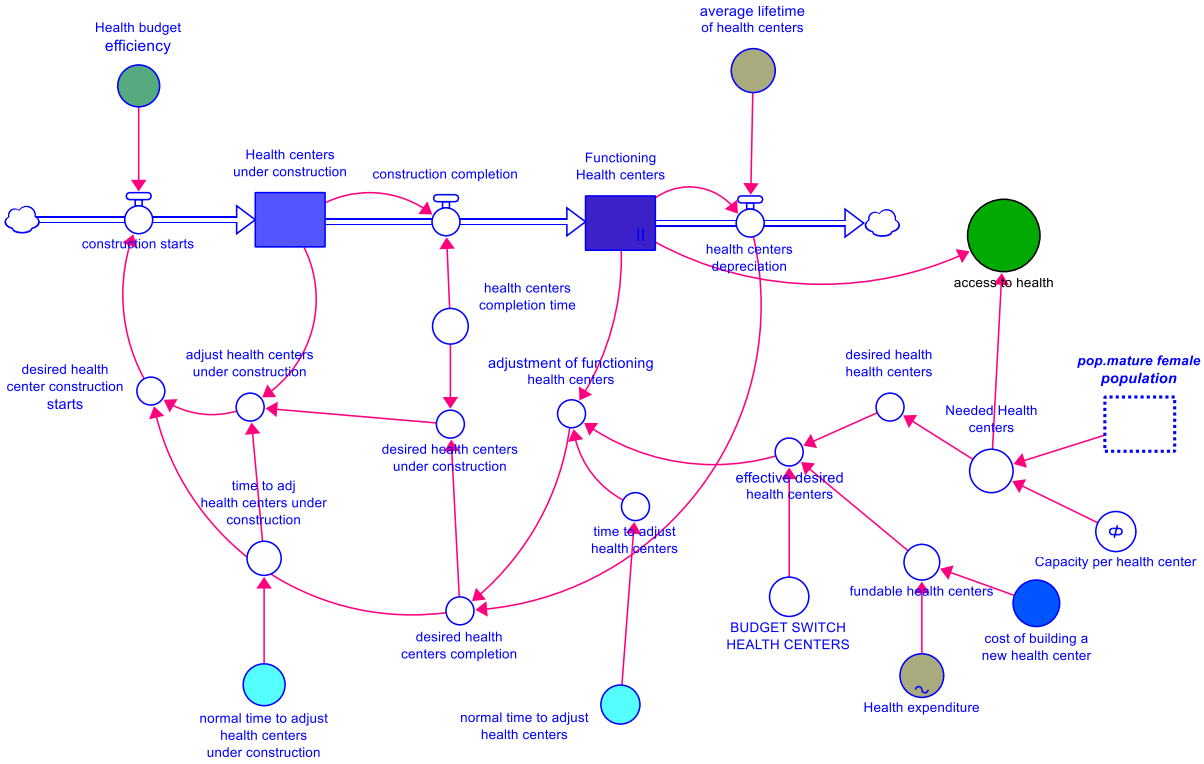


Figure 4.2 Causal loop diagram with access loop incorporated

Figure 4.1 shows a policy structure built to determine how health centers are constructed. The ultimate aim of the policy structure is to increase the stock of the functioning health centers such that access to health increases which will then increase the proportion of females seeking skilled birth attendance thus reducing the maternal deaths and maternal mortality ratio.

With the initial value of the functioning health facilities as 671 in year 2000, initialized our Health facilities. With the Health expenditure, we calculate the number of fundable health centers to obtain the desired effective health centers- we add the desired health centers and the fundable health centers.

Table 2 showing Health Expenditure Trends 1992 to 1998

Expenditure	1992	1993	1994	1995	1996	1997	1998
Per Capita in Shillings	4,998	4,206	10,847	13,424	13,662	13,664	16,611
Per Capita in US $	4.9	4.01	9.86	11.67	11.58	11.37	12.19
Total GDP in Billions of Shillings	3,725	4,800	5,482	5,956	6,565	7,414	7,818

Source: Ministry of Health 2002 Statistical Abstract

Table 3 showing number breakdown of facility

Region	Hospitals	Health Centre IV	Health Centre III	Total Beds	Population Per Bed
Northern	23	98	194	5894	658
Eastern	19	210	237	5499	935
Central	37	210	182	8606	670
Western	23	153	261	5587	1011
Total	102	671	874	25586	799

With number of functioning health facilities and required health centers, then access to health is calculated as a ratio of the functioning health facilities to needed health centers. The access to health is the variable colored in green as shown in *figure 4.1*

Chapter 4: Model Validation and Analysis

According to (Sterman, Business Dynamics, 2000) He defines modelling as a part of the learning process, is iterative, a continual process of formulating hypotheses, testing, and revision, of both formal and mental models"

Therefore, the process of validating a SD model is both built into its development and an iterative, gradual process which targets to build confidence in the simulation model (Senge J. .., 1980). To be in position to build such a confidence, the modeler seeks to demonstrate that "both the structure and behavior of the model correspond to existing knowledge about the system under testing. A logical order of tests that can assist the modeler in their attempt to validation their model and this is the order that we will also follow here as proposed by (Barlas Yaman, 1990).

As Barlas suggests, a logical sequence as a guideline for carrying out model validity tests is in three stages as stated below to be in position to validate any model. They are as stated below:

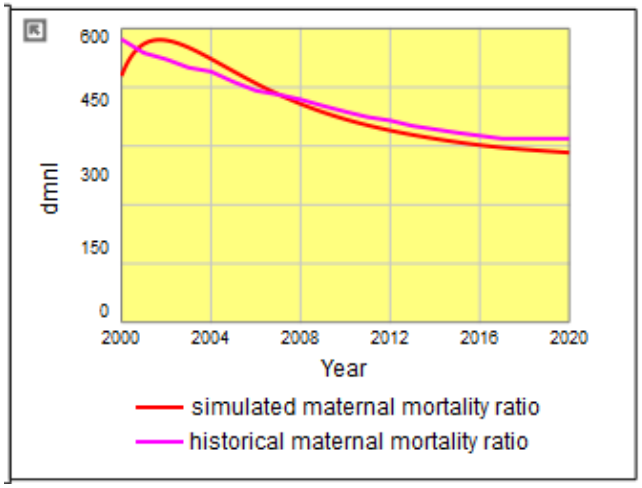
- Behavior tests.
- Direct structure tests and
- Structure-oriented behavior tests, and

