

Understanding Maternal Mortality Ratio

Reduction Bottlenecks in Uganda

A System Dynamics Approach for Policy Development

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Thesis

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To my Mum ,Dad, late Paternal grand mum and Juliet Nasuna,

You opened gates to my new life!.

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Abstract.

Despite all efforts initiated by government and its partners , maternal deaths has remained obstinate in Uganda. Even though the incidence shows adown ward trend in the last two decades since 1990 , women still finds it very risky to conceive 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 approach has been used in this study with an ultimate aim of understanding this public health problem for policy development. An explanatory model and policy model explaining the relationships between variables and feedback loops involved in maternal health care system have been developed. 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 recruitment of Midwives and control of fertility as a crux for maternal mortality ratio reduction. However the study recognizes that this problem would be dealt with comprehensively if a synergy of different strategies are employed because causes that brings about this problem are many layered.

Keywords: Maternal mortality ratio, model, maternal deaths, simulation, policy, Uganda.

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"Who can be compared with the lord, who is enthroned high? Far below him are the heavens and the earth. He stoops to look, and he lifts the poor from the dirt and the needy from the garbage dump. He sets them among princes, even the princes of his own people" Psalms 113:7-8

Abbreviations/ Acronyms

MHS Maternal health care system

LMIC's low and middle income countries.

MDG Millennium development goals.

UN United nations.

WHO World health organization.

PHC Primary health care.

HSD Health -sub district strategy.

EMOC Emergence Obstetric care

PHC Primary Health Care

UN United Nations

DSM Dynamic synthesis methodology

i.e. That is

CLD Causal loop Diagram.

NRM National resistance movement.

MMR Maternal Mortality Ratio.

UBOS Uganda bureau of statistics

MW married women.

UNFPA United Nations Population Fund.

UDHS Uganda Demographic health survey

UNICEF United nations international children's Emergency Fund.

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1. INTRODUCTION

Reducing maternal death is not only a Ugandan top priority public health issue but it's an international community top priority public health issue especially with the advent of international millennium development goals. Maternal deaths occur due to risks attributable to pregnancy and child- birth as well as poor quality care from health services. (Khalid S., et al.,2006). The level of Maternal Mortality in any country is a sensitive index of the prevailing health conditions and the socioeconomic development of a country(Jagdish,1993). Uganda like many other countries in sub Saharan Africa, is one of the countries where maternal mortality is still a burden with literature showing maternal mortality ratios being on the down ward trend but still very high. Today, despite various interventions that have been undertaken, maternal mortality ratios have remained obstinate and hopes of meeting MDG target by 2015 i.e. to have reduced maternal deaths by 75% as per MDG set goal is almost an illusion. Our thesis aims at assisting us in identifying and understanding the bottlenecks that have derailed these reduction efforts by using *system dynamics approach*. The thesis involves creating *an explanatory model* and *policy model* whose sole purpose is to help us understand the dynamics of maternal health care challenges in Uganda and *design new policies* to lower them.

The first three sections of this chapter will present definition of key concepts, conceptualization of maternal deaths, a briefly history about maternal mortality situation Globally, Maternal health care situation and major causes of maternal deaths in Uganda, interventions (policies) that have been initiated towards maternal mortality ratio reduction in Uganda and a precise outline of this thesis. The preceding chapters will be unveiled and explained as we move on in our quest to replicate the historical dynamic problem.

1.1. **Definition of key concepts.**

Maternal health ,refers to the health of a woman during pregnancy, childbirth and postpartum period. Its health of mothers and their children usually 0-5 years. Maternal health is usually described in terms of *safe motherhood* often full of joy and positive feeling. It's all about making sure that all women of child-bearing age receives the care they need to be safe both before, throughout pregnancy ,at child birth and after the delivery.(Christopher ,s,etal 2011)

Maternal health care, implies a package of care in totality that mothers and their children receives to ensure their safety before, throughout pregnancy period and after child birth.

Maternal mortality(deaths) is the death of a woman of child bearing age while pregnant or with 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 causes,(WHO definition).

Maternal mortality ratio, is defined as maternal deaths in a time period, usually 1 year, divided by the number of live births in the same period and conventionally expressed per 100,000 live births. It is an indicator that measures or represents the risk associated with each pregnancy i.e. obstetric care because complications during pregnancy and child birth are the leading causes of death and disability among women of reproductive age especially in developing countries.(Hill, Kenneth, etal 2007)

1.2. **Conceptualization of Maternal Deaths**

One of the scientific tools that guided our modeling project was based on Campbell and Wendy's schema (1989). The Schema conceptualizes maternal deaths not *as a chance event* but as an *endpoint* or *an outcome* from a process i.e. an outcome from a series of intertwined stages where each stage is conditional upon the preceding one. The schema postulates that a woman must become

pregnant, experience a problem associated with pregnancy and fail to have that problem solved in order for maternal deaths to occur. Conditions for maternal deaths to occur are according to this schema are ; a woman must be in fertile period, there must be conception due to coitus frequency, then pregnancy complications must arise, failure to manage those complications culminates into deaths of a woman. This implies that any action aimed at managing or regulating at any point in one of these stages portrayed below in **Figure 1.1** helps to minimize maternal deaths. **Figure 1.1** below portrays the process of how maternal occurs.

Schema showing the process of how maternal deaths occurs

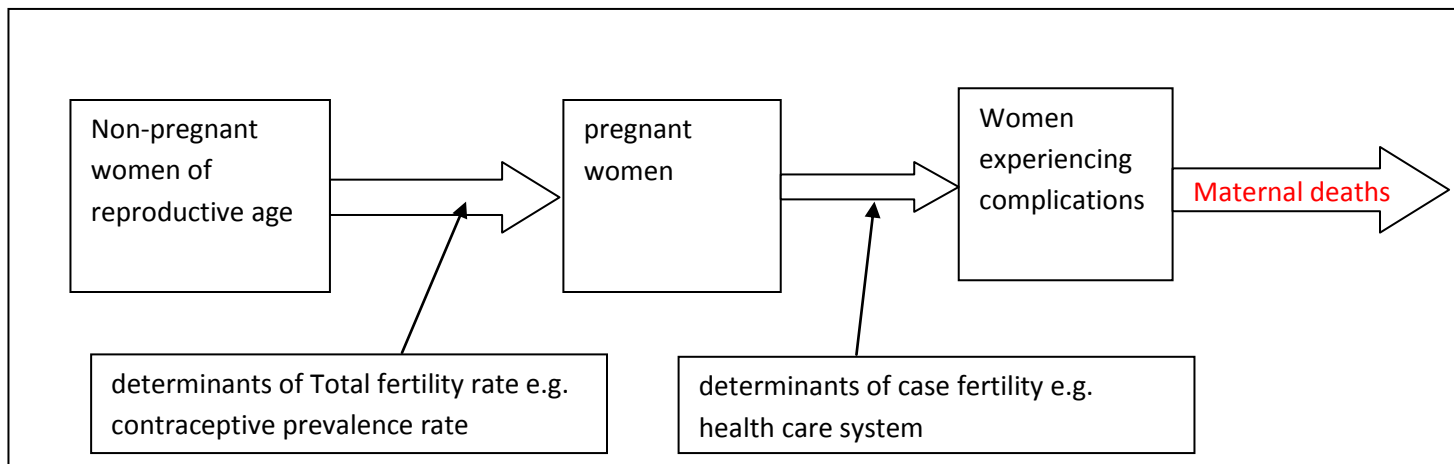


Figure1.1: Schema showing stages that produces maternal deaths according to Campbell and Wendy (1989)

1.3. A brief history about Maternal health care Globally.

A little look back into the history, literature shows that pregnancy and child birth experience were once as "risky" and "hazardous" for women in developed countries as it is today to most women in developing countries. Most countries in Europe and other high income countries , maternal death was just "a tip of iceberg" among other multitude of problems they had. But today's rates of maternal mortality shows a far greater disparity between "high income" and "low and middle income countries" as almost 98% of the maternal deaths worldwide

occur in LMICs compared to high income where it's almost less than 1% (WHO,1991, F. Donnay 2000).

While a woman in Chad for instance faces a one in 16 risk of succumbing to deaths due to pregnancy and child birth during her life time, her counterpart in Finland faces a risk more than 1000 times smaller (WHO,1990). Countries like Netherlands, Norway and Sweden, literature shows that these countries even experienced low mortality rates as early as 20th century. Research shows that to achieve this, it was not accidental rather it was deliberate via concerted effort .It is believed to have been an outcome of an extensive collaboration between highly competent physicians and locally available midwives, a robust antenatal and obstetric care of high quality that was engineered during 1930s and 1970s (Hogberg,2004,1986).

Strategies and circumstances that helped developed countries to achieve significant reductions may ironically help us to understand why big pockets of maternal deaths are still prevalent in most African Countries when the technology to avoid maternal deaths is well known. African countries are greatly represented among 10 countries with high maternal deaths when compared to most developed countries (Mpembeni ,et al, 2007). The real brunt of the problem is specifically felt mostly in sub-Saharan Africa. In countries like Nigeria, DRC and Ethiopia its estimated that 1 in 16 women are likely to die due to complications of pregnancy, abortion attempts and child birth every day. Besides majority women survive with debilitating disabilities like fistula, emotional and psychological effects etc (Rosen field, A, etal, 1985, Christopher ,S, etal ,2010). What is disheartening is that most of these fatal outcomes would have been avoided.

Such discrepancy in Maternal Mortality rates between developed and developing countries poses a very huge mountain to climb towards meeting both national and international goals. One good example of international goals is the

5th millennium development goal, a UN declaration that was signed at the turn of this century by 189 countries with call for the 75 % reduction in maternal mortality between 1990 and 2015 (Ronsmans et al, 2006). This call according to the WHO report 2003, led to a number of countries turning their attention towards revamping the capacity of their health care systems so as to provide timely and adequate health care services particularly reproductive services through;

(a) expansion of maternal and child health care services all in the context of PHC

(b) bridging the gap between the rich and the poor between countries via socio-economic, geographical tailored policies.

(c) provision of information on family planning and reproductive health services

(d) Increased focus on the management of high risk pregnancies.

(e) meeting nutritional needs of child bearing females.

The positive point to note is that there has been a noticeable progress or decline trend in maternal mortality ratios globally . However this global decline is solely reflected by the few countries that initially had few maternal mortality ratios. Countries that initially had high mortality ratios have virtually made no or little progress in reducing the ratios in the past 15 years.(WHO). All signatories to UN declaration committed themselves to reducing maternal mortality rate drastically by 2015 but few years down the road, a few countries have tried to fulfill this pledge and in others the progress is too slow especially countries in Sub-Saharan Africa where the ratios are still unacceptably high much as there is observed progress in the last 23 years since 1990. **Figure 1.2** below shows the disparities by region in terms of the number of maternal deaths.

¹Maternal deaths disparities by region

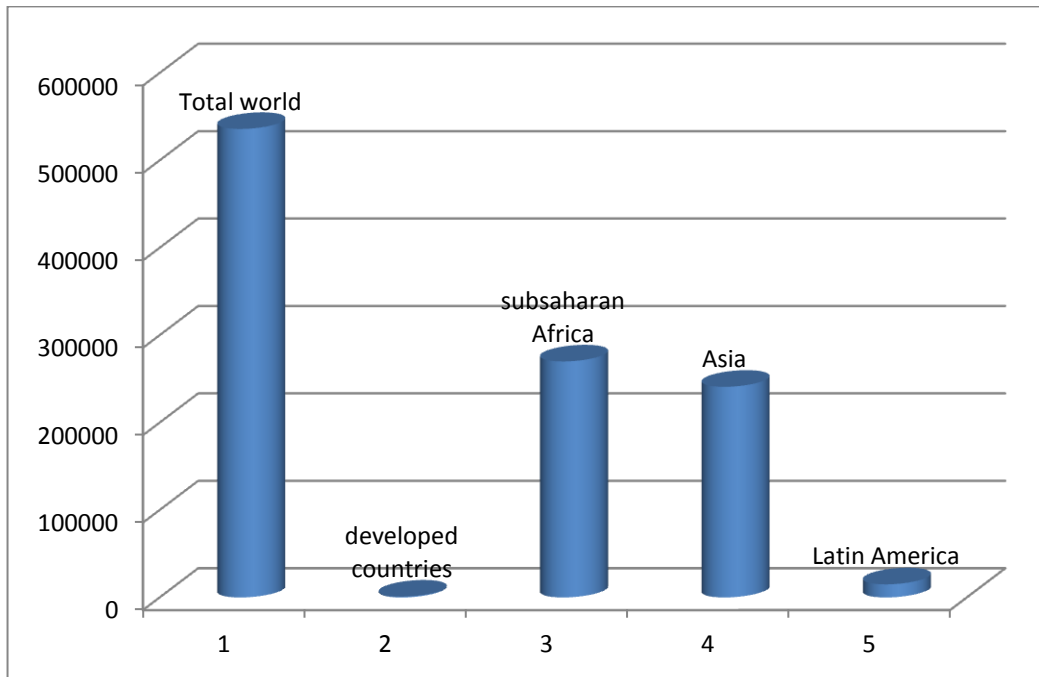


Figure1.2: Maternal mortality in 2005 (WHO,UNICEF,UNFPA and World bank)

One of the biggest policy initiative globally for maternal health came from United Nation's Millennium Declaration which created MDGs. The 5th goal of the United Nations' Millennium Development Goals (MDGs) initiative is to reduce the maternal mortality ratio by three quarters between 1990 and 2015¹. Various Countries and local governments have taken political steps towards reducing this public health problem.. http://en.wikipedia.org/wiki/Maternal_death

1.4. Maternal health care situation in Uganda

After improving community awareness to increase women seeking maternal services from a health facility, the number of pregnant women delivering at home in Uganda decreased from 56 % to 42% by 2011(UDHS 2011). Beaming with hope Uganda thought that it had gone an extra mile in reducing maternal deaths. On contrary however, today the situation seems to be more wanting than before as the decline is very slow and hopes of meeting 5th MDG by 2015 is almost an illusion. Like many sub Saharan African countries, in Uganda maternal mortality remains a burden to reckon with . Although literature shows a significant progress in the last two decades since 1990, Uganda demographic health survey 1995 and 2000 portrays a slight decline in Maternal mortality ratio from 600 in 1990 to about 348 deaths per 100,000 live births by 2010. This suggests that the incidence of the problem has been on the declining trend but still un acceptably high when compared to other countries both in developed and in fellow African countries mostly in sub-Saharan. In developed countries specifically in countries like Sweden, Netherland, Norway etc, MMR ranges between 5 to 25 deaths per 100,000 live births whereas in most sub- Saharan African countries MMR ranges between 640 to 418 deaths per 100,000 live births (MDG report for Uganda,2010, Hog berg ,1986, Carine,etal.,2006).

In the past all poor performance indicators in Uganda not only in the health sector but in other sectors including maternal mortality ratio have always been largely and justifiably blamed on the country's historical political instability especially in 1970s that was characterized by destruction of what would be called the "pillars" of economic growth and development. The destruction of health infrastructure, road infrastructure ,factories and a mass trek of health professionals to other countries etc all left the economy crippled (Kyomuhendo,2003)). But in the last two decades since 1990, Uganda at least has enjoyed a relatively peaceful

political environment that in reality should have enabled formulation of good policies and initiation of various measures to reduce maternal deaths at least to a lower ratios more than otherwise. Formulation of policies entails all measures undertaken by both the Government and NGOS to improve maternal health services in Uganda.

On contrary however, the study that was conducted in 97 health centers in the whole country including hospitals instead found out that hospital based maternal mortality ratio was estimated to be as high as 846 per 100,000 live births bigger than even national estimates that ranges from 600 to 556 deaths per 100,000 live births which depicts a different picture from how the situation should have been (Mbonye, K, 2001, Christopher S,atal,2011, UDHS 2005/6). This translates to about 6000 women in Uganda losing their lives in the course of *bringing new life in this world every year*.

Most important to note is that these figures of MMR computed by both national and international agencies like WHO, UNFPA, world data bank and national institutions in Uganda like UBOS and periodic surveys like Uganda demographic survey are based on "institutional delivery "and yet due to low urbanization, vast majority of Ugandan women live in rural areas and therefore rarely do they deliver in health facilities. This portrays that computed figures based on institutional delivery masks a big chunk of maternal deaths that happens every day un registered meaning that maternal mortality problem in Uganda is actually much bigger than what is thought to be (Kyomuhendo, 2003)

The thesis's sole purpose therefore is to understand using *system dynamics approach* why despite the peaceful political environment since 1990 that has enabled formulation of good policies and initiation of various measures both by the Government and its partners in the last two decades , women in Uganda still finds

it *extremely very risky* to conceive and deliver a baby . The findings have policy implications that requires *re-thinking* and *re-designing* in the ways of how public health problems are approached to in Uganda particularly maternal mortality problem because it is a social and personal tragedy that can be avoided.

1.5. Major Causes of Maternal deaths in Uganda.

Causes of maternal are many layered(Wendy and graham (1989). WHO (1991) recognizes that universally all causes of maternal deaths are categorized into three forms; *direct causes*(pathogenic causes), *indirect and non-medical causes*. *Direct causes* are causes that directly contributes to maternal deaths . They include; hemorrhage, puerperal sepsis, obstructed labor, Hypertensive disorders and abortion and they account to more than 80% of maternal deaths in the whole worldwide(F.Donnay,2000). *Indirect causes* are mainly due to conditions that in association with pregnancy precipitate the fatal endpoint and these includes AIDS, malaria etc and these are most common in Uganda. Last category is known as *Non-medical causes* and this may be in form of both social, economic, political and accidental causes that aggravates pregnancy for instance accident by car.