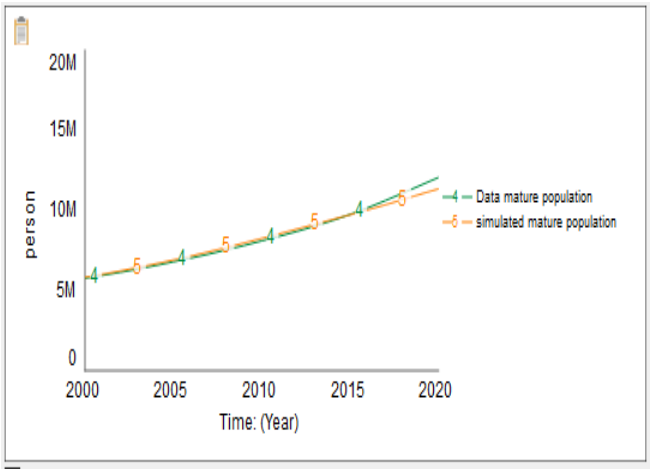
4.1 Behavior reproduction test

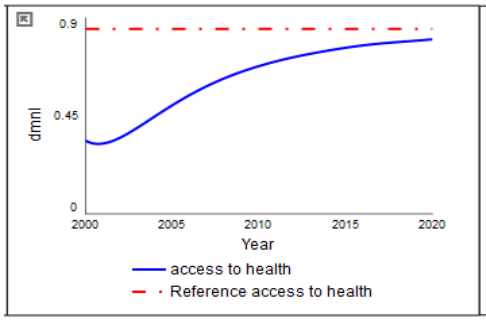
This is one of the tests of model behavior that evaluates the adequacy of model structure analysis of the behavior generated by the behavior of the structure. (Senge J. .., 1980)

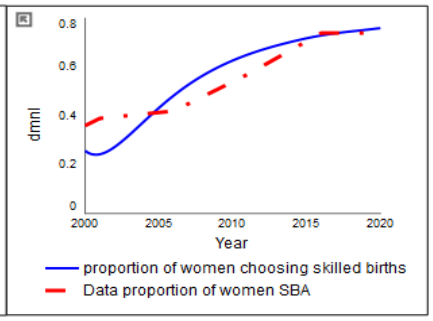
Figure 4.1 portrays the behavior of the actual data (historical values) and the behavior produced by the model. The behavior on the graph in red color is simulated behavior and the one in pink color is historical data behavior. it is observed clearly that the historical data behavior and the simulated behavior all shows a down -ward trend decline. We can truly conclude that the behavior produced by the model replicates almost the historical values.

Figure 4.1 Simulated behavior Verses reference mode









4.2 Direct Structure tests

4.2.1 Structure Verification Test:

Verifying structure means comparing the structure of the model directly with structure of the real system that the model represents. (Senge J. .., 1980)

Theoretical Structure Verification test, as compared to Empirical, involve the comparison of the model structure with knowledge about the system as it exists in the literature (Barlas Yaman, 1990), and it is this type of testing that we have performed throughout the development of the model. The grounding of the structural components to existing literature is presented in more detail under the relevant sections of this thesis, as well as further described in the model documentation.

4.2.1 Parameter verification test

Parameter verification test means comparing model parameters to knowledge of real system to determine parameters correspond conceptually and numerically to real life. (Senge J. .., 1980).

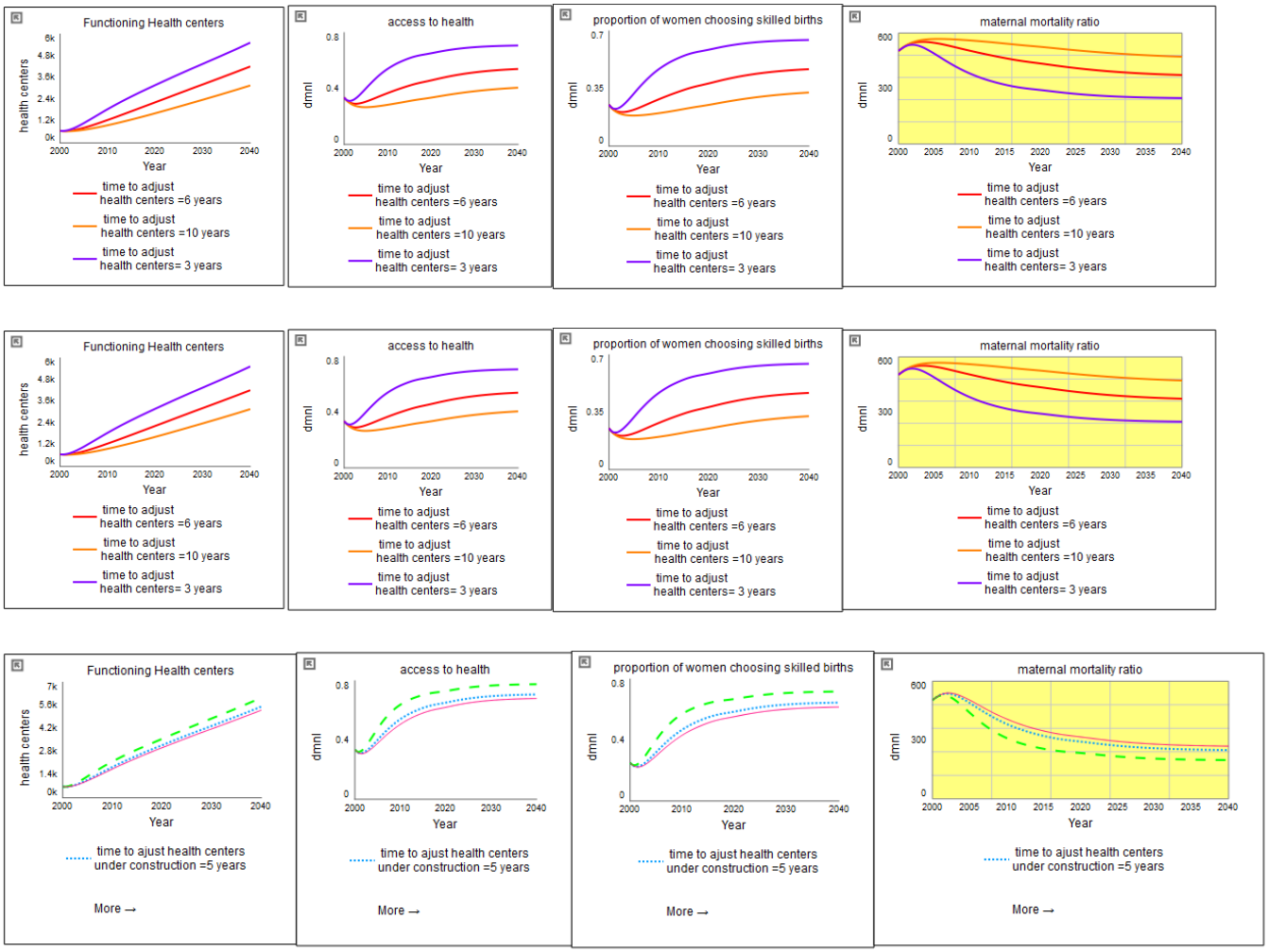
Numerical verification of the normal inventory-correction time involves determining if the value given the parameter falls within a plausible range of values for correction time. (Ssenge, and Forrester, p. 213)