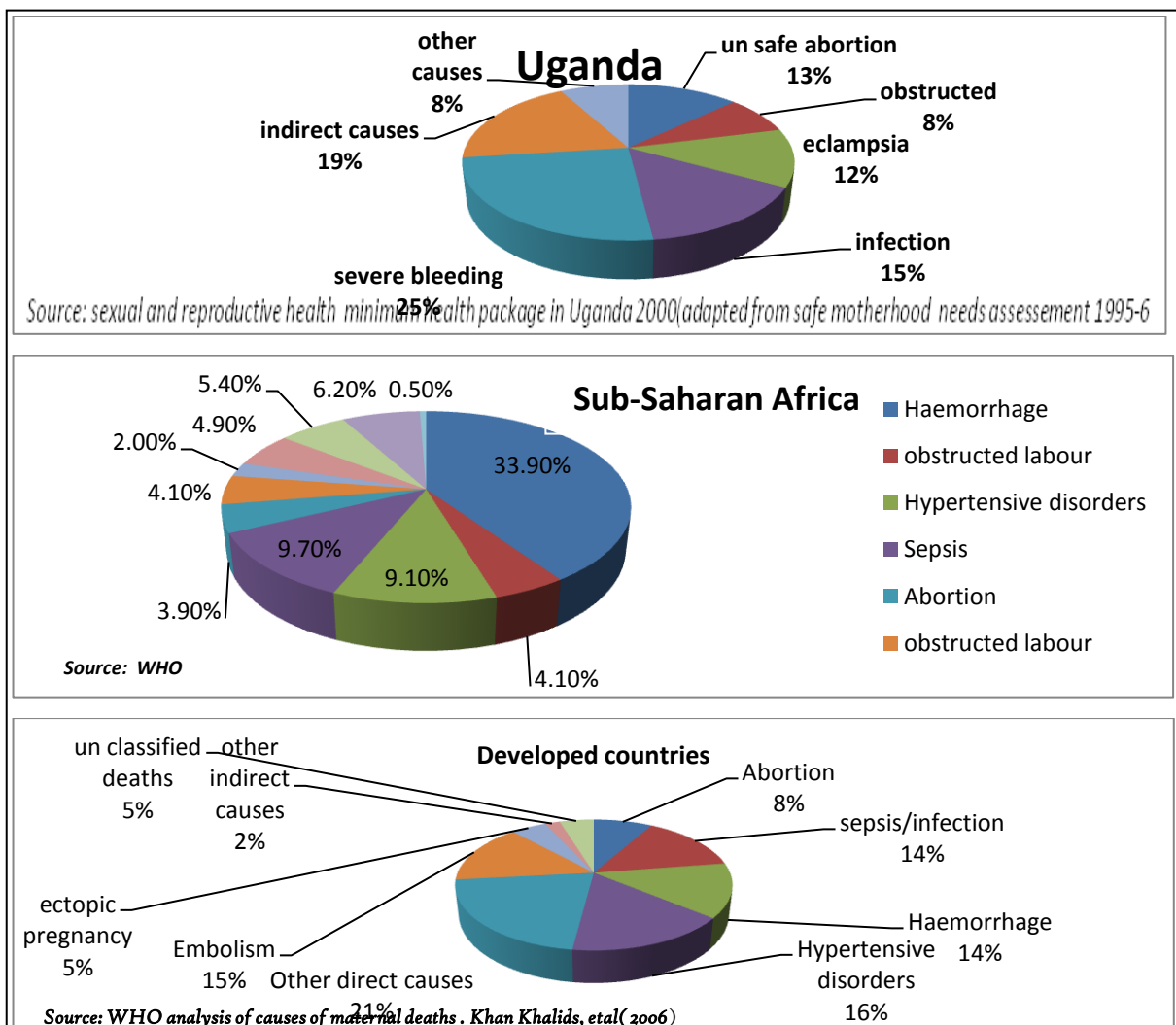
What then kills most pregnant women while giving birth in Uganda?.

Figure 1.2 . below identifies major causes of maternal deaths in Uganda compared to fellow sub -Saharan African and developed countries. *Severe bleeding*(both intra and in postpartum period) appears to be the largest contributor of maternal deaths across all countries in the whole world including Uganda (Carine Ronsmans and Wendy Graham(2006).

In Uganda research shows indirect causes as second major contributor that aggravates pregnancy complications into maternal deaths especially AIDS and malaria among pregnant women. Malaria accounts for 87.4 % out of the total indirect causes of maternal deaths(Mbonye, etal (2006). AIDS too continues to be

a major public health problem although the incidence is declining. According to one study, 26.5% of pregnant women in Uganda are assumed to be transmitting the infection to their new born babies. (Ssengooba,F,etal,2003).

Just like it is in most developing countries, in Uganda too the situation is not without efforts to deal with such causes, but lack of readily, reliable data to be able to make *evidence based decisions* continues to curtail all efforts to deal with reproductive challenges in general. The fragmented nature of data ought to be amalgamated ,revised and stored for future planning.



Figure(1.3): Shows maternal deaths causes comparison between Uganda, sub-Saharan Africa and developed countries'

In all Countries there are pockets of maternal deaths . This is partly

because as a fact all women by nature face some level or degree of *maternal risk* because complications that culminates into maternal deaths knows no social status. They can neither be predicted nor prevented because they are sudden in nature. *Pregnancy complications can only be managed to prevent fateful outcomes in case normal delivery ceases to happen.* However this degree of risk varies from one country to another due to differences in the levels of social-economic development between countries . In **Figures 1.3** , we can vividly observe that most life-threatening complications both in Uganda, sub- Saharan African and developed countries occur during and shortly after birth. This implies therefore that targeting *intrapartum care* via timely recognition , prompt treatment and good management can *substantially* minimize or reduce maternal deaths in any country despite economic levels. (Campbell and Wendy, 2006).

1.6. Policy environment on maternal health system in Uganda.

Since two decades ago, there have been various government policy interventions aimed at tackling the dynamic problematic behavior specifically by improving the quality of and access to maternal services in Uganda. Some of these policies have had impact, others little and others the impact is yet to be noticed. They include the following;

The operationalization of emergence obstetric care(EMOC) services at HC,II,IV and hospitals via HSD strategy .This operationalization was provided for in the national health policy1of 2000-2009.((Annual health sector performance report 2010,). The ultimate aim of this policy was to get essential services nearer to the people. It basically focused at ensuring basic and comprehensive EMOC services via infrastructure development for instance appropriate infrastructure for obstetric surgical procedures, equipment and supplies including drugs and blood,

providing transport options in form of ambulances to each health center (III) ,etc.(Uganda MDG report 2010). This has led to an increase in the ambulance services especially in the rural areas although there are still various hiccups facing the transportation process for instance asking for bribes from patients before usage.

Government of Uganda recognized that having skilled attendance at birth is among key pillars of reducing maternal mortality ratio and thus made it apriority in the reproductive and health strategic plan (iii) and road map(2005-2007). The government's health sector strategic plan (III) foresees an increase in the percentage of deliveries by skilled attendants from 44% to around 60% by 2015. One ways of realizing it is via recruiting more health workers to expand the capacity of health centers at all levels(v,iv,iii,ii). However this is still a challenge because the capacity is still far below the average when compared to the population increase per year for instance the patient per bed ratio is still low estimated to be 1:10 (Uganda MDGreport,2010).

At service level, efforts have been made to encourage access to health care services including maternal services via elimination of cost sharing(user fees) at public facilities in 2001. This resulted into creation of a two-window(paying and non-paying system) at a hospital level . Research shows that as a result of this number of women using maternal services increased and usage of ambulatory services also rose up despite various challenges like physical or terrain inaccessibility, attitudes of women towards formal health services especially those living in rural areas (F, Ssenooba,etal., 2003 , Kyomuhendo, 2003).

Government did complete the national development plan(2010-2014), national health policy11(2010-2019) and health sector strategic plan III(2010-2014) with main emphasis being shifted from specific programs to strengthening the organization and management of the national health systems, including referral.(Uganda MDG report2010). In spite of these policies, maternal deaths

remains obstinate in Uganda a factor that requires thorough investigation to unearth the root cause of the dynamic problem.

1.7. A precise outline of this thesis

It is vital to recall that our thesis is arranged into eight chapters. Chapter *one* provides us with the historical background about maternal deaths both globally and locally in Uganda, conceptualization of maternal deaths and measures that have been undertaken to reduce maternal mortality ratio(policy environment) .

The ultimate motive of chapter *two* is to describe and assess literature on prior approaches that have been used to study maternal health care challenges. The *third* chapter presents us with system dynamics approach with its principles and why system dynamics is an applicable and a suitable method to study this complex issue of maternal deaths. Chapter *four* introduces us to the model i.e. explanatory model while chapter *five, six, and seven* covers model validation processes ,policy testing and analysis and policy implementation for future development. The document concludes with limitations of the model, major contributions and findings , suggestions for future research, appendix and references.

2. LITERATURE REVIEW.

This chapter reviews literature on the approaches that have been previously used to study the dynamic problematic behavior(maternal deaths). Our thesis understood that most approaches previously employed *are statistical and qualitative* in nature. The ultimate aim of these approaches was to provide insights and deeper understanding into maternal health care challenges in various countries. They even proceed to propose interventions aimed at improving

maternal health care systems in such countries. Some of the studies undertaken relevant to our study are further discussed below;

Hill, Kenneth, et al (2007) employed and used a range of methods depending on the available data to come up with a comparable country, regional and global estimates of maternal mortality ratios of 2005 and to assess data trends between 1990 and 2005. The study involved usage of different analytical strategies to enhance comparability a cross countries and time due to different sources of data. Some of the approaches used included but not least "random" effects time series regression model". Advantages of using this model was that it related the outcome variable to the reference date of the estimate. The study revealed that in the context of MDG 5, progress is very slow. The great concern out of this study was that whereas most countries have shown progress in maternal deaths reduction since 1990, maternal mortality ratio has remained very high in sub-Saharan Africa with little or no evidence towards improvement in fifteen years. To meet the MDG 5 target, the study suggested huge investment and much emphasis on the improved pregnancy and delivery throughout developing countries.

Christopher Sooka, et al (2010) used system dynamics approach to study and capture the complex and dynamic nature of maternal health care in Uganda with the ultimate aim of understanding the problems towards improved decision making. The study involved development of *a research design frame work* based on Dynamic synthesis Methodology (DSM) that included six stages i.e. problem statement, field studies, case study, model building, simulation and analysis. It also involved usage of system dynamic's tools like *CLD* (causal loop diagram) to explain the complex nature of health care system in Uganda. However the study focused solely on the "qualitative aspect" of system dynamics approach, there was no development of quantitative simulation model to be used to run simulations and test different policy options. The study just provided understanding of the complex

nature of maternal health care system in Uganda using causal loop diagram. It identified key issues to be behind the reason as to why maternal deaths are still high in Uganda and these issues identified include; a growing population that puts pressure on the scarce resources, poor infrastructure, affordability factor by mothers to maternal services level of awareness etc. The study recommended collection of vital data for improved decision making in future and also development of quantitative simulation model for further research.

Another study was also undertaken to review maternity services in Australia. The study involved collection of data from post natal mothers . The data then was analyzed using logistical regression model. The study discovered that there is a strong relationship between intrapartum care and the following factors; high importance of obstetric initiatives, insufficient information, women being under looked in matters of the family and the perception of pregnant mothers on institutional delivery especially health attendants.(Brown, etal 2000).

Relevant to most developing countries where different sources of data and methods of deriving estimates of maternal mortality are often insufficient and inappropriate, Graham ,etal (1989) used what is known as "*sisterhood method*" an indirect technique to estimate maternal mortality based on population. The techniques used *a proportion of adult sisters* who die during pregnancy, child birth or during postpartum period reported by individuals who are adults during either in a survey or population census to ascertain a number of various maternal mortality indicators. The method involved asking questions like "*how many sisters have you ever had who were ever married* "?, *how many of these ever married sisters are alive now? etc.* The ultimate aim was to obtain data from respondents to be able to estimate various indicators of maternal deaths. This technique was first used in Gambia and west Africa in 1987. The outcomes of the study portrayed *a lifetime risk* of a pregnant woman living in those countries of 0.0584 or 1in 17

approximating to a maternal mortality ratio of 1005 per 100,000 live births.

Brace,etal (2004) used *prospective observational study* to quantify severe maternal morbidity in Scotland. The study involved developing various categories of severe maternal morbidity from the already published work. Recruitment and training of staff of maternity units took place at national meeting and each month every unit was expected to report cases fulfilling the agreed upon definitions, the category of incident and date. Data was later analyzed to determine the frequency of incidents. The outcomes from the study showed that obstetric hemorrhage accounted for 50% of the events. Lesson learnt from the study was that it's very possible to quantify cases of maternal morbidity to provide useful measures of the quality of maternal services especially in developed countries where maternal mortality is gradually dwindling to almost zero. This can be done by setting up *a national reporting system* for maternal morbidity as well as mortality.

Summary

In this chapter we have reviewed literature portraying different approaches that have been used to study maternal deaths and morbidity dynamics. There are different approaches that have been used which include *statistical ,analytical, observational methods , regression modeling* and *system dynamics approaches*. Each of these methods used have merits and demerits associated with each as analyzed further below;

The *sisterhood method* enables researchers to estimate and derive different indicators of maternal deaths.

Christopher Sooka, etal (2010) used system dynamics approach was to study maternal health care dynamics in Uganda which included usage of qualitative system dynamics tools like causal loop diagrams. The study provided insightful results and deeper understanding into complex nature of maternal health

care dynamics in Uganda.

However the two methods used entailed weaknesses most importantly the inability to provide the "physics" or "the operational structure" of the system that produces that undesirable behavior. The two methods do not avail to us a platform for testing different policy options for improved future decision making. Justification for such two weaknesses are observed in Christopher Sooka, etal (2010) 's study where system dynamics approach was used. A *quantitative simulation model* was not developed instead, the study was purely qualitative in nature. By its nature, it was totally impossible to test different policy options for policy analysis and development to ascertain the best policy option. Besides most of the research done , has been done on developed countries where maternal mortality accounts to almost 1% out of the total deaths of women in reproductive age compared to developing countries where maternal deaths contributes to more than 75% out of the total deaths of female between 15 to 49.

Its upon this background that this thesis focuses on the maternal deaths in Uganda one of the countries in sub-Saharan Africa where maternal deaths is still unacceptably high. The ultimate goal of this thesis is to provide insights into the maternal health care system challenges particularly why maternal deaths have remained obstinate in Uganda . The study is expected to help health managers and policy makers to enhance decision making process and formulate relevant maternal health care policies from an informed point of view. *An act of delivery by a mother should be a moment of joy not sadness because maternal deaths happens when it would have been otherwise avoided (One of the respondents in Hoima district.....)*

Data used to estimate different variables in the model have been obtained from multiple sources for instance; world bank data, UBOS website, UN websites

and different research reports. Most of these data are simply estimates as maternal death is one *problem* whose data is hard to come by due to miss -representations and under-reporting of the exact causes of death of a woman especially in developing countries. The purpose of the model is to provide an explanation of why maternal deaths have remained high since 1990 and what can be done to change the course of the behavior in future. While reading the results from this model, one ought to recall and appreciate the estimations and assumptions used in this model due to data flaws.

In the next chapter, we are going to present *the research method* used in this thesis and why we believe it best suits or it is worth to be used to study this dynamic problem of maternal deaths in Uganda.

3. RESEARCH METHOD.

In this study the problem of emphasis is maternal mortality ratio in Uganda. The research question to answer is "*why Maternal deaths have remained high despite various interventions undertaken both by government and its partners. and what can be done to change the course of the dynamic behavior in future.*" The approach used in this thesis is "*system dynamics approach*" where we develop an *explanatory model* and *policy model*. In this thesis we develop an explanatory model to identify the historical systemic reasons for a pattern of behavior widely viewed as a serious issue and the *policy model goal* is to explore and evaluate ways to alleviate a dynamic problem by re-designing the explanatory model.(Wheat ,2013).

This study uses system dynamic approach with an ultimate aim to capture the complex and dynamic nature of maternal health challenges in Uganda . It intends to promote deeper understanding into the genesis of the dynamic problem

of maternal deaths towards improving decision making.(Sooka,etal 2011, Ford 2010,p-3). As Forrester states it it's only after one has clearly understood what is causing the problem that he or she will see where to focus his attention which is the main focus of this thesis. (wheat 2013)

The explanatory model will cover the historical period of a decade that is from 1990 to 2010 and will project up to 2035 . The reason why the historical period was chosen to start from 1990 not below is that it is with in that period that's when political stability returned to Uganda after a mass political strife that befell on the country for almost five years since 1980 that brought the current NRM government into power in 1986. The first five years from 1986 were the years of recovery from the ruins of war.

We chose SD as research method because we found it to be so unique in terms of its tools. We thought it will help us to understand better the problem in question. If human brains had the capacity to see through, internalize and understand problems with in systems, then the world would be a paradise. To the contrary however human brains have got a lot of flaws that cannot enable a human being manage systems especially systems of *non-linearity nature* without help of tools. Sterman states that human brains lacks the capacity to intuitively capture and solve complex problems.(Sterman 2000 p-39). System dynamics is that powerful approach that uses potent tools good at enabling researchers analyze *dynamic problems*. This is basically why this thesis uses "system dynamics" as a research method to provide insights into the dynamics of maternal deaths by developing an explanatory model specifically to help us understand why it has consistently remained a social and personal tragedy in Uganda with an estimation of 1 woman dying in every 10 women every day(Christopher S,etal 2010). Such dynamic problem requires a method that will help us "*dig out*" existential realities explaining the magnitude of the problem .

In addition, the *policy model* will answer the questions of "*what can be done to alleviate that problem*". This will be done as we try to explore different policy options i.e. testing different policy simulations to ascertain which policy option works better or not .

To reiterate this, the model is not to intended to predict the future of Uganda in terms of maternal deaths which is a fundamental error that most researchers make according to Ford but rather the ultimate goal of this study is to help us understand the behavior pattern in question better and seek the solution of the problem. (Ford,2010 p-9).

The rest of this chapter goes on by introducing to us system dynamic principles and why it is a suitable and applicable approach to be used to study the dynamic problematic behavior.

3.1. Why system dynamics is an applicable and suitable method to study maternal deaths in Uganda.

System dynamics methodology presents a unique and better approach towards tackling particular problems especially problems of dynamic nature. Its uniqueness is portrayed in the following ways.

It provides tools that enhances deeper understanding of the gist of the problem. The methodological tools digs out the "structure" of the problem being studied at hand for instance usage of "stocks and flows " creates a fertile ground for a researcher ,policymaker or health manager to understand the root cause of the problem and where to re-adjust to change the course of the problem. Christopher, s,etal, (2011) for instance explains how System dynamics have been previously used by innovative researchers to study some of the toughest problems that are intractable to be understood by health managers using *conventional epidemiological methods*. A good example to justify this is Leeza Osipenko and Leon Bazel 1990 model that used system dynamics methodology to answer

questions of whether ELI-P bio chemical technology could be cost effective to be implemented in US for population-wide prenatal care screening. Simulation results clearly pointed out benefits of implementing ELI-P innovative technology. Findings were that costs of screening per year were significantly lower than the savings that comes from birth defects and pregnancy pathology results if prevented. Such study clearly demonstrates that system dynamics is the best approach to use to propose cost effective policies or discard costly policies that otherwise would have been hard to come by using *conventional approaches*.

Problems of dynamic nature require dynamic approaches. Maternal deaths as a concept is dynamic in nature meaning that it changes over time. It can increase or decrease. This requires us to use a method that will provide with us with tools good at analyzing a behavior pattern over time and SD(System dynamics) provides us with such tools for example time series graph.

In most cases by mere of eyes it is very difficult to single out one factor that justifies the causes of a particular problem in a systemic environment. Problems of Systemic nature requires systemic thinking which is the basic principle of system dynamics (Barlas,1994) . Therefore it's very difficult to ascertain the real cause of maternal deaths in Uganda unless " maternal health care" is studied or approached to as a system (as *whole*) . A system is a set of interrelated aspects all functioning as whole . Approaching this problem with this mental image will help us locate where *the root cause of the problem is* and *what can be done* to change the course of the behavior. This is possible when SD approach is used. They say "*in order to get away with dangerous red ants , it's always better to locate where the anthill is (their inhabitant), remove it in order to sustainably destroy their regular attacks*."

Using this *dimension of system thinking*, the thesis will be beneficial not only to health managers, academicians but also to policy makers in understanding

complexities involved in maternal health care for better decisions in Uganda in the following ways;

(1) System dynamics will help us to identify data flaws and gaps that if rectified can go a long way to facilitate development planning in Uganda.

(2) The approach's capacity to enable a researcher or policymaker experiment different policy scenarios(options) in order to identify the best scenario that works better if implemented makes SD interesting. This answers the questions of "*why some policies don't yield their intended outcomes?*". This could be probably because the policy option wasn't or weren't the best option/options at hand or it or they would have worked better if it was or were combined with other policy options. This can only be experimented using system dynamics approach.

3.2. Tools of system dynamics methodology

In this chapter we unveil tools used in system dynamics and a sample of how they are applied in real life situations just for understanding purposes.

Causal loop diagram.

Commonly abbreviated as CLD, causal loop diagrams are useful tools for simplifying the presentation of a complex system dynamics model. Sterman (2000, p-137-138) defines CLD as variables connected by arrows denoting the causal influences among variables. Sterman demonstrates that CLD are important tools for representing *the feedback structure* of systems. However much according to Ford (2010,p-110) that CLD are not always needed if the stock and flow diagram communicate the same thing, Sally Brailsford and Nicola Hilton(2001,p-2) believes that during initial stages *CLD* are vital tools in identifying elements deemed fundamental to generate the behavior of the problem being studied. A researcher identifies elements that are behind a particular problem and presents them in form of *influence diagram* as further illustrated by

this example of *population dynamics* in **Figure 3.1**.

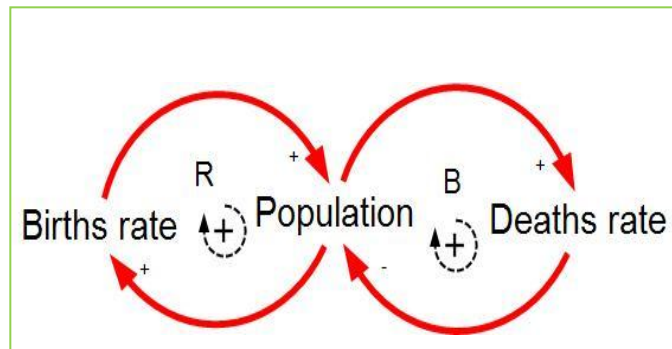


Figure 3.1. Causal loop diagram demonstrating population Dynamics.

In **figure 3.1**, the identified elements are connected by arrows with signs + and - . Such signs denotes the *causal influence* or direction of how variables affect each other but do not show how big or small the effect is. One of the ultimate goals of CLD is to identify loops where variables are connected by a cycle of arrows with positive and negative signs.(Sterman 2000,pg-142). *Balancing loop* or *counteracting loop* contain -(negative) signs that are odd numbers while *reinforcing loop* entails -(negative) signs that are even numbers.

The example demonstrated in **Figure 3.1** entails both a *balancing or counteracting loop* and a *reinforcing loop*. **Loop B** is a balancing loop because it contains an odd number of negative signs. It demonstrates how a system regulates itself to stay in balance . In the example given in **Figure 3.1**, "*the more the population increase the more the death rate and vice-versa*". **Loop R** is a reinforcing loop because it does not contain odd signs at all. Such loop denotes how a system may expand or double or triple itself . If we use an example in **Figure 3.1**, "*the more the birth rate , the more population and the more population, the more the birth rate*".

Since CLD diagrams aid in visualizing the system structure, to perform a more detailed quantitative study *its always* very prudent to transform CLD into "*a stock and flow diagram*". This is partly because stocks and flows captures the *accumulation effect*, decisions and provides platform for *experimenting different*

policy options via different simulation scenarios(Sterman 2000).

Stock and Flow diagrams

Stocks and flows forms one of the important core tools of the system dynamics. Sterman (2000,p-192) defines stocks as accumulations and flows as pipes categorizing them inflows and outflows. An *outflow* as a pipe taking out and an *inflow* as a pipe adding into. Pipes add into or takes out at a particular time a reason why they are defined as *rates* e.g. *a rate at which he drinks alcohol is too much!!!* a phrase that denotes time element in it . According to Sterman(2000) stocks act as a basis upon which decisions and actions are based because they generate information. If we consider the example above, we can define *Population* as a stock , *Birth rate and Deaths rate* as pipes(rates) as shown further in **Figure 3.2**.

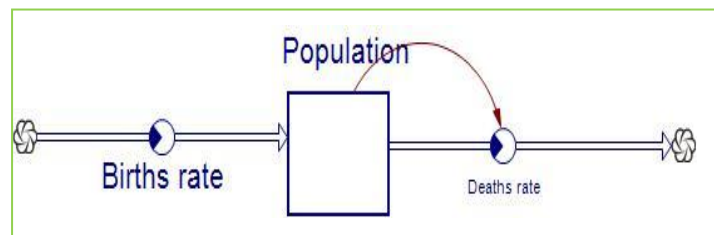


Figure 3.2: Stocks and flows diagram illustrating the example

Figure 3.2 above clearly portrays "*the physics*" or "*structure*" of the problem and with that nature of diagram , it easy to know *where, why* and *how* to tackle the problem at hand. One can decide either to increase the inflow (birth rate) or decrease the outflow (death rate) because one of the System dynamic principles is that we tackle a particular problem by changing the stocks that defines the problem and since we cannot change the stocks directly, we have to regulate the flows(taps) via valves that increases the stocks (problem) or decreases it (Wheat,2013). Using computer software like *I think* or *vensim*, one can place in numerical values inside stocks and variables, form equations and then simulate to

be able to study and analyze the pattern behavior over time using *time series graph*.

4. MODEL BUILDING

In the previous sections, we have demonstrated what inspired us to study maternal mortality ratio as the topic of this thesis, analyzing literature to help us justify the need to identify the flaws in the methods previously employed to study the problematic dynamic behavior and why system dynamic approach is best applicable and suitable method to study the dynamic problematic behavior (maternal deaths). This chapter then will help us apply system dynamics tools to provide further insights into the problem. We will think *operationally* by using system dynamics tools like stocks and flows, CLD, time series graph etc to understand the dynamic problematic behavior. We will first present key variables of interest and why?, the reference mode, time horizon chosen and then after we will proceed with the basic model structure and feedback loops that will help us gain deeper understanding into the complexities of maternal deaths. Model building process will continue until the explanatory model is able to replicate the historical problematic behavior that ought to be altered for better future. If the model replicates the historical problematic behavior, the structure will be *re-designed* to change the course of the problematic dynamic behavior. The new structure that will be formed after re-designing the structure will be known as *policy model*. Final details will be added in the last chapters.

4.1. Key variables of interest and Why?.

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), die due either reasons related to pregnancy complications and death aggravated by pregnancy or death due to any other reason. This thesis solely focuses on the

deaths due to pregnancy related complications. The thesis tries to study *why maternal deaths is still the main cause of deaths of women aged between 15 to 49 in Uganda* . The main concern inspiring the study is "*why child bearing is and continue to be extremely risky in Uganda despite various interventions that have been undertaken*. By reality, child bearing should not be a moment of sadness but rather it should be a moment of joy and happiness when new life is brought into this world! . A moment of joy when a child is born can only prevail if effective interventions to make pregnancy safer are undertaken tailored on peculiar issues in Uganda.

4.2. Time Horizon

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 (Ford ,2010 pg-139) . The time horizon used in this thesis is 36 years (1990-2026). In our study, we decided to extend as far back as 1990 because that was the period with in which stability relatively prevailed after several years of unrest in Uganda that led to the new NRM government into power in 1986. The first five years from 1986 up to 1990 were years of recovery from the ruins of the war so there was no significant achievements in several economic and health indicators by then . And choice of 2026 is reasonably enough to capture the effects of potential policies designed to lower maternal mortality ratios further down.

4.3. Reference Mode.

Having a reference Mode is the best way of being specific about the dynamic problem. Drawing a reference mode helps because it makes the goal of the study very clear (Ford ,2010 pg 140). **Figure 4.1** therefore portrays a dynamic problematic pattern over time of Ugandan MMR for the period of 20 years that

needs to be understood and controlled. It shows the trend of the dynamic problem over time i.e. over the last 20 years, Uganda's MMR declined from around 600 per 100,000livebirths in 1990 to 310 deaths per 100,000livebirths by 2010. This clearly shows that Uganda's MMR has been on a declining trend but at a slow rate an aspect of urgency to be understood why in order to further lower the ratios down as portrayed in **Figure 4.1**.

Maternal mortality ratio reference mode for Uganda

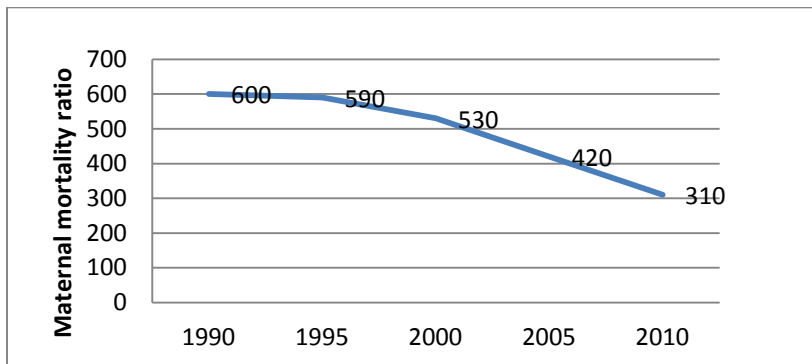


Figure 4.1: Uganda's MMR estimates based on the world bank data ,WHO,UNFPA and UNDS

Figure 4.1 shows that the ratios have been on a down ward trend decline but still unacceptably high when compared to other countries. These mortality ratios translates into about 6000 women dying every year in Uganda due to pregnancy related causes(UDHS 2005/2006). Besides these estimates are based on institutional delivery yet majority of Ugandan women do not deliver in a hospital facility implying that both national and international data estimates in reality masks a big chunk of maternal deaths that happen un registered (Kyomuhendo,2003). This suggests that the problem is actually bigger than what is thought to be. A woman losing her life in most developing countries is a social and personal tragedy because women perform pivotal roles vital for the existence of most communities in Africa . Roles include productive, reproductive and community roles. (Rosenfield, A, etal, 1985).

Using the same time horizon of 20 years in this study, we tried to compare MMR of Uganda with both developed and developing countries portrayed in **Figure 4.2**. In the study we chose Ethiopia because its among the countries in sub-Saharan Africa, Bangladesh(Asia) and Sweden because of its tremendous success registered in lowering the ratios down. Indeed in our study we noticed a very huge difference between these countries. In Sweden the ratios are in *tens* while in Uganda, Ethiopia and Bangladesh the ratios are in *hundreds* deaths *per 100,000 live births*. This shows how *more risky* it's for a woman in Ethiopia, Uganda and Bangladesh to conceive a baby compared to the same woman in Sweden .

Comparing Maternal mortality ratios between Sweden , Uganda, Ethiopia and Bangladesh

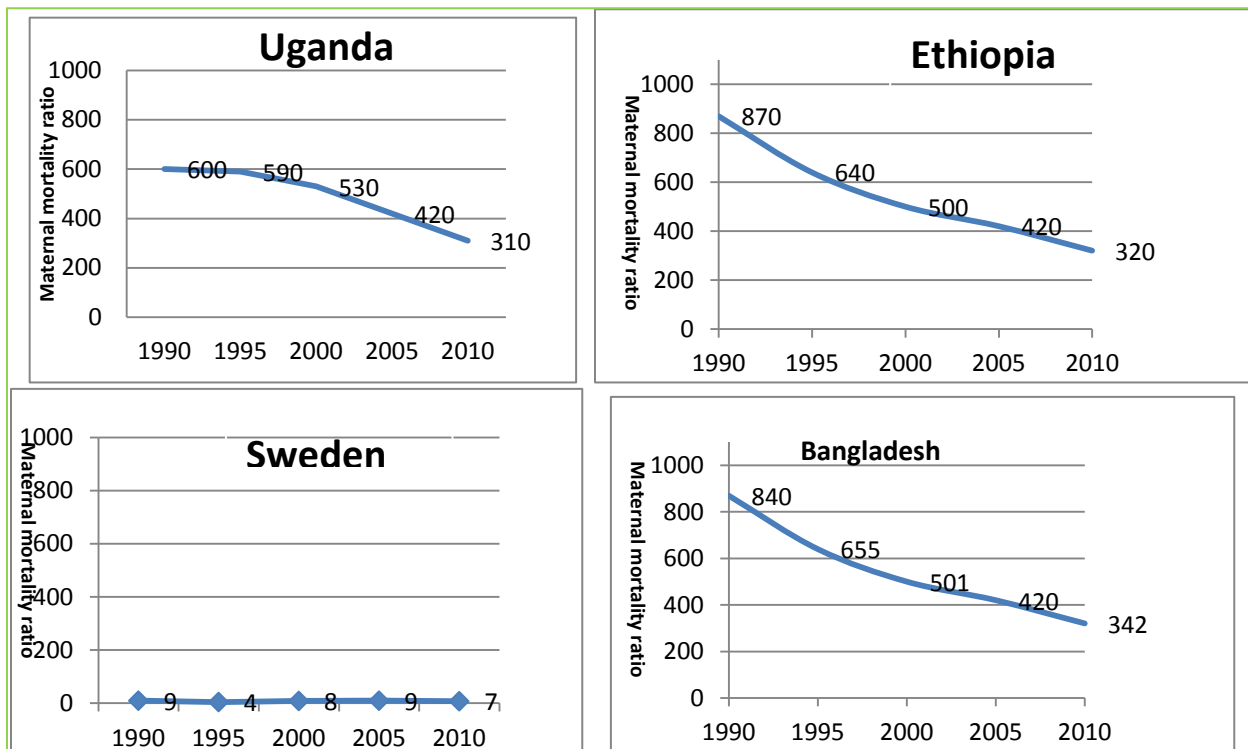


Figure 4.2: Uganda, Ethiopia, Bangladesh, Sweden's maternal mortality ratio estimates based on world bank data,

We asked a self question of how Sweden managed to reduce maternal drastically in 19th century by that margin. Research shows that successful

maternity care intervention based *on equity and professionalization of midwives* was responsible for the massive decline in maternal deaths in Sweden from "*thousands*" deaths per 100,000 live births to around "*tens*" deaths per 100,000 live births (Hog berg, U.1986). This implies that maternal deaths can drastically be reduced if strategic interventions are made. This serves as a big lesson to Uganda that maternal deaths can substantially be reduced if existential realities justifying the magnitude of the problem are understood and policies tailored to such realities designed.

4.4. Dynamic Hypothesis.

In order to come up with a solution of the dynamic problem and to understand the behavior shown in (**Figure 4.1**), it is vital to understand the underlying structure that brings about the problem. In this section, we present a tentative theory in form of "a structure" responsible for producing that dynamic problem.

The study understood that causes of maternal deaths are as complex as a process that culminates into maternal death itself and its solutions. Reducing maternal deaths has no single formula because its causes are complex and very hard to discern. Much as its causes are hard to identify, experience shows that the risk of a woman dying due to pregnancy related complications stems from *poor quality maternity care* particularly lack of access to life saving treatment and management of complications for high risk women and those in emergency situations (WHO, 1991). Most maternal deaths are preventable if there is *timely and effective management of complications* because research shows that most maternal deaths occur during and shortly after intrapartum period (Rosenfield, A, & Maine, D (1985)). Unfortunately Uganda like many other countries in sub-Saharan Africa falls short of the described conditions to prevent maternal deaths.

According to our study , we hypothesize that maternal mortality ratios are still high in Uganda due to *inadequate Effectiveness of MHS* to deliver maternal services to mothers. Effectiveness is synonymous with "**delivering desired outcomes**". *Effectiveness of MHS* according to our hypothesis depends on the *capacity of health units to provide EMOC services*, and *the presence of enough, skilled and motivated midwives in those health units to execute the roles*.

The model postulates 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 4.3** 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 4.3**. This is partly due to *high fertility rate in Uganda* that stands at around 6.9 births per woman.(Sooka,etal ,2011).