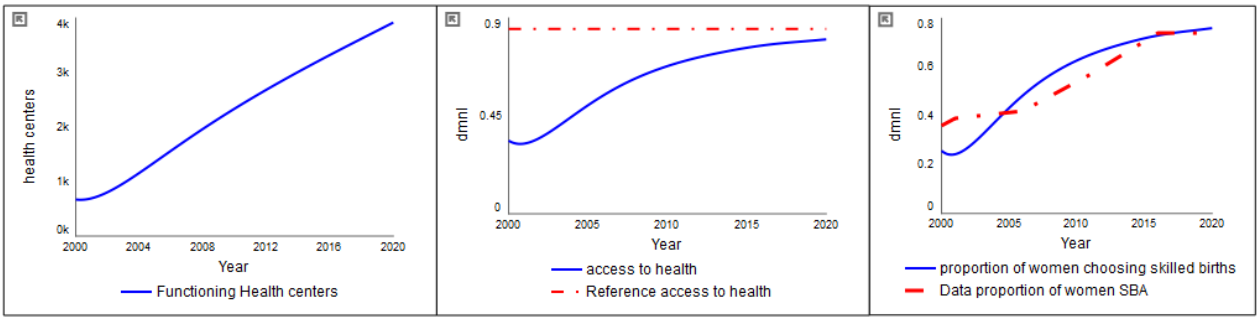
If parameter data was unavailable, assumptions were made and stated using the proxy indicators or available information e.g., the proportion of sterile women, time to adjust the function health facilities and health centers under construction.

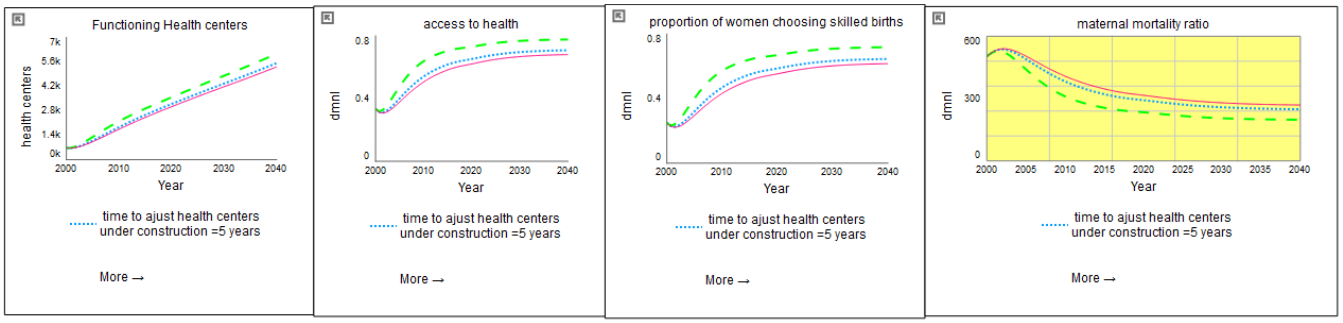
4.2.2 Direct extreme-conditions

The Direct Extreme Conditions Test is an assessment of all the equations of the model so that they are under extreme conditions. Each equation has been inspected to ensure it responds adequately to extreme inputs. Wherever appropriate, MIN or MAX functions have been employed to not allow the equations to take unreasonable values and the upper and lower bounds of table functions were estimated to ensure that values remain reasonable under extreme conditions. (Forrester & Senge, 1980).