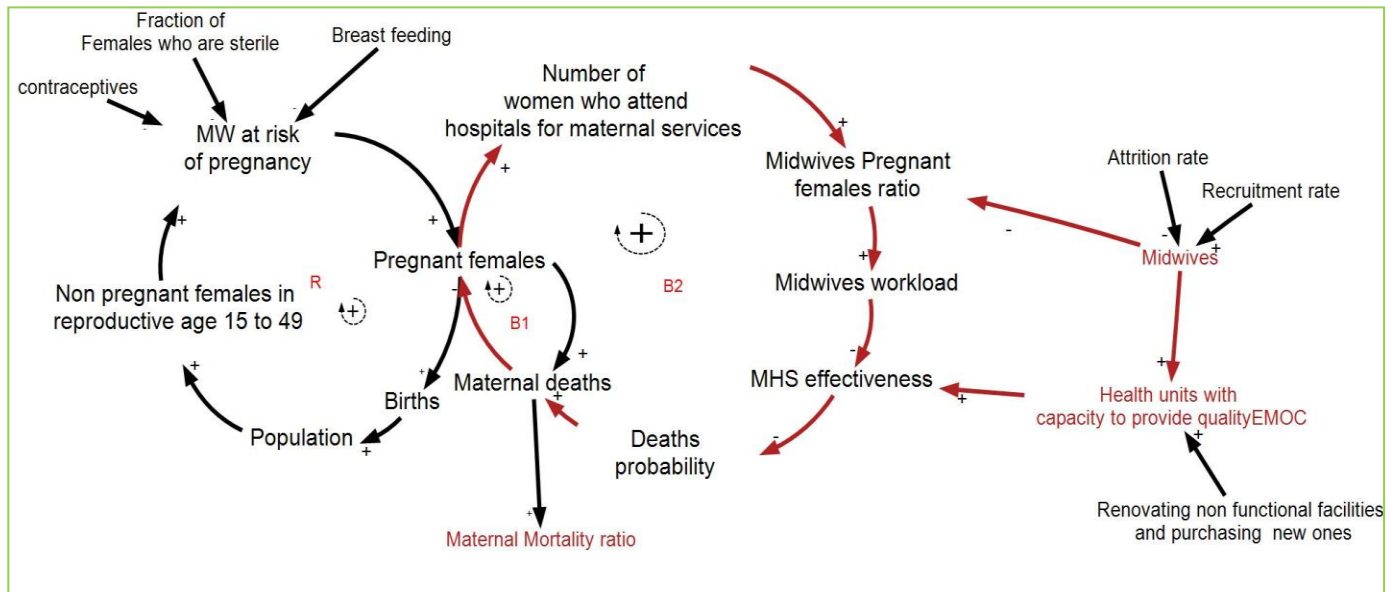


Figure 4.3: Basic CLD showing loops that constitutes the dynamic problem.

According to our model **death probability** reduces if **MHS effectiveness** 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. *Effectiveness* is determined by the **capacity of health units** to deliver maternal services . By capacity we imply good infrastructure, equipment, adequate drugs and enough workforce (midwives) to "*effectively*" deliver maternal services to pregnant mothers. But on contrary the situation is still more wanting in Uganda. According to EMOC assessment report 2003 and Mbonye,etal's study in 2001, 97.2% of health facilities expected to offer EMOC services were not doing so. Most health units particularly health centers II,III, and IV have no capacity to deliver both basic and comprehensive maternity services because they lack basic utilities like running water, electricity supply, piece meal nature of supply of drugs and equipment ,little or no supply of blood ,few health workers(midwives) and dilapidated maternity wards (Mbonye,etal,2007 and 2001).

CLD in **Figure 4.3** therefore briefly illustrates dynamic intricate and complex relationships associated with what the *situation ought to be* and *what its*

(the gap) in terms of maternal service delivery. The diagram simplifies the tentative theory of a dynamic negative relationships between chances of a woman dying in Uganda (*death probability*) and the *effectiveness of MHS in Uganda to deter such fatal outcome from happening*. The CLD shows **one reinforcing loop (R1)** and **two counteracting loop(B1 and B2)**.

Loop R (reinforcing loop) Figure 4.3, posits that an increase in pregnant females increases births, this increases population growth increasing mother's population again in the long run(age -cohort of females between 15 to 49). This loop is most common in Sub-Saharan Africa including Uganda where Total fertility rate is still high despite its slow decline .According to UHDS (2006) Uganda has a total fertility of 6.9 births per woman. Such **Loop(R)** eventually increases *mothers population* exacerbating pressure onto maternal services making health units overburden appearing as if there is no service delivery (in **loop two ,B2, Figure 4.3**)

² **Loop B2 shows the relationship between high numbers of pregnant mothers and deaths probability.** 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 *worker force- pregnant females ratio(midwives- pregnant females ratio)* implying that workers have too much to carry on their shoulders (work load). This eventually compromises *MHS's effectiveness* increasing chances of a woman dying while pregnant (probability of deaths). **Loop B2(counteracting loop)** works to stabilize the system.

A national study that was done in 97 health facilities in Uganda, including 30 hospitals found out that out of 97.2 % of health facilities supposed to offer EMOC services, only 37% of the hospitals had the capacity to deliver such services. The crippling factors identified were ,presence of vacant posts of nurses and midwives, inadequate equipment to use, dilapidated maternal wards, lack of essential utilities like water, electricity etc.

<http://www.worldacademicunion.com/journal/1746-7233WJMS/wjmsvol07no03paper01.pdf>

The model categorically posits that the "inadequacy of MHS" effectiveness in Uganda to be able to deliver maternal related services as required to the huge "stock of mother's population" exacerbates their higher chances of dying while pregnant. MHS effectiveness being crippled by the dismal number of midwives and inadequate facilities visa-vis the looming huge population of mothers to be served makes everything just not enough fueling woman's susceptibility to death while pregnant.

According *Loop B2* the inverse influence between *MHS effectiveness* and *death probability* is solely determined by the net effect of factors that influence that loop.

Among various influences portrayed in *Loop B2* is the effect of *midwives-pregnant ratio* which assumes that an increase in the number of midwives and nurses reduces the patient -midwives ratio a factor that reduces workload because midwives will be available enough to have flexible working shifts. This increases *effectiveness of MHS* in the long run . This is based on Mbonye,etal's findings in Uganda that found out that about 28% out total posts of midwives in most public and private health units are vacant.(Mbonye,etal,2001)

However much there is no empirical evidence linked to *reduction of maternal deaths* and *availability of health professionals specifically midwives because of various confounding variables* especially in sub- Saharan Africa, research shows that there is relationship between staffing levels and patient quality care. Most evidence comes from high- income country health systems that generally supports the intuitive association between staffing shortfalls and quality of health care. A UK study reported that midwifery shortages and poor placement of such midwives exacerbated tragedy events i.e. personal injury and frequent near misses such as delays in carrying out caesarian operations that contributed to either death of a kid or a mother.(Gerein, Nancy, Andrew green ,and Stephen Pearson (2006)). Shortages of health professionals reduces the number of health

units equipped enough to offer emergence obstetric care 24 hour O' clock and this significantly increases risks of birthing in any country.

4.5. Model building

In this part of chapter four ,we present the stock and flow structure we hypothesize to be responsible for the historical dynamic problematic behavior portrayed in (**Figure 4.1**). To create the explanatory model structure, we used the *conceptualization schema by Campbell and Wendy (1989)* as a major scientific guiding tool in our modeling process shown in (**Figure 1.1**).³ The model structures shown in **Figures 4.4, 4.6,4.7,4.8 and 4.10** have been constructed to allow us digest and understand the dynamic problematic pattern further.

We started modeling process by building *population aging chain structure sub sector* shown in **Figure 4.4** . The ultimate aim was to obtain the population stock of *females aged between 15 to 49* as further high lightened by the red circle in (**Figure 4.4**). This is the stock that is deemed fertile enough to conceive if there is coitus frequency because *conceiving pregnancy* is one of the major pre-requisites for maternal deaths occurrence according *Campbell and Wendy (1989)* .

in this study we started our conceptualization process by using Campbell and Wendy's schema demonstrating the process of how maternal deaths occurs . In their paper entitled "determinants of Maternal morbidity and mortality: defining and selecting outcomes and determinants and demonstrating Associations", they state it categorically that there are three stages , each conditional upon the proceeding one via which maternal deaths occurs i.e. she must become "pregnant", "experience a problem associated with pregnancy" and "fail to have that problem solved.

[//www.google.no/?gfe_rd=cr&ei=S-FkU-eJGuPJ8gfTmYDgAg#q=measuring+the+determinants+of+maternal+morbidity+and+mortality](https://www.google.no/?gfe_rd=cr&ei=S-FkU-eJGuPJ8gfTmYDgAg#q=measuring+the+determinants+of+maternal+morbidity+and+mortality).

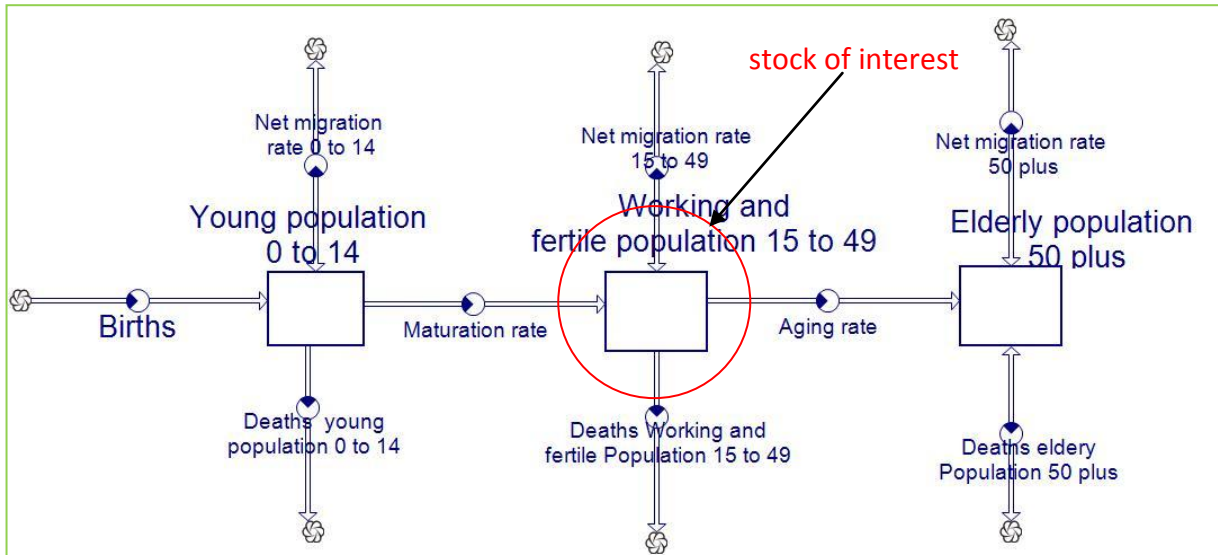


Figure 4.4: Basic stocks and flows of population aging chain showing the stock of interest

.Behavioral patterns from Figure 4.4.

The behaviors both historical and simulated behavior (model behavior) from (Figure 4.4) are displayed in (Figure 4.5) below where all initial values used to calculate different stocks and flows were obtained from different sources. These sources included UBOS website in Uganda, World bank data , WHO web site and from different research reports and journals. Color in blue shows a behavior of historical data and color in red portrays a behavior produced by the model.

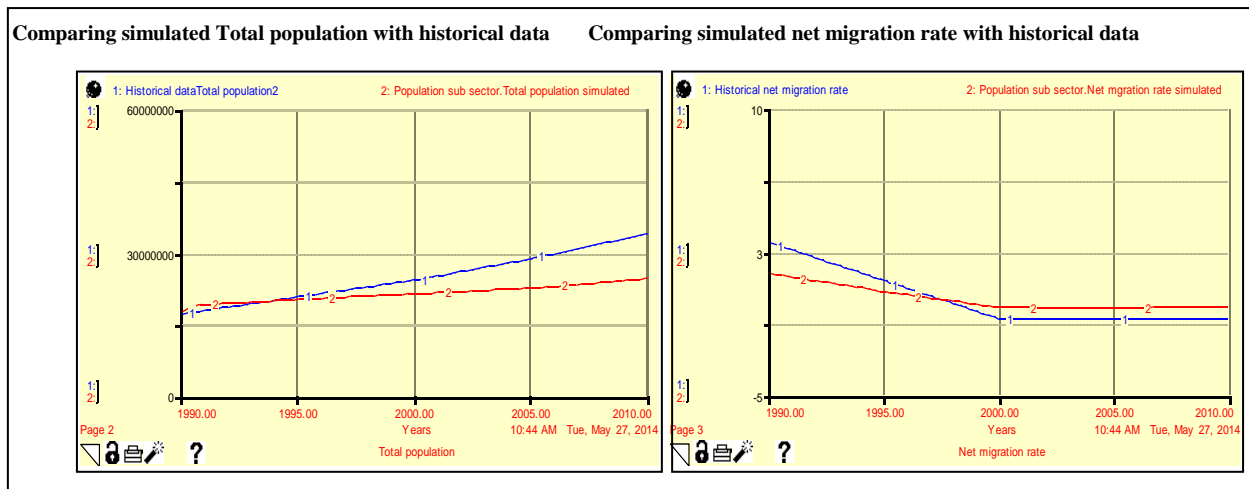


Figure 4.5: Behavior from population aging chain comparing it with historical values.

In **Figure 4.5**. Net migration rate is in negative because emigration in Uganda is greater than immigration. People moving out of the country are more than those entering into the country. This is why the graph is negative. From Both graphs the model replicates the historical behavior relatively good the gap between the two lines in each graph is explained by data flaws that were hard to come by as will be explained further in the part of limitations of study.

Since we had used arrays while building stocks and flows of a **population aging chain subsector** , we only chose **the stock of females aged 15 to 49** as **in -put** to build another sub-sector in order to determine how maternal deaths occur. This is because maternal deaths in this study is understood not as **one time event** but rather **an end-point or an outcome** from a process . It is understood as a product from a series of intertwined stages where one stage is determined by the preceding one. (Campbell and Wendy (1989). The stock of *non pregnant females of reproductive age 15 to 49* is high lightened by a black circle in **(Figure 4.6)**.

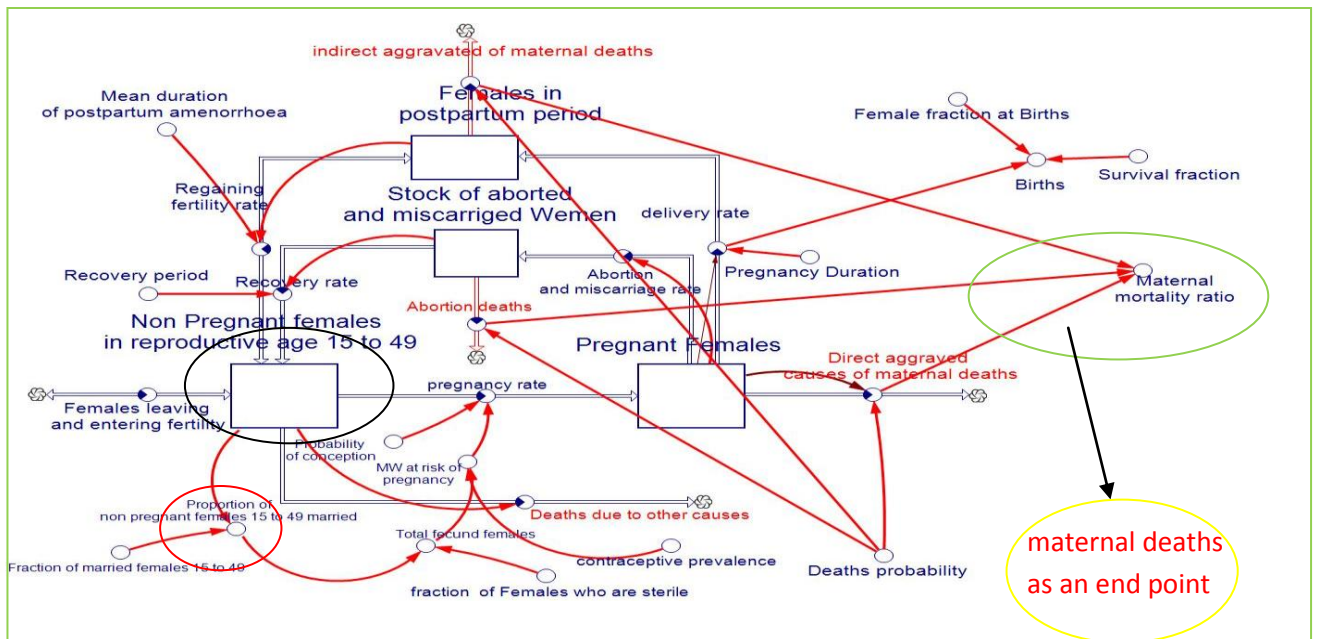


Figure 4.6: Basic stock and flow showing how maternal occurs .

⁴The three arrows in **Figure 4.6** shows maternal deaths as an *outflow(end-point)* from various stocks. These stocks includes the *stock of pregnant females, stock of aborted and miscarriaged females and a stock of females in postpartum*. Maternal deaths is a summation of three outflows as shown in **Figure 4.6** in yellowish color circle i.e. deaths due to *indirect causes, deaths due to direct causes* with *deaths due to abortion* being inclusive . The **three outflows** constitutes the dynamic problematic behavior that the study seeks to understand.

In this study we realized that there are pre- requisites for a maternal death to occur. A woman has to be in *fertile period*, she has to *conceive, experience complications* and have *complications failed to be worked upon* for her to succumb to death. (Campbell and Wendy (1989). This is the reason why we have four stocks in **Figure 4.6** showing the *process* that produces maternal deaths.

The first stock of *non pregnant females 15 to 49 in fertile period*(circled in Black color **Figure 4.6** is assumed to be comprised of both women who are married and not married. The auxiliary variable of *fraction of married women per year* Circled with red color **Figure 4.6** is multiplied with the stock of *non pregnant females 15 to 49 in fertile period* ascertain *proportion of women who are married* . The formula is further shown below;

Non_pregnant_Females_in_reproductive_age__15__to_49*Fraction_of_married_wemen_per_year

⁴ We realized in our study that maternal deaths is an outcome or an end-point from a process-like cycle. This is why we build stocks like non-females of reproductive age 15 to 49, pregnant females, aborted and miscarriaged females and females in postpartum period. This sub-model looks like a model that determines Total fertility rate!. Yes it is true because one of the pre-requisites for maternal deaths is a woman being in a fertile period, she conceives, experience complications and failure to manage them culminates into fatal outcome. At each stage maternal deaths can occur. This is why maternal deaths is portrayed as a complex issue because its causes are many layered and intertwined in nature and therefore difficult to discern.