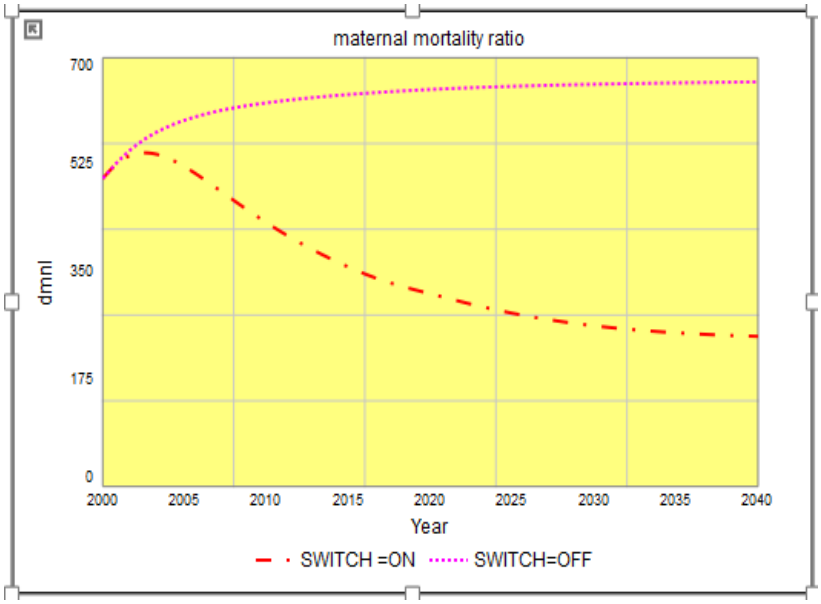
Figure: extreme direct test







With Policy Switch ON and OFF



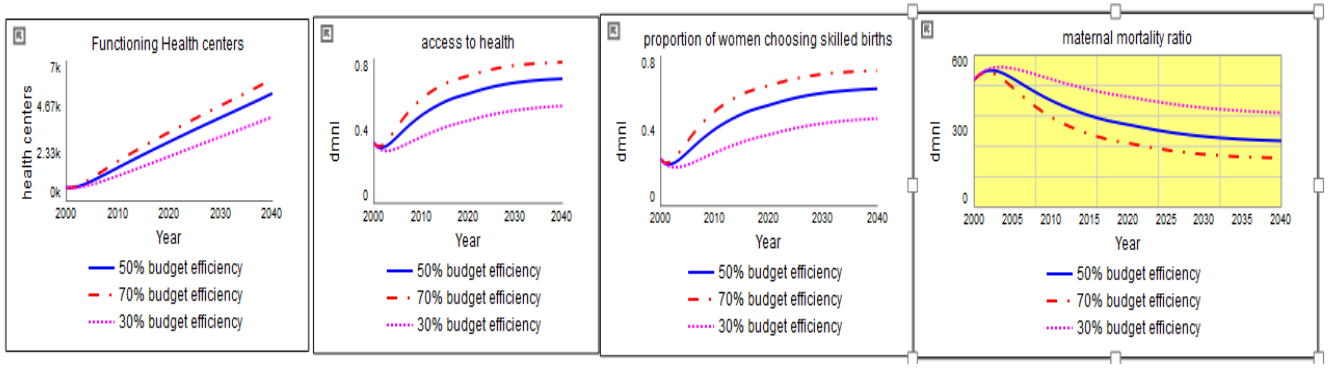
The figure above shows that, the when the switch = ON, there is a decrease in the maternal deaths, this because there is an increase in the supply of the health centers or functioning health centers, this the further increase the proportion of women seeking skilled births attendance.

Likewise on the other hand when the SWITCH=OFF, there is an increase in maternal deaths, this is because the demand supersedes the supply, thus leading to a decrease in the proportion of women seeking skilled birth attendance.

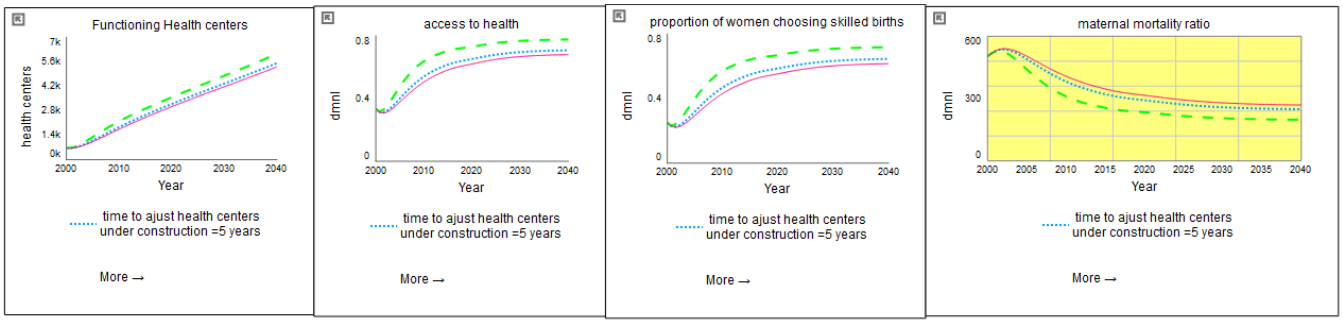
Mugarura suggests (Mugarura, 2001) Inadequate budgetary allocation is a major obstacle to improving public health services. The percentage share of the public budget going to health services ranged from 2.7% to 6.6% in the period 1995 – 1999. In addition, low priority has been given to capital development in the health sector resulting in poor equipment and infrastructure support for service delivery. (Ssengooba, 2002)

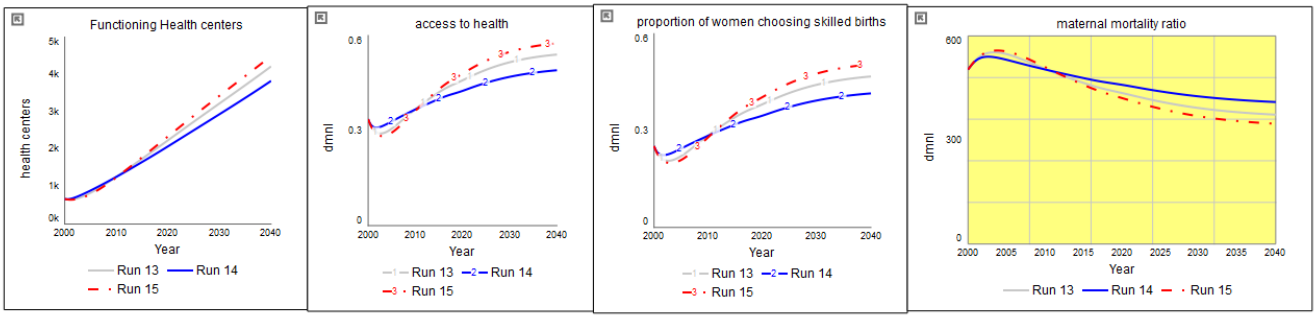
As the figure 4.3 portrays that there has been an increase in the number of function health centers over time. As the number of functioning health centers increase, then the access to health increases thus having a positive effect on the proportion of women choosing skilled birth attendance.

Figure 4.4 With budget efficiency effect



At budget expenditure of 70%, the more the functional health facilities, and increases access to health leading to proportion of females choosing skilled births increases finally decreasing the maternal mortality ratio.





Chapter 5 Conclusion and Limitations

5.1 Research challenges

The concept of knowing what works in terms of reducing maternal mortality is complicated by a huge diversity of country contexts and of determinants of maternal health

5.1.1 Policy level

The national health policy clearly outlines the need for improvements in national health indicators, with maternal mortality one of the indicators that government plans to prioritize. Expansion of service delivery infrastructure is one of the strategies proposed by government to improve maternal health status. Concerns of disproportionate expenditure at hospital-level has been a key policy driver for the government as it has sought to target financing to primary health care levels.

However new developments in the financing of health services may not be structured in a way that will maximise policy goals – so for example the government is increasing public subsidies to NGOs for service provision, yet the subsidies are not explicitly linked to performance or deliverables for priority areas. The lack of a strong financial base and reliance on development assistance further presents challenges to implementing national priorities and producing wide-scale improvements in services. However, new opportunities in financing health services are emerging, including partnership with the private sector and the Sector Wide Approach to health care financing that is being pursued. The overall trend in financing of health services is improving, although the government's stewardship in financing needs further development.

Uganda's skilled birth attendance policy aimed to increase access to obstetric care, but recruitment of human resources, and infrastructural capacity to provide good quality care remain a challenge. This study highlights the complex issues and unexpected consequences of policy implementation. Further evaluation of this policy is needed as decision-makers develop strategies to improve access to skilled care at birth. Systems Thinking avails the opportunity for this understanding, it further allows the opportunity for modelling our perception of the system and testing areas of interventions so as to see what outcomes they will yield, that is intended and unintended outcomes. To achieve the desired uptake level among pregnant women and nursing mothers, economic empowerment of households and women is vital.

1. Research question one Why is the maternal mortality deaths still high?

As explained in chapter 2, Maternal deaths are still high because of many reasons that I have explained in the literature review, the leading causes of maternal death are hemorrhage, eclampsia (high blood pressure), unsafe abortion, and infection.

1. *Research Question two 'What are the causal feedback mechanisms influencing proportion of women choosing skilled births attendance in Uganda, then maternal mortality ratio.*

Unfortunately, there is no connection between the fertile structure and the health sector, so I cannot be able to clearly state out the feedback mechanism influencing the maternal deaths. But

2. *Research question three*

Which potential policy that can affect proportion of females choosing skilled births attendance. How can this policy be cost effectively implemented?

Construction of health centers in that translates into access to health definitely has an increase on the proportion of females seeking skilled birth attendance

5.2 Limitations

The model built in this thesis held several assumptions. Thus, there are some limitations of the model and the modelling process which are mentioned below:

- Currently, the model works on several exogenous variable that only fits in for this modelling scope. The exogeneous parameter like initial proportion of females seeking skilled births attendance. Thus, endogenizing this parameter has not been done which is an important limitation of this model.
- Then, the fertile sector and health have no structure connecting them, thus there is a missing loop, but I improvised used effect of access on proportion of women choosing skilled births attendance.
- The model looks at the access to health only It considers the number of functioning health centers for per population. This doesn't account for the number midwives per population/female. This would have been a very effective way to reduce the maternal deaths.
- The leverage points such as probability of dying is very important and it one of those points to look on for further studies and research.
- Lastly my model runs on mostly assumption, finding data was a bit of a challenge.

5.3 Recommendations

The study therefore recommends that expectant mothers should be encouraged to visit health centers quite regularly, Skilled health workers such as gynecologists, midwives, nurses, and medical officers should be available at all times to provide pregnancy care services including delivery at the health facilities. Quality services must be accessible, available, and as close as possible to where women live for safety and effectiveness. In addition, these services must be acceptable to women by being responsive to local cultural and social norms.

The government of Uganda and other stakeholders should increase their efforts in enhancing female education to attain favorable maternal health outcomes in the future. Interventions aimed at keeping girls in school for longer should be part of this effort. Scholarship programmes can be used to target girls from poor families and government legislation against early marriages may help girls to remain in school for more years.

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Appendix A: Model Documentation

Total	Count	Including Array Elements
Variables	86	99
Sectors	1	
Stocks	7	10
Flows	17	26
Converters	62	63
Constants	25	26
Equations	54	63
Graphicals	5	5
Macro Variables	10	

Fertile sector						
cumulative_maternal_deaths(t)	cumulative_maternal_deaths(t - dt) + (total_Maternal_deaths) * dt	INIT cumulative_maternal_deaths = 0	person		NON-NEGATIVE	
Functioning_Health_centers(t)	Functioning_Health_centers(t - dt) + (construction_completion - health_centers_depreciation) * dt	INIT Functioning_Health_centers = 671	health centers	This stock represents functioning health centers i assumed them to be 671 https://www.health.go.ug/cause/nkwanzi-rakai-lwengo-kalangala-mukono-buikwe-mpigi-butambala-butam-butamba-wakiso-mubende-lyantonde-n-n-n-sembabule-buvuma-kampala-m-m-a-complete-list-of-all-health-facilities-in-uganda/	NON-NEGATIVE	
Health_centers_under_construction(t)	Health_centers_under_construction(t - dt) + (construction_starts - construction_completion) * dt	INIT Health_centers_under_construction = 0	health centers	This is a stock the health centers under construction https://www.health.go.ug/cause/nkwanzi-rakai-lwengo-kalangala-mukono-buikwe-mpigi-butambala-butam-	NON-NEGATIVE	

				butamba-wakiso-mubende-lyantonde-n-n-n-sembabule-buvuma-kampala-m-m-a-complete-list-of-all-health-facilities-in-uganda/		
non_pregnant_females(t)	non_pregnant_females(t - dt) + (regaining_fertility[Assisted] + regaining_fertility[Traditional] + recovery_rate[Assisted] + recovery_rate[Traditional] + females_entering_fertility - becoming_pregnant[Assisted] - becoming_pregnant[Traditional] - other_deaths - becoming_elderly_2 - female_poulation_net_migration_2) * dt	INIT non_pregnant_females = 3442477	person	This represents females that non pregnant whose range in ages of 15-49	NON-NEGATIVE	
Post_abortion_and_miscarriage_women[Assisted](t)	Post_abortion_and_miscarriage_women[Assisted](t - dt) + (abortion_and_miscarriage_rate[Assisted] - recovery_rate[Assisted] - deaths_due_abortion_and_miscarriage[Assisted]) * dt	INIT Post_abortion_and_miscarriage_women[Assisted] = 25	person	This is a stock of females that have just under gone abortion and miscarriage and have not yet recovered	NON-NEGATIVE	
Post_abortion_and_miscarriage_women[Traditional](t)	Post_abortion_and_miscarriage_women[Traditional](t - dt) + (abortion_and_miscarriage_rate[Traditional] - recovery_rate[Traditional] - deaths_due_abortion_and_miscarriage[Traditional]) * dt	INIT Post_abortion_and_miscarriage_women[Traditional] = 65				
pregnant_females[Assisted](t)	pregnant_females[Assisted](t - dt) + (becoming_pregnant[Assisted] - direct_maternal_deaths[Assisted] - delivery_rate[Assisted] -	INIT pregnant_females[Assisted] = 12586	person	This stock represents the women that are period in a time period	NON-NEGATIVE	