The justification given is that the model assumes only those in sexual union are capable of conceiving because of high chances coitus frequency. Besides in Uganda by culture only those in marriage union are the ones supposed to conceive, contrary to it, it becomes an abomination in most local communities. **(The whole structure is portrayed in the appendix for more details.)**

The flow of *Pregnancy rate* depends on *MW at risk of pregnancy* and Probability of conception. In this model we used an assumption to be 0.5. *MW at risk of pregnancy* depends on the number of women using contraceptives and those who are fecund. **(figure 4.6)**. We included contraceptive prevalence in our model partly because contraceptives in any country is considered as one of the major determinants of Total fertility rate according to Bongaarts model (Jean-Pierre guengant, 2009). **(For more details of the model structure take a look in the appendix part).**

To reiterate, maternal deaths according to our model structure as shown in **(Figure 4.6)** can happen at the following stages i.e. during *abortion process, giving birth* (direct causes) and shortly during *postpartum period*. (indirect causes) all *three outflows* totaling up to form *maternal deaths* concept.

4.6. What then determines the three outflows that constitutes a dynamic problem.

Explaining the three *outflows* that forms maternal deaths is a complex issue (the whole model can be seen in the appendix part). It is an outcome from a series of interrelated issues that are difficult to discern. However research shows that although causes of maternal deaths are as complex as maternal deaths itself, most maternal deaths occurs due to **failure to manage effectively serious pregnancy complications** around birth or shortly after birth like *eclamptic*

convulsions or hemorrhage and obstructed labor (WHO, 1991). Revamping **facility-based intrapartum care** according to research helps in managing such complications effectively . However such facility-based intrapartum care in reality requires **a well stocked and equipped hospitals with enough and highly trained personnel** to effectively provide the care needed. Besides such pregnancy complications are neither *predicted* nor *prevented* but can be managed meaning that a reliable and timely care is paramount. (Rosenfield and Maine,1985,Campbell and Wendy (2006).

In our model a variable known as MHS *Effectiveness* (as already stated in *figure 4.3*) has been used as an indicator to determine the *maternal mortality risk* or *deaths probability*. *It is a fraction (ratio) between initial effectiveness 1990 and current MHS Effectiveness*

The module hypothesize that MHS effectiveness in Uganda has been increasing since the initial year of 1990 due to peace recovery programs and policies in a country that experienced political strife for long time but still lagging behind due to the excessive demand for maternal services by the huge population of mothers who gets pregnant per year in need for such services(Uganda MDG report,2010). This is attributed to high total fertility rate of about 6.9 births per woman(UDHS,2006). Such population of mothers exerts pressure on already staggering health system thus creating a gap that ought to be filled. Such gap between what the situation ought to be and what it is puts lives of most mothers and young ones in Uganda in jeopardy .

However in our study ,we realized that the term "effectiveness" is an **abstract concept** that is very hard to be quantified. We used estimates to attach values on effectiveness based on research. MHS *effectiveness* of the initial year

i.e. 1990 as shown in the red circle (**Figure 4.7**), we estimated its values based on research to ascertain what was the MHS effectiveness in 1990 by then. This is based on the assumption that since 1990 *MHS effectiveness* compared to the *current MHS effectiveness* has been increasing but still outpaced by the looming *population of mothers*(Pregnant females) making the situation in Uganda appear as if there is no maternal service delivery.

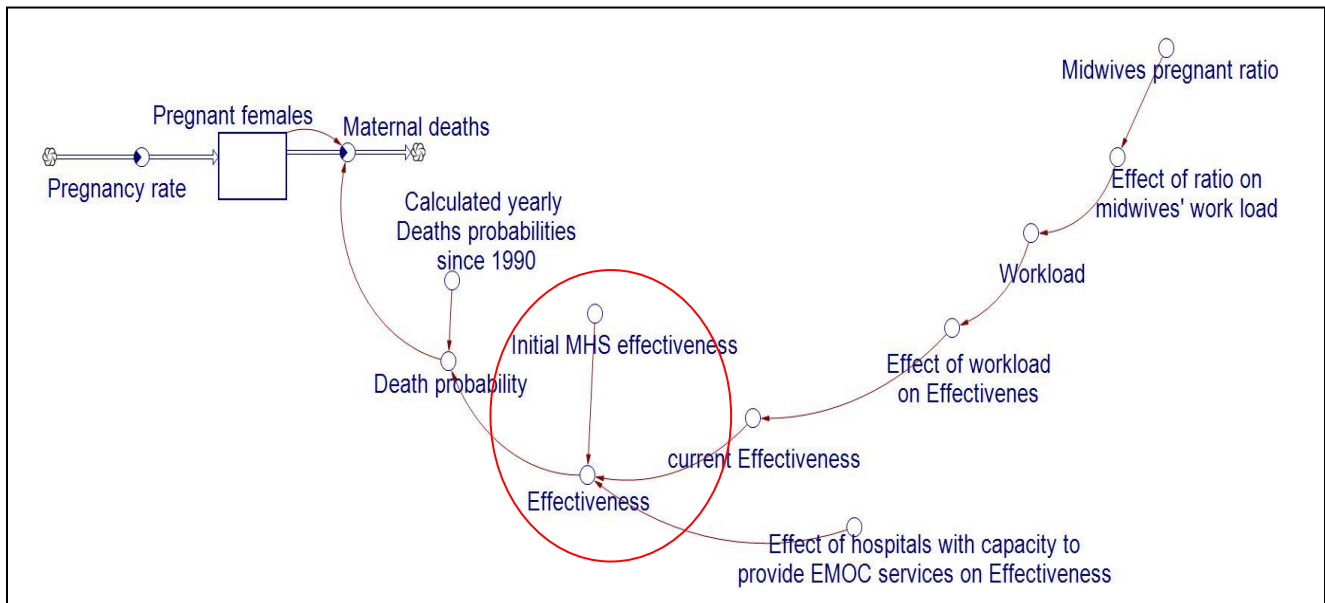


Figure 4.7: shows variables determining death probability

⁵ The equation for *Effectiveness* is a fraction between *initial MHS effectiveness 1990* and *the current MHS effectiveness*. The *initial MHS effectiveness of MHS 1990* is a unit less constant parameter that provides the initial value of how effectiveness was in 1990. The 0.004 value attached is estimated based on research.

The value measuring Initial effectiveness is estimated basing on Ronard L.william's article entitled "measuring effectiveness of perinatal Medicare". The article shows how the size of maternal delivery care in a hospital has a significant effect on neonatal deaths and mother too. That the risk is less in high ranked hospitals especially those in urban areas than those hospitals in lower ranks especially in rural areas in spite of the intervening variables there in between. He did this research in California's hospitals.
<http://www.jstor.org/discover/10.2307/3763882?uid=4&sid=21103872778057>.

Effectiveness=

Initial_MHS_effectiveness_in_1990/Current_MHS_Effectiveness

However *current MHS effectiveness* is a variable that changes depending on the situation on ground. The Effectiveness (fraction) changes if the denominator (*current MHS effectiveness*) changes. Current MHS effectiveness is determined by the effect of *mid wives workload* and *effect of hospitals with capacity to provide EMOC services* as shown in **Figure 4.7**.

The midwives' work load depends on the number of midwives available in relation to the pregnant mothers to be served (midwives- pregnant females ratio) . The model posits that if the ratio is low i.e. the number of *pregnant females* outweighs the *number of midwives* available, the workload on the shoulders of midwives increases and vice versa. This is demonstrated in form of graphical functions table in **Figure 4.9**. The values used to calculate the index were estimated since the two concepts are abstract (hard to measure). According to the index calculated, the effect is 1 when the ratio of midwife to pregnant woman is 1:1 (*one woman, one midwife*). The effect goes beyond 1 on midwives' workload when the ratio between pregnant women and midwives ceases to be 1:1.

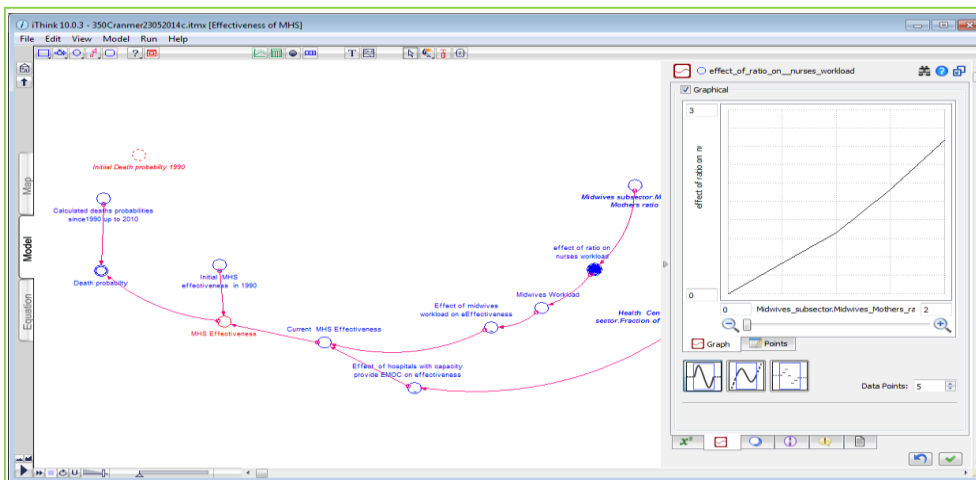


Figure 4.9: Graphical function showing relationship between Midwives pregnant females ratio and workload

⁶ The model postulates that if the ratio is low i.e. *many pregnant females on one midwife*, the affect on midwives' performance is drastically a disaster a factor that lowers *MHS effectiveness*.

Among other influences on the *current MHS effectiveness* as portrayed in **Figure 4.7** is the *effect of fraction of health units with capacity to provide EMOC services*. The model also postulates that *the fraction of hospitals with capacity to deliver EMOC services* has been below the average affecting *current MHS effectiveness*. Research shows that 97% of health units in Uganda expected to provide EMOC services were not doing so(Christopher S,etal 2010,Mbonyi K,etal (2001). This is attributed to lack of basic utilities like lack of water, electricity, inadequate drugs and staff. This significantly affects MHS effectiveness to deliver maternal services . We used graphical functions to portray the relationship between two variables in **Figure 4.1**

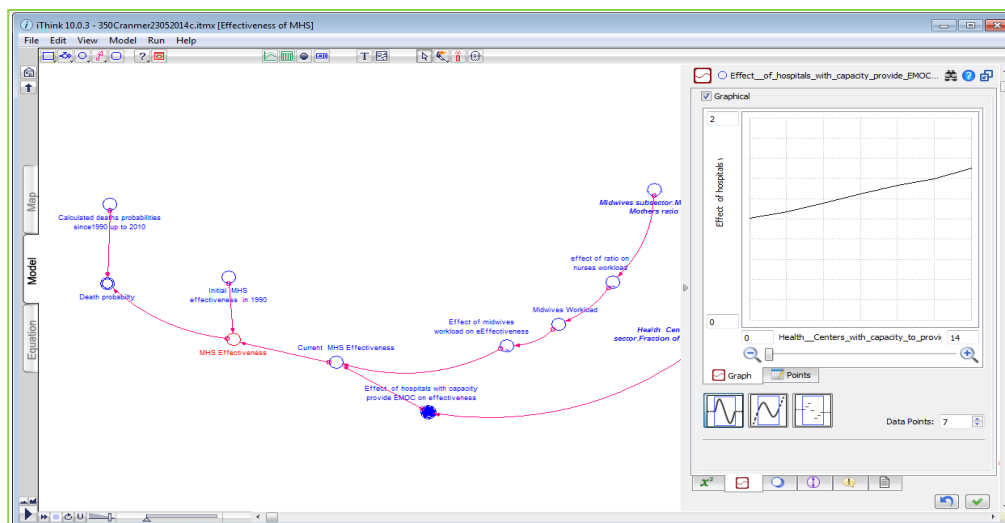


Figure 4.10: Graphical function showing relationship between health units with capacity and current effectiveness.

Lack of human resources has been high lightened as a major factor affecting health sector in Uganda in totality. It has been identified that most hospitals especially health centers (111)s and (11)s have posts of health workers that are vacant particularly midwives' posts. This is due various reasons among which includes low remuneration and poor working conditions especially in rural areas thus acting as a de-incentive to attract them to work. Uganda in fact according to research is in dire situation that requires additional midwives which if not done, meeting goals such as the 5th MDG will be an illusion.

<http://www.worldcademicunion.com/journal/1746-7233WJMS/wjmsvol07no03paper01.pdf>

The graphical function shows that the higher the numbers of health units with capacity, the higher the MHS effectiveness.

Determining MHS Effectiveness helps us to determine death probability. In order to determine *Death probability shown in Figure 4.7* ,we multiplied the fraction(effectiveness) with the *calculated yearly death probabilities since 1990*.

Death probability=

*Calculated_yr_deaths_probabilities_since_1990*MHS_Effectiveness.*

We calculated yearly death probabilities since the initial 1990 by getting the number of women who died within that year over the number of women who were pregnant to be able to calculate yearly death probability .

The formula for the calculated yearly death probabilities since 1990 is as follows;

Number of maternal deaths in that year/number of women who were pregnant in that year.

When the ratio or fraction (Effectiveness i.e. between initial and current MHS Effectiveness) is 1;0 deaths probability would be the same as it was in 1990 otherwise if not so it would mean that all women died in 1990.This justifies the multiplication of the fraction(Effectiveness) with the yearly death probabilities since1990 (**Figure 4.7**). Therefore the equation of *death probability* has a multiplicative effect on the maternal deaths outflows.

5. MODEL VALIDATION AND ANALYSIS

In order to be sure that the outcomes of the model portrayed above can be trusted and be used to inform health managers and policy makers not only in Uganda but outside Uganda , series of reiterative tests have been carried out with

an ultimate aim of validating the model thoroughly. Validating the model helps in ascertaining usefulness and building confidence in the soundness of the model in relation to the assumptions made when estimating values of the parameters and the model boundary.(Forrester (1973) and Senge ,1980). It was done in the following ways;

5.1. Matching simulated behavior with reference Mode.

One of the vital principles in system dynamics is to find out if the simulated behavior produced by the model matches with or fits or replicates the historical values(Ford 1999). To ascertain the accuracy of the model, the behavior produced by the model should be compared with the reference mode. This is the first step that most modelers have at the back of their minds when commencing modeling process. Most parameter values used in our model are based on the data estimates from world data bank, Uganda bureau of statistics(UBOS), research reports and WHO.

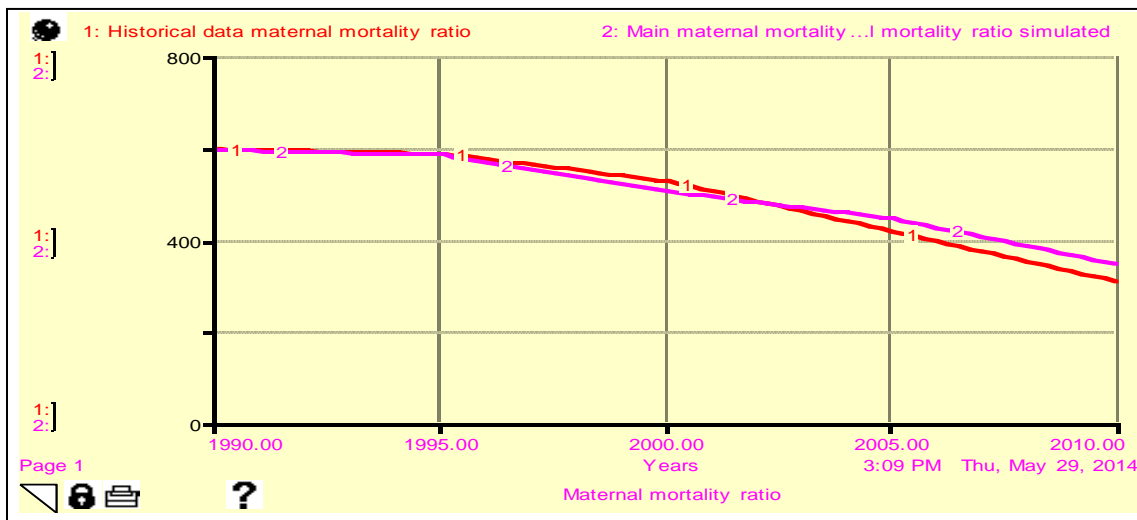


Figure 5.1 : Comparing simulated behavior and the reference mode

Figure 5.1 portrays the behavior of the actual data(historical values) and the behavior produced by the model. The behavior on the graph in pink color is simulated behavior and the one in red 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. Taking into account data flaws associated with maternal deaths especially how its either under reported or over reported in not in Uganda but in the whole world (**will be discussed later in limitations of the study part**), one can truly conclude that the behavior produced by the model replicates the historical values.

5.2. Structure assessment

Ascertaining whether the model build represents reality outside is known by carrying out structure assessment. Sterman asserts that structure assessment asks whether the model is consistent with the knowledge of the system with in which it is built for (Sterman 2000:888). All throughout the modeling process, a series of reiterative checks have been done to find out if the equations formulated inside variable logically represents the real decisions people make outside classroom i.e. whether they really make sense. This test Ford calls it "*common sense test*"(Ford 2010:166).

5.3. Structure -behavior test.

According to Barlas, in a systemic dynamic problem, the dynamics of the variables must be closely associated with how the *internal structure operates*. This is caused by the internal *feedback structure* of the system(Barlas ,1970). **The structure -behavior test** acts as a tool in ascertaining these *feedback structures* by either omitting or deleting some relationships between variables. This helps by providing us with information of which *feedback loop* is more vital or dominant than the other.(Sterman,2010,pg-880). In our model, the loop that is more

dominant is the *Effectiveness loop (B2)* in **Figure 4.3**. It is the loop that contributes much to the behavior pattern observed in **Figure 5.1**. The population loop (*Loop R1*) and *Loop (B1)* are simply enabling loops. **More detailed structure will be portrayed in the appendix part.**

5.4. Face validity

Using *inspection method*, we took time to look at the stocks used in the model to find out whether stocks used represents the meanings and decisions of the system to which the model is trying to explain (Star man 2000:888) . Stocks like " a stock of females in reproductive age 15 to 49", "pregnant women", "women in postpartum", "aborted women" etc, indeed each of these stocks must be included in the study to explain maternal deaths occurrence. A woman to die of maternal deaths , she must first become pregnant, either aborts or experience miscarriage or not or continue with pregnancy. If the risks are high either by her nature i.e. her age or prior biological status for instance having diabetes or the environment is not safe delivery , she may succumb to death. This is all represented with stocks in **Figure 4.6**.