	abortion_and_miscarriage_rate[Assisted] - still_births[Assisted]) * dt					
pregnant_females[Traditional](t)	pregnant_females[Traditional](t - dt) + (becoming_pregnant[Traditional] - direct_maternal_deaths[Traditional] - delivery_rate[Traditional] - abortion_and_miscarriage_rate[Traditional] - still_births[Traditional]) * dt	INIT pregnant_females[Traditional] = 32363				
women_in_postpartum[Assisted](t)	women_in_postpartum[Assisted](t - dt) + (delivery_rate[Assisted] + still_births[Assisted] - regaining_fertility[Assisted] - indirect_maternal_deaths[Assisted]) * dt	INIT women_in_postpartum[Assisted] = 1398	person	This represents the number of women after childbirth or following birth before regaining their fertility.		
women_in_postpartum[Traditional](t)	women_in_postpartum[Traditional](t - dt) + (delivery_rate[Traditional] + still_births[Traditional] - regaining_fertility[Traditional] - indirect_maternal_deaths[Traditional]) * dt	INIT women_in_postpartum[Traditional] = 3596				
abortion_and_miscarriage_rate[Births_type]	pregnant_females*abortion_and_miscarriage_rate_per_year	OUTFLOW PRIORITY: 3	persons/year		UNIFLOW	
becoming_elderly_2	pop.entering_menopause	OUTFLOW PRIORITY: 4	persons/year			
becoming_pregnant[Assisted]	females_likely_to_get_pregnant*proportion_of_women_choosing_skilled_births*probability_of_getting_pregnant	OUTFLOW PRIORITY: 1	persons/year		UNIFLOW	
becoming_pregnant[Traditional]	females_likely_to_get_pregnant*(1-					

	proportion_of_women_choosing_skilled_births)*probability_of_getting_pregnant					
construction_completion	Health_centers_under_construction/health_centers_completion_time		healthcenters/Years		UNIFLOW	
construction_starts	desired_health_center_construction_starts*Health_budget_efficiency		healthcenters/Years		UNIFLOW	
deaths_due_abortion_and_miscarriage[Births_type]	probability_of_dying*abortion_and_miscarriage_rate*percentage_of_deaths_due_to_abortion_and_miscarriage_cause	OUTFLOW PRIORITY: 2	persons/year		UNIFLOW	
delivery_rate[Births_type]	pregnant_females/pregnancy_period	OUTFLOW PRIORITY: 2	persons/year		UNIFLOW	
direct_maternal_deaths[Births_type]	(pregnant_females*probability_of_dying)*percentage_deaths_from_direct_causes	OUTFLOW PRIORITY: 1	persons/year	This is an outflow that shows of females that die per year	UNIFLOW	
female_poulation_net_migration_2	pop.female_population_net_emigration	OUTFLOW PRIORITY: 5	persons/year			
females_entering_fertility	pop.becoming_mature		persons/year	This is an inflow that shows the females entering fertile period.	UNIFLOW	
health_centers_depreciation	Functioning_Health_centers/average_lifetime_of_health_centers		healthcenters/Years		UNIFLOW	
indirect_maternal_deaths[Births_type]	delivery_rate*probability_of_dying*percentage_of_deaths_from_indirect_causes		persons/year	This is an outflow that shows of number females that die per year. Due to	UNIFLOW	
other_deaths	pop.mature_female_population_deaths	OUTFLOW PRIORITY: 3	persons/year			

recovery_rate[Births_type]	Post_abortion_and_miscarriage_women/recovery_period	OUTFLOW PRIORITY: 1	persons/year		UNIFLOW	
regaining_fertility[Births_type]	women_in_postpartum/time_to_regain_fertility		persons/year	The rate at which it take to regain fertility after childbirth	UNIFLOW	
still_births[Births_type]	pregnant_females*still_birth_fraction	OUTFLOW PRIORITY: 4	persons/year	This is the still births rate and it is determined by pregnant female multiplied still birth fraction.	UNIFLOW	
total_Maternal_deaths	SUM(deaths_due_abortion_and_miscarriage)+ SUM(indirect_maternal_deaths)+ SUM(direct_maternal_deaths)		persons/year	https://www.who.int/news-room/fact-sheets/detail/maternal-mortality		
abortion_and_miscarriage_rate_per_year	GRAPH(TIME) Points: (2000.00, 0.002), (2005.00, 0.004), (2010.00, 0.005), (2018.00, 0.0053)		per year	This is the abortion and miscarriage rate per year.		
access_to_health	Functioning_Health_centers/Needed_Health_centers		dmnl	This is the main driver: defined by a ratio of functioning health centers to needed health centers		
adjust_health_centers_under_construction	(desired_health_centers_under_construction-Health_centers_under_construction)/time_to_adj_health_centers_under_construction		health centers/Years	This is the adjustment of health center under construction This is the gap of health centers under construction.		
adjustment_of_functioning_health_centers	(effective_desired_health_centers-Functioning_Health_centers)/time_to_adjust_health_centers		health centers/Years	This is the adjustment of functioning health center This the the gap of functioning health centers		
annual_adjustment_rate	policy_time_peroid		Year			
average_lifetime_of_health_centers	20		year	This is the average life time of health centers before they can be replaced.		
BUDGET_SWITCH_HEALTH_CENTERS	0		1	This variable represents a budget switch for health centers		