5.5. Parameter sensitivity analysis

The ultimate aim of the parameter sensitivity analysis is to find out if alterations in the values of parameters has an effect on the model behavior(Sterman 2010:867). In our model, we did vary values of some parameters with an intention of ascertaining whether each value changed has an influence on the model behavior. The major goal is to gain deeper understanding of which loop is dominant by changing values of some parameters. The table below shows the results.

Little influence on the shape of the behavior	Significant influence on the shape of the behavior.
-midwives recruitment fraction	-Probability of conception. -Initial MHS effectiveness in 1990 -calculated yearly death probabilities from 1990 to 2010

Table 2: Results from sensitivity test.

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Summary

If the purpose of testing is to ascertain the usefulness of the model, well we can conclude that the model is useful in explaining the maternal health care dynamics in Uganda. In the next chapter we will perform policy design and analysis as we move on.

6. POLICY DESIGN AND ANALYSIS

The final stage and one of the ultimate aim of this study is to develop a *policy model structure* in order to change the course of the dynamic problematic behavior in future. It's a lie to write that we can change the past but it's possible to change the future. Policy design help us to consider how the future could change via making an improvement on the structure that explains the historical dynamic problem in question. The process of doing so is much more than changing values, it includes entirely creation of new structures, strategies and new decisions rules(Starman 2000,pg- 129). Whether in Uganda or elsewhere **if we** write that "*we know what works well*" to minimize the problem of maternal deaths , it will be a *deceptive phrase*. However *enough is known* to make an action in Uganda if the

will is there and the underlying existential realities explaining the dynamic problem are understood.(Campbell,2006).

Research shows that strategies aimed at *increasing skilled attendance at birth* will significantly reduce maternal deaths decline since a big proportion of maternal deaths occurs during and shortly after child birth.(Jagdish,1993). We will start our policy tests by applying one policy simulation test at a time.

6.1. Policy simulation test No 1: **Recruit more midwives**

The first strategy designed to increase skilled attendance at birth is to *recruit more midwives*. Research shows that majority of maternal deaths are due to *insufficient care during pregnancy and delivery*. Complications that exacerbates such fatal outcomes are sudden and difficult to predict . However with *enough and motivated skilled attendants* in place for instance a mid wife or a nurse *cetris paribus*, sufficient care is not without being assured . Such strategies have been adopted in various countries like Malaysia, Sweden and Netherlands and have contributed significantly to low maternal mortality ratios (Sabine and Campbell, 2009).

As revealed in the model analysis part *loop two (B2)* i.e. *the effectiveness loop* is responsible for the big percentage of patterned behavior, the rest of the loops are supporting loops. However this loop is being limited by *midwife-pregant females ratio*⁷ and *fraction of health units with a capacity to provide EMOC services*. The designed policy model suggests that if Uganda is to reduce the ratios

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A local newspaper in Uganda known as [new vision](http://www.newvision.co.ug/) published a story on 20th February 2014 showing how people at kabale hospital(western Uganda) are still reeling and health workers living in regret at kabale hospital from the death of their lecturer. The paper narrates a story of how the lecturer lost her life while pregnant a situation that pundits say could have been avoided had the midwives been enough. A lecturer beaming with hope reached in the hospital early enough, the nurse on duty examined her and found that she was to be in active phase of lab our. After a tough lab our, she delivered but lost a baby. On that day there were only two midwives who had helped 13 midwives. When she delivered a baby, a baby looked very exhausted, a midwife rushed the kid for medical checkup. The woman left un attended to bled up to death because there was no substitute(*the ratio*) and the story continues..... For more information read on this link below.
<http://www.newvision.co.ug/news/654610-maternal-deaths-shortage-of-midwives-derailing-fight.html>

further down, it has to increase *MHS Effectiveness* (maternal health care) to be able to handle maternal associated challenges and pregnancy complications whenever they arise. The possible solution for increasing **MHS effectiveness** is to *recruit more midwives* as simulation No1 suggests. **Figure 6.1** portrays the structure.

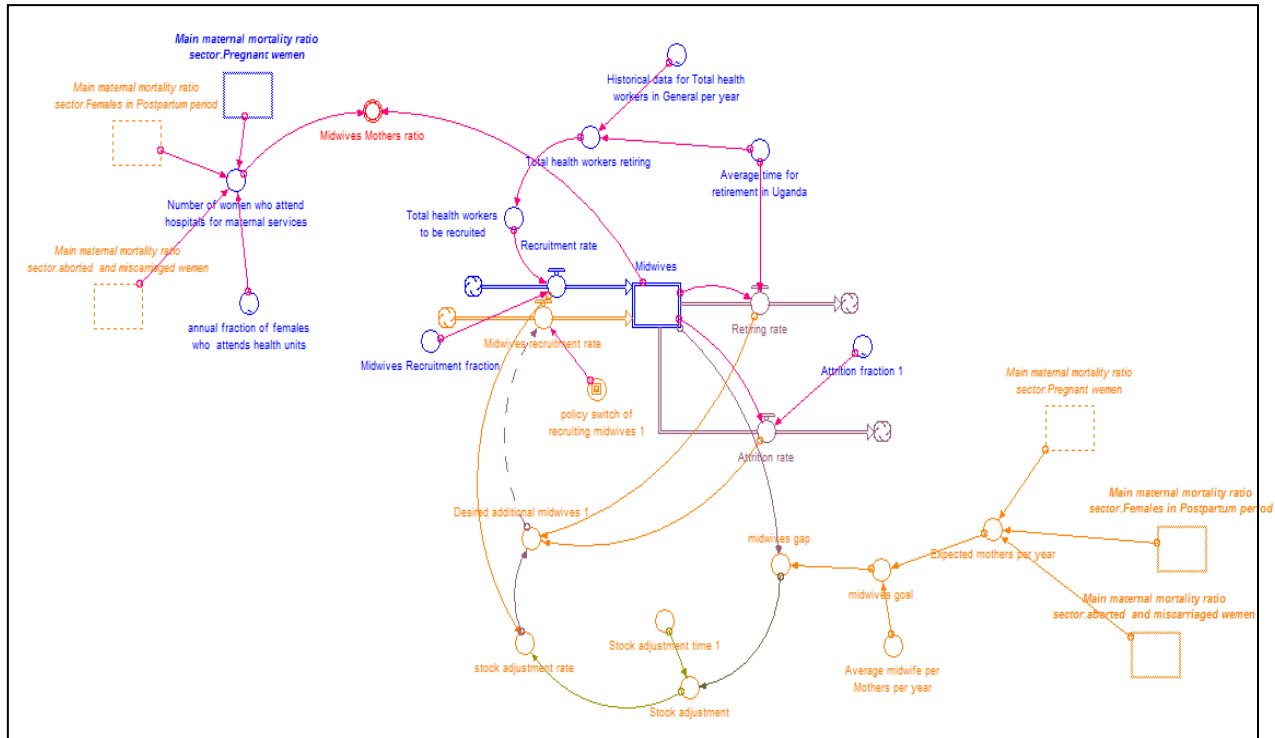


Figure 6.1: Stock and flow diagram extended with suggested policy structure

Figure 6.1 shows a policy structure built to determine how midwives are recruited. The structure is the one in orange color. The ultimate aim of the policy structure is to increase the recruitment inflow such that we can lower the pregnant-midwives ratio for MHS Effectiveness rate to increase. With this re-designed structure, death probability reduces as shown in **Figure 6.3**. Our midwives goal is a moving goal. It is not static. It depends on the number of females who gets pregnant per year. We used an estimated desired ratio between midwives and pregnant females to be 10 pregnant females per 3 midwives per day (10:3).

Research findings shows that timing of maternal deaths is mostly clustered around lab our, delivery and immediate postpartum period. Recruiting more midwives increases *pregnant females-midwives ratio*(midwife per pregnant woman) to be able to deter any fatal outcome that may happen around that period (Carine and Wendy (2006)). **Figure 6.2** shows a CLD in green color mapping out how recruiting more midwives reduces death probability.

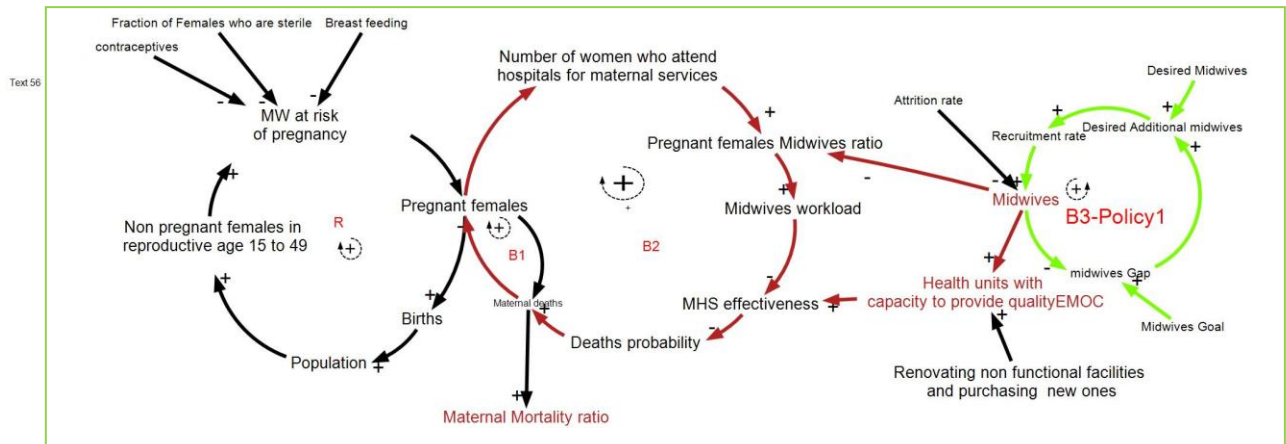


Figure 6.2: Basic CLD diagram showing an extended policy structure and how it affects death probability.

The implementation start time is 2014. A bout 30 % decrease in ratios within 12 years is noticed i.e. from 2014 to 2026 in **Figure 6.3**. The results from recruiting of extra midwives are shown below(the behavior in red color).

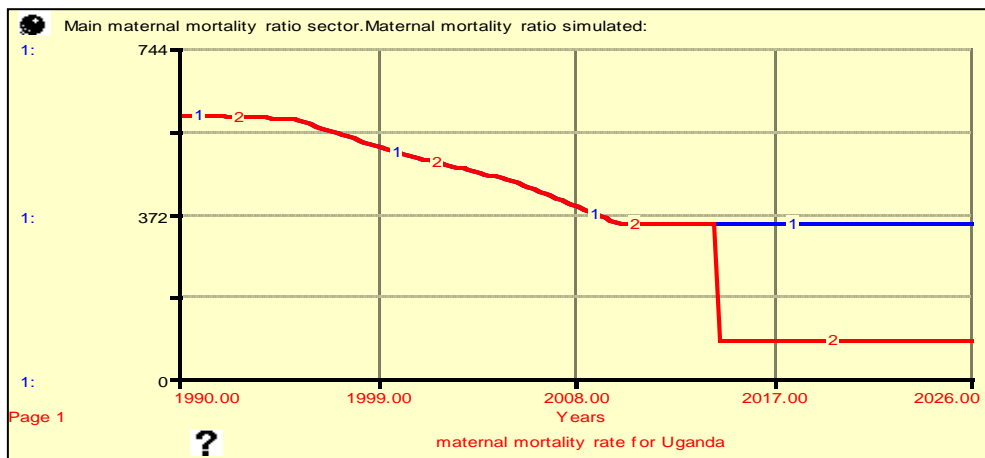


Figure 6.3 : Results from Recruitment of midwives

Recruiting more midwives according to (B3-Policy 1) in Figure 6.2 increases midwife-pregnant female ratio(more midwives per patient). This reduces midwives workload increasing MHS effectiveness .This finally decreases death probability. Besides according to the set up of our model, recruiting more midwives increases hospitals capacity to deliver EMOC services because there will be a enough health workers in a health facility to deliver maternal related services.

The above policy is in line with various studies that have been undertaken in Uganda and have found out that over the years there has been a slow astronomical increase in terms of numbers of midwives in the country. Using job advertisement between 1995 and 2000, a mandua 2001 demonstrated that midwife vacancies formed a lion share i.e. 28% out of the total 3338 positions advertised for health workers at the district level per year in Uganda. This indicates a discrepancy between midwives available and the ones needed (Ssengooba, Freddie, et al,2003). Such discrepancy raises questions about the human resource training, planning and management including the question of how to encourage larger proportions of midwives to be enrolled and graduated from various institutions in Uganda to fill the gap.

6.2. Policy simulation test No2: Fertility control policy

Fertility control measures particularly family planning services have previously been proposed as one of the ways to reduce maternal mortality(Rosenfileld and Maine ,1985). The argument advanced to support this policy is based on the fact that fertility controls allows women to have planned pregnancies reducing the stock of **females pregnant** shown in **Figure 4.6**. This decreases births, reducing mother's population growth in the long run. However the outcomes from this proposed policy takes time(there is a delay) before the brunt is felt on ground as shown in **Figure 6.4**. This is probably because of the time delay it takes before births matures to become females in reproductive age.

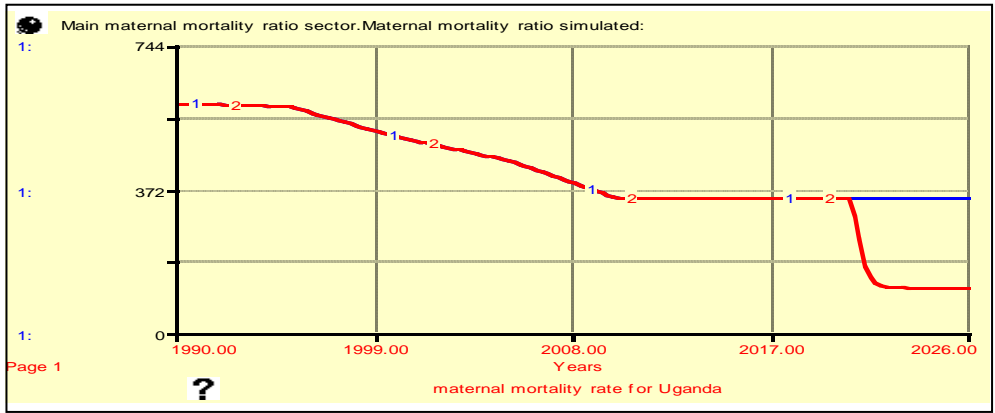


Figure 6.4. Results from fertility control policy

In the Figure 6.4 the implementation start time is 2014 simulated up to 2026. As observed the results shows a delay between the start time and when the impact of the policy is observed. The graph shows that the impact of the fertility control policy will be felt around 2017 (behavior in red color). The policy structure is shown below in green color. (For further details see in the appendix part).

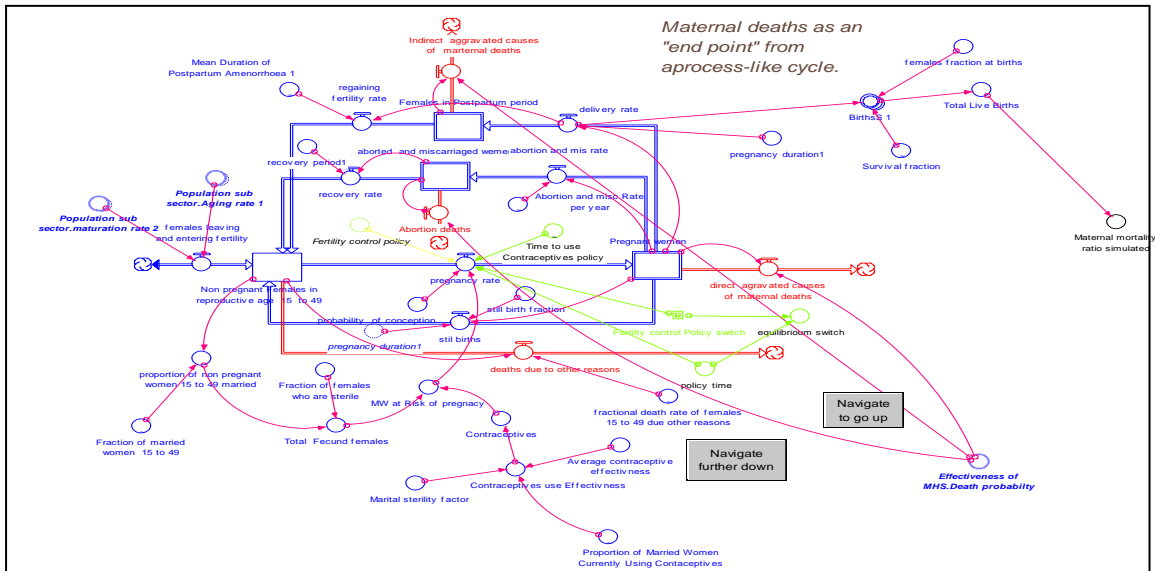


Figure 6.5: Basic stock and flow showing policy structure of fertility control.

6.3. Policy conclusion

With our current model setting ,it appears that the policy of fertility control takes time before the impact is observed on the dynamic behavior(as observed in Figure 6.4). The policy of recruiting more midwives has a significant impact on the dynamic behavior and the impact is sooner compared to fertility control policy. In this study the simulation is done for 36-year period and it extends and reinforces the 2001 findings and recommendations by Christopher S,etal and Mbonye ,etal on most health units and hospitals in Uganda that more health workers ought to be recruited and population growth controlled if there has to be a substantial reductions on maternal mortality ratios in Uganda.(Mbonye,etal ,2001, Christopher S,etal,2010).