Capacity_per_health_center	3100		persons/health centers	This is the capacity of a health center health centers IV have a capacity of 100000 people https://assets.publishing.service.gov.uk/media/57a08d20ed915d3cfd001826/04-03_uganda.pdf https://www.health.go.ug/cause/nkwanzi-rakai-lwengo-kalangala-mukono-buikwe-mpigi-butambala-butam-butamba-wakiso-mubende-lyantonde-n-n-n-sembabule-buvuma-kampala-m-m-a-complete-list-of-all-health-facilities-in-uganda/		
cost_of_building_a_new_health_center	340575404		ugx/health centers	This variable represents funding costs per health center The findings reveal that higher-level facilities had higher average annual economic costs, with hospitals averaging UGX 790,847,320 (USD $316,339) per year, more than a dozen times higher https://pdf.usaid.gov/pdf_docs/PA00THH2.pdf		
desired_health_center_construction_starts	adjust_health_centers_under_construction+desired_health_centers_completion		health centers/Years			
desired_health_centers_completion	health_centers_depreciation+adjustment_of_functioning_health_centers		health centers/Years	This is the desired health center completion		
desired_health_centers_under_construction	desired_health_centers_completion*health_centers_completion_time		health centers	This is the target health centers under construction		

desired_health_health_centers	Needed_Health_centers		health centers	This variable represents the target number of health centers.		
effect_of_access_to_health_on_proportion_of_women_choosing_skilled_births	SMTHN(relative_access_to_health, TIME_FOR_CHANGES_IN_ACCESS_TO_HEALTH_TO_AFFECT_BEHAVIOR, 3, 1)		dmnl			
effective_desired_health_centers	desired_health_health_centers*BUDGET_SWITCH_HEALTH_CENTERS+fundable_health_centers*(1-BUDGET_SWITCH_HEALTH_CENTERS)		health centers	These are the operative heath centers.		
females_likely_to_get_pregnant	females_who_can_get_pregnant*(1-proportion_using_contraceptives)		person	This is variable that represents females likely to get pregnant when no suing contraceptives		
females_who_can_get_pregnant	non_pregnant_females*fraction_of_females_who_cannot_get_pregnant		person	This is a variable that gives us the number of females who are able to conceive		
fraction_of_females_who_cannot_get_pregnant	0.30		dmnl	This is a fraction of the females who cannot get pregnant, or sterile This initial value is an assumed value.		
fundable_health_centers	health_health_budget/cost_of_building_a_new_health_center		health centers	This variable represents the average number of fundable health centers with regards to the available health centers. It is determined by the health budget and cost of funding per heath center		
Health_budget_efficiency	0.5		dmnl	This is a variable that represents		
health_centers_completion_time	3		year	This is the time it takes to complete construction of health center. It takes 3 years.		
health_health_budget	22.5E8		ugx	This variable represents the health budget that changes over time. This will be the policy i test to see how We commend government's		

				efforts towards establishing health infrastructure. Notable infrastructure development in the recent past include: completion and commissioning of the Regional Hospital for Paediatric Surgery in Entebbe, completion of the rehabilitation and equipping of Kawolo and Kayunga hospitals; completion of the upgrading of the 124 HC IIs to IIIs and commencement of works for upgrading of an additional 62 HC IIs to HC IIIs. Infrastructure upgrade at Kyegegwa HC IV and Bisozi HC IV under DRDIP. However, in FY 2021/22, there is no indication that sub-counties and parishes that do not or have low grade health facilities are allocated funds to have those facilities constructed/ upgraded. It is reported that 39 districts do not have hospitals at all4 . These are the districts of Alebtong, Amuria, Amuru, Bukedea, Bukomansimbi, Bulambuli, Buvuma, Buyende, Dokolo, Gomba, lsingiro, Kalangala, Kaliro, Kamwenge, Kibuku, Koboko, Kole, Kotido, Kween, Kyankwanzi, Kyegegwa, Luuka, Lamwo, Lwengo, Manafwa, Mitoma, Nakapiripirit, Namutumba, Namayingo, Ntoroko, Otuke, Pader, Rubirizi, Serere, Sironko, Kibale, Kakumiro, Rubanda and Omoro. Further still, that 29 constituencies do not have		

				health center IVs. Inability to access health facilities poses higher economic and health risks for the most vulnerable people whose first point of call is a public health facility. https://www.iser-uganda.org/images/downloads/Failing_to_Prioritise_Health_Financing_in_the_Middle_of_a_Pandemic.pdf		
historical_access_to_health	GRAPH(TIME) Points: (2000.00, 0.0), (2001.00, 0.0), (2002.00, 0.0), (2003.00, 0.0), (2004.00, 0.0), (2005.00, 0.0), (2006.00, 0.0), (2007.00, 0.0), (2008.00, 0.0), (2009.00, 0.0), (2010.00, 0.0), (2011.00, 0.0), (2012.00, 0.0), (2013.00, 0.0), (2014.00, 0.0), (2015.00, 0.0), (2016.00, 0.0), (2017.00, 0.0), (2018.00, 0.0), (2019.00, 0.0), (2020.00, 0.0), (2021.00, 0.0), (2022.00, 0.0), (2023.00, 0.0), (2024.00, 0.0), (2025.00, 0.0), (2026.00, 0.0), (2027.00, 0.0), (2028.00, 0.0), (2029.00, 0.0), (2030.00, 0.0), (2031.00, 0.0), (2032.00, 0.0), (2033.00, 0.0), (2034.00, 0.0), (2035.00, 0.0), (2036.00, 0.0), (2037.00, 0.0), (2038.00, 0.0), (2039.00, 0.0), (2040.00, 0.0)		dmnl			
"Historical_data_Maternal_Mortality_Ratio_(MMR;_maternal_deaths_per_100,000_live_births)"	GRAPH(TIME) Points: (2000.00, 578.0), (2001.00, 550.0), (2002.00, 537.0), (2003.00, 520.0), (2004.00, 512.0),		dmnl	aternal Mortality Ratio (MMR; maternal deaths per 100,000 live births)		

	(2005.00, 491.0), (2006.00, 473.0), (2007.00, 465.0), (2008.00, 455.0), (2009.00, 442.0), (2010.00, 430.0), (2011.00, 419.0), (2012.00, 412.0), (2013.00, 401.0), (2014.00, 394.0), (2015.00, 387.0), (2016.00, 381.0), (2017.00, 375.0)					
initial_access_to_health	INIT(access_to_health)		dmnl	This takes the initial value of the the access to health		
initial_proportion_of_women_choosing_skilled_births	0.39		dmnl	This is the proportion of the skilled birth attendance.		
Needed_Health_centers	pop.mature_female_population/Capacity_per_health_center		health centers	The actual number of health centers that are needed or demanded. It is determined by dividing the number female population with the capacity per health center		
normal_time_to_adjust_health_centers	5		year	This is the time it takes to adjust functioning health centers		
normal_time_to_adjust_health_centers_under_construction	5		year	This is the time it takes to adjust health centers under construction		
percentage_deaths_from_direct_causes	.18		dmnl/year	This variable shows percentage deaths from direct causes https://assets.publishing.service.gov.uk/media/57a08d20ed915d3cfd001826/04-03_uganda. https://www.ucc.ie/en/mde/definitionandclassificationofmaternaldeath		
percentage_of_deaths_due_to_abor	0.08		dmnl	This variable represents percentage of deaths due to abortion		

tion_and_miscarriage_cause				and miscarriage cause ://assets.publishing.service.gov.uk/media/57a08d20ed915d3cfd001826/04-03_uganda.pdf https://www.ucc.ie/en/mde/definitionandclassificationofmaternaldeath		
percentage_of_deaths_from_indirect_causes	0.13		dmnl	This is percentage of deaths from indirect causes https://assets.publishing.service.gov.uk/media/57a08d20ed915d3cfd001826/04-03_uganda.pdf https://www.ucc.ie/en/mde/definitionandclassificationofmaternaldeath		
policy_adjust_time	annual_adjustment_rate		year			
policy_deadline	2040		year			
policy_start_time	2025		year			
policy_status	IF(policy_switch=1)AND(TIME>policy_start_time)THEN(1)ELSE(0)		dmnl			
policy_switch	1		dmnl			
policy_time_peroid	policy_deadline-policy_start_time		year			
pregnancy_period	9/12		year	This is the time it takes for one to be pregnant. It is 9 months		
probability_of_dying[Assisted]	(1/11700)		dmnl	This is the life risk of dying from maternal related death The risk of maternal mortality from haemorrhage is 1 in 1 000 deliveries in developing countries (100 per 100 000 live births). Most deaths (about 99%) from PPH occur in low- and middle-income countries compared with only		

				1% in industrialized nations. https://www.verywellfamily.com/maternal-mortality-rate-causes-and-prevention-4163653 https://data.unicef.org/topic/maternal-health/maternal-mortality/#:~:text=Maternal%20mortality%20declined%20by%2038%20per%20cent%20between%202000%20and%202017&text=From%202000%20to%202017%2C%20the,reduction%20of%202.9%20per%20cent.		
probability_of_dying[Traditional]	1/38					
probability_of_getting_pregnant	.11		per year	This is the probability of a woman getting pregnant incase there is coitus. The initial value is an assumed value		
proportion_of_women_choosing_skilled_births	MIN(1, initial_proportion_of_women_choosing_skilled_births*effect_of_access_to_health_on_proportion_of_women_choosing_skilled_births)		dmnl	https://data.unicef.org/resources/data_explorer/unicef_f/?ag=UNICEF&df=GLOBAL_DATAFLOW&ver=1.0&dq=UGA.MNCH_SAB.&startPeriod=1970&endPeriod=2021 https://data.unicef.org/resources/data_explorer/unicef_f/?ag=UNICEF&df=GLOBAL_DATAFLOW&ver=1.0&dq=UGA.MNCH_ANC4.&startPeriod=1970&endPeriod=2021 https://data.unicef.org/resources/data_explorer/unicef_f/?ag=UNICEF&df=GLOBAL_DATAFLOW&ver=1.0&dq=UGA.MNCH_SAB.&startPeriod=1970&endPeriod=2021		
proportion_SBA	GRAPH(TIME) Points: (2000.00, 0.78), (2015.00, 0.78)		dmnl			

proportion_using_contraceptives	0.39		dmnl	This is the proportion of females that are using contraceptives Uganda also consistently has one of the lowest contraceptive use prevalence rates among East African countries [6]. It was estimated that only 39% of married women of reproductive age used contraception in 2016 [7]. https://dhsprogram.com/pubs/pdf/SR245/SR245.pdf		
recovery_period	1 {4/12}		Year	This is a variable that shows the time it takes for a woman to recover after chilbirth After a surgical abortion, you may have cramps and light bleeding for up to 2 weeks. Most women can return to normal activities 1 to 2 days after the procedure. Deciding to end a pregnancy is never easy. After an abortion, it is normal to feel relief, sadness, or guilt.		
relative_access_to_health	access_to_health/initial_access_to_health		dmnl			
simulated_maternal_mortality_ratio	(SUM(deaths_due_abortion_and_miscarriage)+ SUM(indirect_maternal_deaths)+ SUM(direct_maternal_deaths))/ (SUM(delivery_rate)/100000)		dmnl	This is the main indicator in the whole model. It is ratio		
still_birth_fraction	1/6		per year	This is a fraction of the babies that die before 28 days of delivery https://www.lstmed.ac.uk/sites/default/files/NIHR%20Stillbirth%204pp%20Report%20A4%20%28Uganda%29%20WEB		

				%20AW_0.pdf In Uganda, the stillbirth rate is reported at 17.8 per 1,000 births.		
TIME_FOR_CHANGES_IN_ACCESS_TO_HEALTH_TO_AFFECT_BEHAVIOR	2		Years	This is the time it takes for the change in access to affect the behavior.		
time_to_adj_health_centers_under_construction	normal_time_to_adjust_health_centers_under_construction		year	This is the time it takes to adjust health centers under construction		
time_to_adjust_health_centers	normal_time_to_adjust_health_centers		year	This is the time it takes to adjust functioning health centers		
time_to_regain_fertility	1 {4/12}		year	This is the time it takes for a female to regain fertility after giving birth. It is usually between 4-8 months I did this by verbally asking women who have given birth		
total_live_births	SUM(delivery_rate)		persons/year	These are live birth is the birth of a child who showed any sign of life; the number of live births refers to the number of births excluding stillbirth		