6.4. Validation of Policy model

The model extended with additional structure should also be tested to instill confidence into the client that the simulation outcomes can be trusted. To test the policy model structure, extreme tests were performed and they did not reveal any flaws in the policy structure equations. When we tried to alter the adjustment time, the model showed realistic results in **Figure 6.6** as anticipated shown further below;

- The sooner or the shorter the adjustment time of the policy, the higher the impact on the pattern behavior and the higher the adjustment time ,the later the impact on the behavior. We used an example of 5,7,9 and 10 years as adjustment time and the results were as follows.

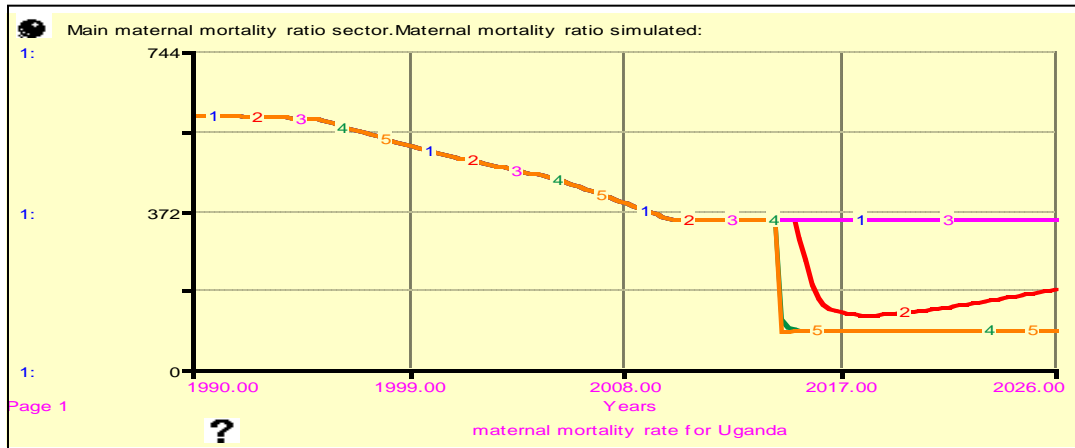


Figure 6.6: Reference mode behavior and the simulated policy structure validation results

This therefore implies that long adjustment times will delay policy results. The sooner the adjustment time the better.

7. Policy implementation obstacles.

7.1. Financial obstacles.

Implementation costs that will be incurred in terms of wage bill and recruitment costs of new staff(midwives) all implies an extra luggage onto the health sector budget that is already underfunded in Uganda. The implementation of such policies might appear challenging most especially with in the current situation where the health sector budget largely depends on "*out-pocket funding*" i.e. donor Aid that is not reliable(Today it's on , tomorrow it may not more over with strings attached) . The financial obstacles therefore ought to be looked at with in the context of the performance of the whole economy for a country to have a meaningful budget for substantial allocations in its various sectors and it should be modeled separately.

7.2. Organizational Obstacles.

Organizational obstacles are understood as organizational set-backs that might derail the proposed policies from being turned into reality. With the current bureaucracy full of corruption, recruitment of new staff and allocating new funds for institutional development in Uganda might be compromised by such systemic challenges. Recruitment and hiring of new staff might take some time and therefore shift the impact of the proposed policies for some good time in future.

8. CONCLUSION:

8.1. Limitations of the model and future research.

The model produces good behavior for right reasons but it does not include many vital details and explanations for that behavior. Indeed Uganda is in short supply of midwives and fertility control, the **policy model** proposes recruitment of new staff and fertility control by merely showing " **a wishful thinking links**" as shown in **Figure 6.1 and 6.5**. The *policy structure* does not show how those "**wishful thinking links**" will be turned into reality. The structure does not show how implementation obstacles like corruption and financial hindrances will be overcome for the proposed policies to have an impact on ground. It is globally known that Uganda has always been praised for having good policies on paper but difficult to be put into practice.

The other limitation of the model is the fact that health institutions in this model are treated as if they are "whole" implying that challenges affecting them are similar in Uganda. But health institutions in Uganda are divided into two i.e. private and public health institutions. The challenges affecting the two types are somehow related but not alike. Most institutions facing the huddles of inadequate work force, poorly remunerated etc are public health institutions (government institutions) compared to private -owned institutions. Besides the

fact that a big proportion of the population is still poor in Uganda, most mothers attend government institutions for maternal services compared to private institutions which are considered to be expensive. The model does not differentiate the two types of health institutions in terms of their challenges for better understanding in order to adjust the proposed policies even better.

In the midwives and hospitals with capacity models, we built simple model structures simplifying the assumptions made in this study. The structure of midwives did not involve a lot of details on how midwives are trained, recruited, motivational issues and their productivity. The next model in future should contain the structure that portrays how midwives in Uganda are enrolled into institutions, trained, then recruited into labor market plus their productivity. Probably these additional details might explain the root cause of the dynamic problem better however much there is little or no documentation about such details in Uganda.

In general, the reasons why those apparently characteristics are not included in the model is first and foremost because of inadequate data and inadequate time. Throughout our modeling process we based mostly on estimates and assumptions on most variables used. Some parameters and variables had contradicting values from different sources of data. But all those factors mentioned above are all important, so it is recommended to be included in the model especially in future research and modeling processes.

8.2. Major Contribution and Findings

This study has critically examined the bottlenecks derailing the reduction efforts by Ugandan government and its partners to reduce maternal mortality ratios further especially meeting the MDG target of reducing maternal deaths 75% by 2015. It has investigated the setbacks as well as government efforts that have been put in place to reduce the ratios further to minimal levels.

Step by step, the System Dynamics model has enabled us to gain some insights and deeper understanding into the process that brings about maternal deaths occurrence via model structure especially **Figure.4.6**. This is the first *quantitative model* of the kind about Ugandan maternal deaths. The study extended Christopher S,etal's qualitative study that used *only qualitative tools* such as CLD and Descriptive framework to illuminate the complexity of maternal health care related bottlenecks in Uganda (Christopher S,etal,2010). The approach used in this thesis to study the dynamic problem presents some uniqueness on how the problem is approached to different from other approaches. It provides us with the "*structure or physics*" that brings about the problem and how , why and where to change in order to tackle the problem. It provides us with a platform upon which we can be able to test *different policy options* to ascertain which policy option works better and why?.

8.3. Conclusion.

Maternal deaths is a major public health issue. Uganda still has one of the highest maternal deaths in sub- Saharan Africa. Whereas the statistics shows a declining trend , the situation is still more wanting. Besides most statistics such as national averages and international data are simply estimates based on "institutional delivery". Most maternal deaths goes un registered since most women in Uganda rarely do they deliver from a health facility. This implies that the problem is much bigger than what is thought to be. Whereas the magnitude of the problem is not well known because of data deficiencies, enough *is known to acts* as long as continuous improvements in general maternal health care system is done in Uganda especially more efforts to *increase skilled attendance at birth via recruitment of midwives , control measures on the looming population growth and increasing capacity of health units to offer EMOC services* because ideally these are the crux of maternal health care service provision. However something vital

ought to be noted, a distinction has to be made between a woman delivering in a hospital and having skilled attendance at birth. A woman delivering in one of the floors or verandas around a hospitals like *Mulago national hospital in Uganda* is not skilled attendance we mean. Efforts have to be made to increase *the ratio between midwives and pregnant women* to increase skilled attendance during the time of emergence. We would be more than willing to work with any one in future to involve such details in the model.

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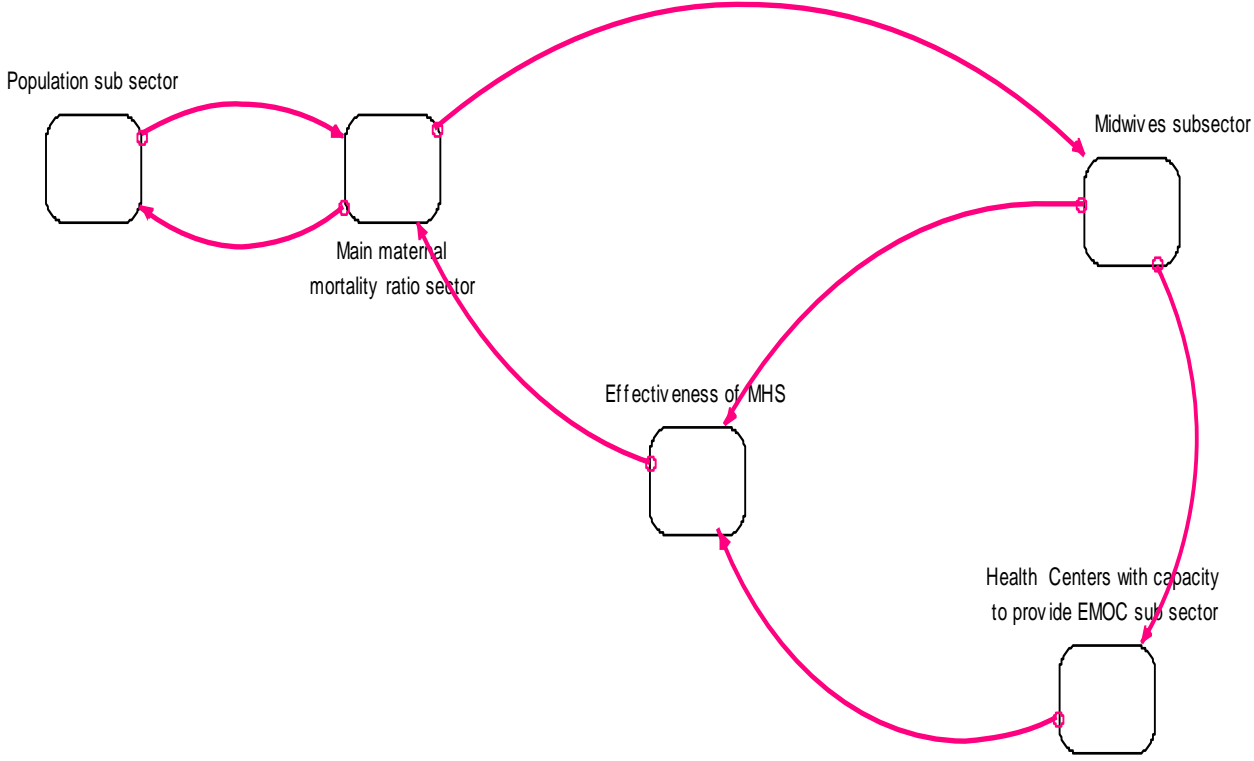
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10. APPENDIX

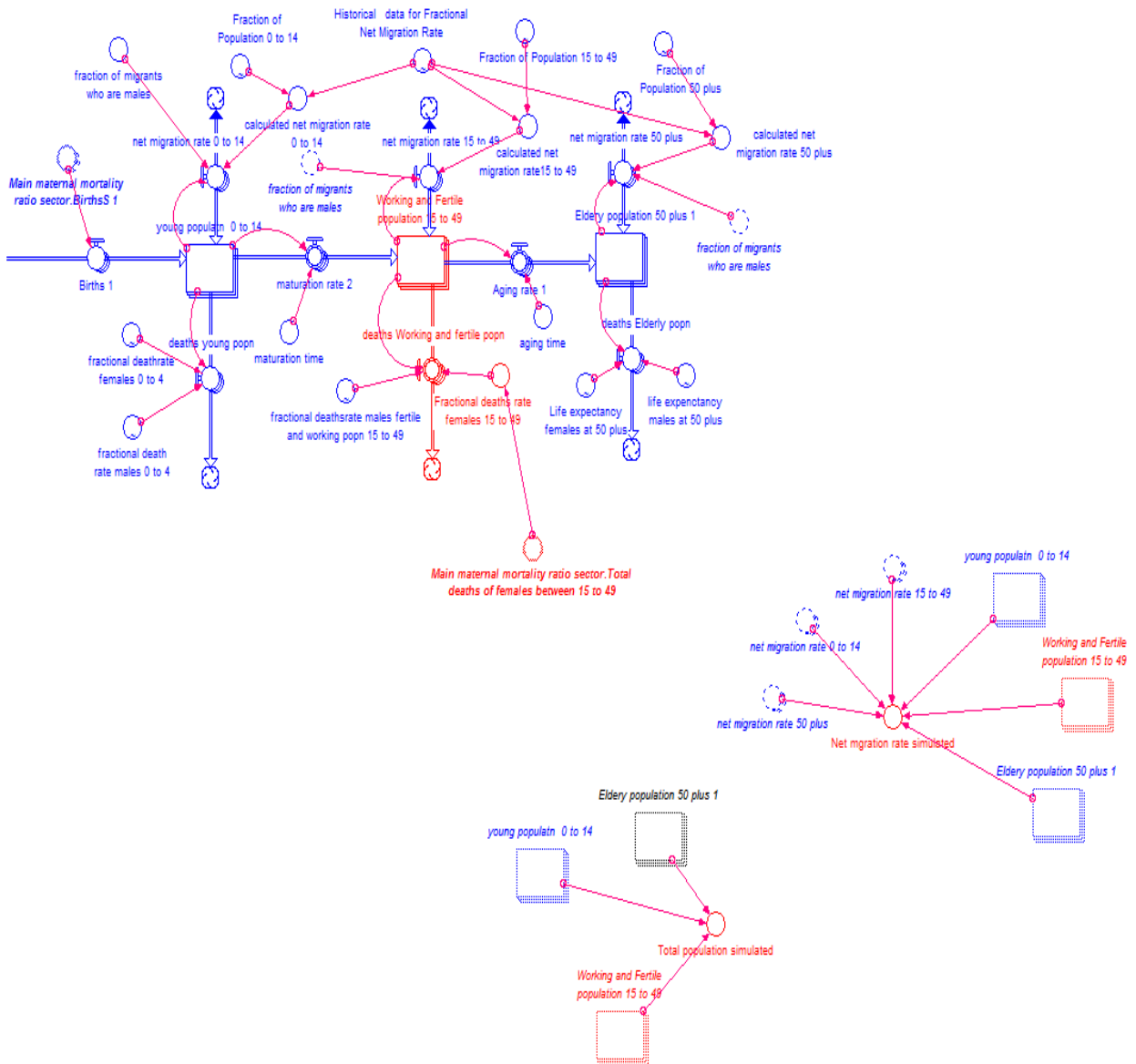
10.1. Models built.

(a) model over view



(b) model 1: Population subsector.

(b) model 1: Population subsector.



Population -subsector equations.

Eldery_population_50_plus_1[Females](t) =
 Eldery_population_50_plus_1[Females](t - dt) + (Aging_rate_1[Gender] +
 net_migration_rate_50_plus[Gender] - deaths_Elderly_popn[Gender]) * dt
 INIT Eldery_population_50_plus_1[Females] = 806531.018
 {persons}

Eldery_population_50_plus_1[Males](t) =
 Eldery_population_50_plus_1[Males](t - dt) + (Aging_rate_1[Gender] +
 net_migration_rate_50_plus[Gender] - deaths_Elderly_popn[Gender]) * dt
 INIT Eldery_population_50_plus_1[Males] = 749121.982
 {persons}

INFLOWS:

Aging_rate_1[Females] =
 Working_and_Fertile_population_15_to_49[Females]/aging_time
 {people/yr=people/year}

Aging_rate_1[Males] =
 Working_and_Fertile_population_15_to_49[Males]/aging_time

net_migration_rate_50_plus[Females] =
 (Eldery_population_50_plus_1[Females]+Eldery_population_50_plus_1[Males])
 calculated_net_migration_rate_50_plus(1-
 fraction_of_migrants_who_are_males)

net_migration_rate_50_plus[Males] =
 (Eldery_population_50_plus_1[Males]+Eldery_population_50_plus_1[Females])
 *calculated_net_migration_rate_50_plus*fraction_of_migrants_who_are_males

OUTFLOWS:

deaths_Elderly_popn[Females] =
 Eldery_population_50_plus_1[Females]/Life_expectancy_females_at_50_plus

deaths_Elderly_popn[Males] =
 Eldery_population_50_plus_1[Males]/life_expenctancy_males_at_50_plus

Working_and_Fertile_population_15_to_49[Females](t) =
 Working_and_Fertile_population_15_to_49[Females](t - dt) +
 (maturation_rate_2[Gender] + net_migration_rate_15_to_49[Gender] -
 Aging_rate_1[Gender] - deaths_Working_and_fertile_popn[Gender]) * dt
 INIT Working_and_Fertile_population_15_to_49[Females] = 3989405.042

Working_and_Fertile_population_15_to_49[Males](t) =
 Working_and_Fertile_population_15_to_49[Males](t - dt) +

$(\text{maturation_rate_2}[\text{Gender}] + \text{net_migration_rate_15_to_49}[\text{Gender}] - \text{Aging_rate_1}[\text{Gender}] - \text{deaths_Working_and_fertile_popn}[\text{Gender}]) * dt$
 INIT Working_and_Fertile_population_15_to_49[Males] =
 3711613.977

INFLOWS:

$\text{maturation_rate_2}[\text{Females}] =$
 $\text{young_populatn_0_to_14}[\text{Females}] / \text{maturation_time}$
 $\text{maturation_rate_2}[\text{Males}] =$
 $\text{young_populatn_0_to_14}[\text{Males}] / \text{maturation_time}$
 $\text{net_migration_rate_15_to_49}[\text{Females}] =$
 $(\text{Working_and_Fertile_population_15_to_49}[\text{Females}] + \text{Working_and_Fertile_pop}$
 $\text{ulation_15_to_49}[\text{Males}]) * \text{calculated_net_migration_rate15_to_49} * (1 -$
 $\text{fraction_of_migrants_who_are_males})$
 $\text{net_migration_rate_15_to_49}[\text{Males}] =$
 $(\text{Working_and_Fertile_population_15_to_49}[\text{Males}] + \text{Working_and_Fertile_pop}$
 $\text{ulation_15_to_49}[\text{Females}]) * \text{calculated_net_migration_rate15_to_49} * \text{fraction_}$
 $\text{of_migrants_who_are_males}$

OUTFLOWS:

$\text{Aging_rate_1}[\text{Females}] =$
 $\text{Working_and_Fertile_population_15_to_49}[\text{Females}] / \text{aging_time}$
 {people/yr=people/year}
 $\text{Aging_rate_1}[\text{Males}] =$
 $\text{Working_and_Fertile_population_15_to_49}[\text{Males}] / \text{aging_time}$
 $\text{deaths_Working_and_fertile_popn}[\text{Females}] =$
 $\text{Fractional_deaths_rate_females_15_to_49}$
 $\text{deaths_Working_and_fertile_popn}[\text{Males}] =$
 $\text{Working_and_Fertile_population_15_to_49}[\text{Males}] * \text{fractional_deathsrate_mal}$
 $\text{es_fertile_and_working_popn_15_to_49}$
 $\text{young_populatn_0_to_14}[\text{Females}](t) = \text{young_populatn_0_to_14}[\text{Females}](t$
 $- dt) + (\text{Births_1}[\text{Gender}] + \text{net_migration_rate_0_to_14}[\text{Gender}] -$
 $\text{maturation_rate_2}[\text{Gender}] - \text{deaths_young_popn}[\text{Gender}]) * dt$
 INIT young_populatn__0_to_14[Females] =
 4213915.054

$\text{young_populatn_0_to_14[Males]}(t) = \text{young_populatn_0_to_14[Males]}(t - dt) + (\text{Births_1[Gender]} + \text{net_migration_rate_0_to_14[Gender]} - \text{maturation_rate_2[Gender]} - \text{deaths_young_popn[Gender]}) * dt$
 INIT young_populatn__0_to_14[Males] = 4210919.948

INFLOWS:

$\text{Births_1[Gender]} = \text{Main_maternal_mortality_ratio_sector.BirthsS_1}$
 $\text{net_migration_rate_0_to_14[Females]} = (\text{young_populatn_0_to_14[Females]} + \text{young_populatn_0_to_14[Males]}) * \text{calculated_net_migration_rate_0_to_14} * (1 - \text{fraction_of_migrants_who_are_males})$
 $\text{net_migration_rate_0_to_14[Males]} = (\text{young_populatn_0_to_14[Males]} + \text{young_populatn_0_to_14[Females]}) * \text{calculated_net_migration_rate_0_to_14} * \text{fraction_of_migrants_who_are_males}$

OUTFLOWS:

$\text{maturation_rate_2[Females]} = \text{young_populatn_0_to_14[Females]} / \text{maturation_time}$
 $\text{maturation_rate_2[Males]} = \text{young_populatn_0_to_14[Males]} / \text{maturation_time}$
 $\text{deaths_young_popn[Females]} = \text{young_populatn_0_to_14[Females]} * \text{fractional_deathrate_females_0_to_4}$
 $\text{deaths_young_popn[Males]} = \text{young_populatn_0_to_14[Males]} * \text{fractional_death_rate_males_0_to_4}$
 $\text{aging_time} = 35$
 $\text{calculated_net_migration_rate15_to_49} = \text{Fraction_of_Population_15_to_49} * \text{Historical_data_for_Fractional_Net_Migration_Rate}$
 $\text{calculated_net_migration_rate_0_to_14} = \text{Historical_data_for_Fractional_Net_Migration_Rate} * \text{Fraction_of_Population_0_to_14}$
 $\text{calculated_net_migration_rate_50_plus} = \text{Historical_data_for_Fractional_Net_Migration_Rate} * \text{Fraction_of_Population_50_plus}$

$\text{fractional_deathrate_females_0_to_4} = \text{GRAPH}(\text{TIME})$
 (1990, 0.03), (1995, 0.02), (2000, 0.02), (2005, 0.01), (2010, 0.01)

fractional_deathsrate_males_fertile__and_working_popn_15_to_49 =
 GRAPH(TIME)
 (1990, 0.014), (1995, 0.012), (2000, 0.012), (2005, 0.009), (2010, 0.008)

Fractional_deaths_rate_females_15_to_49 =
 Main_maternal_mortality_ratio_sector.Total_deaths_of_females_between_15_to_49

fractional_death_rate_males_0_to_4 = GRAPH(TIME)
 (1990, 0.003), (1995, 0.02), (2000, 0.02), (2005, 0.02), (2010, 0.01)

fraction_of_migrants_who_are_males = 0.529

Fraction_of_Population_15_to_49 = GRAPH(TIME)
 (1990, 0.64), (2000, 0.65), (2010, 0.647)

Fraction_of__Population_0_to_14 = GRAPH(TIME)
 (1990, 0.23), (2000, 0.2), (2010, 0.191)

Fraction_of__Population_50_plus = GRAPH(TIME)
 (1990, 0.13), (2000, 0.15), (2010, 0.162)

Historical__data_for_Fractional__Net_Migration_Rate = GRAPH(TIME)
 (1990, 0.00349), (1995, 0.001), (2000, -0.000903), (2005, -0.000974), (2010, -0.000763)

Life_expectancy_females_at_50_plus = GRAPH(TIME)
 (1990, 1.00), (1995, 1.00), (2000, 1.00), (2005, 1.00), (2010, 5.00)

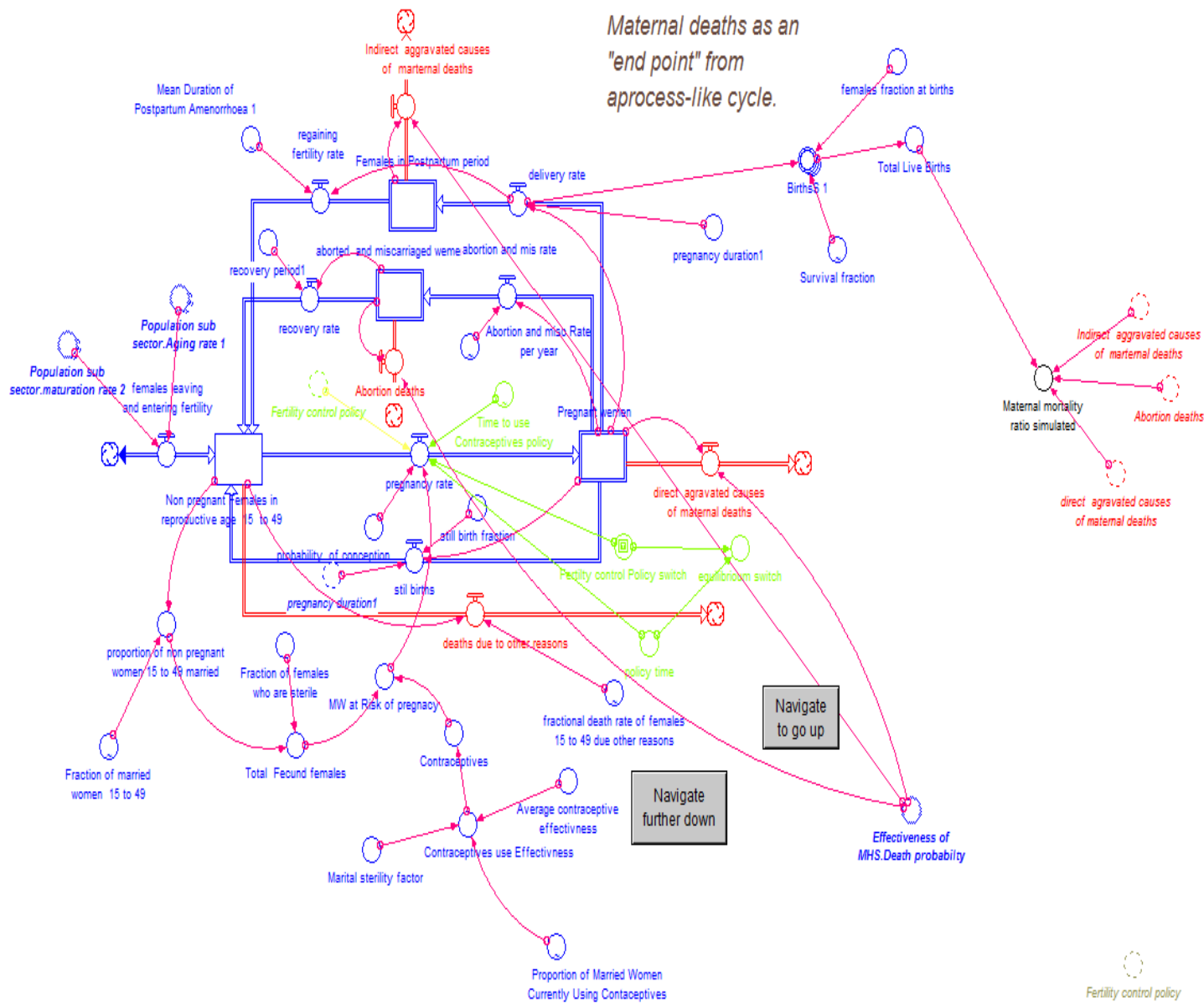
life_expenctancy_males_at_50_plus = GRAPH(TIME)
 (1990, 1.00), (1995, 1.00), (2000, 1.00), (2005, 1.00), (2010, 2.00)

maturation_time = 15

Net_mgration_rate_simulated =
 (net_migration_rate_0_to_14[Females]+net_migration_rate_0_to_14[Males]+net_migration_rate_15_to_49[Females]+net_migration_rate_15_to_49[Males]+net_migration_rate_50_plus[Females]+net_migration_rate_50_plus[Males])/(young_populatn__0_to_14[Females]+young_populatn__0_to_14[Males]+Working_and_Fertile_population_15_to_49[Females]+Working_and_Fertile_population_15_to_49[Males]+Eldery_population_50_plus_1[Females]+Eldery_population_50_plus_1[Males])*1000

Total_population_simulated =
 young_populatn__0_to_14[Females]+young_populatn__0_to_14[Males]+Working_and_Fertile_population_15_to_49[Females]+Working_and_Fertile_population_15_to_49[Males]+Eldery_population_50_plus_1[Females]+Eldery_population_50_plus_1[Males]

(C) model 2: main maternal mortality ratio subsector.



main maternal mortality ratio subsector equations;

$\text{aborted_and_miscarriaged_wemen}(t) = \text{aborted_and_miscarriaged_wemen}(t - dt) + (\text{abortion_and_mis_rate} - \text{recovery_rate} - \text{Abortion_deaths}) * dt$

INIT aborted_and_miscarriaged_wemen = 166

INFLOWS:

abortion_and_mis_rate =

Pregnant_wemen*Abortion_and_misc_Rate__per_year

OUTFLOWS:

recovery_rate = aborted_and_miscarriaged_wemen/recovery_period1
{person/yr}

Abortion_deaths =

aborted_and_miscarriaged_wemen*Effectiveness_of_MHS.Death_probabilty

Females_in_Postpartum_period(t) = Females_in_Postpartum_period(t - dt) +
(delivery_rate - regaining__fertility_rate -

Indirect__aggravated_causes_of__marternal_deaths) * dt

INIT Females_in_Postpartum_period = 30000

INFLOWS:

delivery_rate = pregnant_wemen/pregnancy_duration1
{person/yr}

OUTFLOWS:

regaining__fertility_rate =

DELAY3(delivery_rate,Mean_Duration_of_Postpartum_Amenorrhoea_1)
{person/yr}

Indirect__aggravated_causes_of__marternal_deaths =

Females_in_Postpartum_period*Effectiveness_of_MHS.Death_probabilty

Non_pregnant_Females_in_reproductive_age__15__to_49(t) =

Non_pregnant_Females_in_reproductive_age__15__to_49(t - dt) +

(regaining__fertility_rate + stil_births + recovery_rate +

females_leaving__and_entering_fertility - pregnancy_rate -

deaths_due_to_other_reasons) * dt

INIT Non_pregnant_Females_in_reproductive_age__15__to_49 = 159000.6666

INFLOWS:

regaining__fertility_rate =

DELAY3(delivery_rate,Mean_Duration_of_Postpartum_Amenorrhoea_1)
{person/yr}

stil_births = pregnant_wemen*still_birth_fraction/pregnancy_duration1
{person/yr}

recovery_rate = aborted__and_miscarriaged_wemen/recovery_period1
{person/yr}

females_leaving__and_entering_fertility =
Population_sub_sector.maturation_rate_2[Females]-
Population_sub_sector.Aging_rate_1[Females]

OUTFLOWS:

pregnancy_rate = If (fertility_control_Policy_switch=1) and (TIME>policy_time)
then

(MW_at_Risk_of_pregnacy*probability__of_conception)/(Time_to_use_Contrac
eptives_policy+Fertility_control_policy)else(probability__of_conception*MW_a
t_Risk_of_pregnacy)

deaths_due_to_other_reasons =

Non_pregnant_Females_in_reproductive_age__15__to_49*fractional_death_ra
te_of_females_15_to_49_due_other_reasons

Pregnant_wemen(t) = Pregnant_wemen(t - dt) + (pregnancy_rate - delivery_rate
- stil_births - direct__agravated_causes_of_maternal_deaths -
abortion_and_mis_rate) * dt

INIT Pregnant_wemen = 3800238.376

INFLOWS:

pregnancy_rate = If (fertility_control_Policy_switch=1) and (TIME>policy_time)
then

(MW_at_Risk_of_pregnacy*probability__of_conception)/(Time_to_use_Contrac
eptives_policy+Fertility_control_policy)else(probability__of_conception*MW_a
t_Risk_of_pregnacy)

OUTFLOWS:

delivery_rate = pregnant_wemen/pregnancy_duration1
{person/yr}

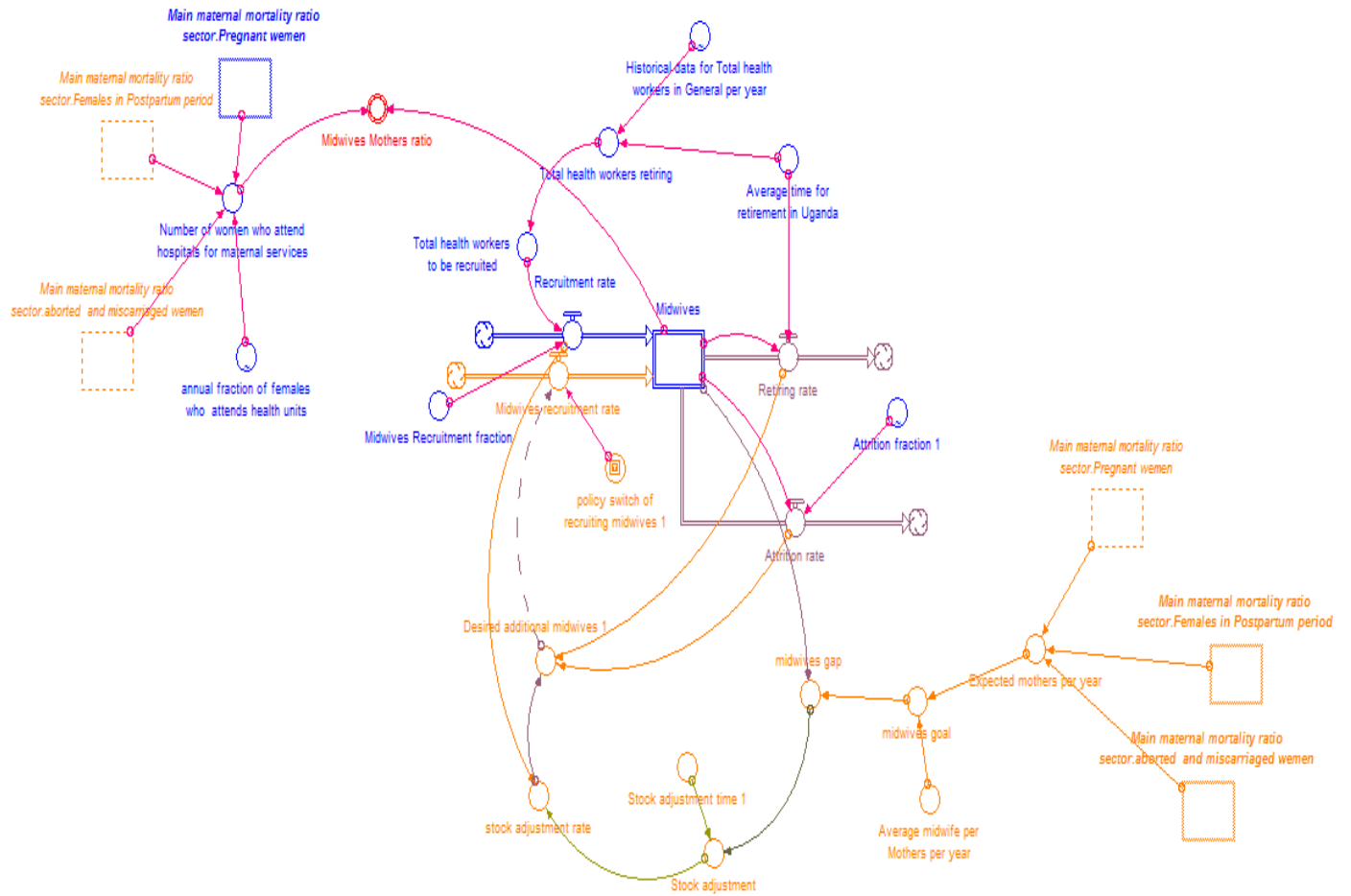
stil_births = pregnant_wemen*still_birth_fraction/pregnancy_duration1
{person/yr}

direct__agravated_causes_of_maternal_deaths =
 Pregnant_wemen*Effectiveness_of_MHS.Death_probabilty
 abortion_and_mis_rate =
 Pregnant_wemen*Abortion_and_misc_Rate__per_year
 Abortion_and_misc_Rate__per_year = GRAPH(TIME)
 (1990, 0.001), (1995, 0.002), (2000, 0.002), (2005, 0.004), (2010, 0.005)
 Average_contraceptive_effectivness = 0.85
 BirthsS_1[Females] =
 delivery_rate*Survival_fraction*females_fraction_at_births

 BirthsS_1[Males] = delivery_rate*Survival_fraction*(1-
 females_fraction_at_births)
 Contraceptives = 1-Contraceptives_use_Effectivness
 Contraceptives_use_Effectivness =
 Marital_sterility_factor*Proportion_of_Married_Women_Currently_Using_Cont
 aceptives*Average_contraceptive_effectivness
 Desired_contraceptives = 1-goal_of_contraceptives
 equilibrium_switch = If (fertilty_control_Policy_switch=1) and
 (TIME>Policy_Time) then(1) else (0)
 females_fraction_at_births = 103/(100+103)
 Fertility_control_policy = Desired_contraceptives*Total__Fecund_females
 Fertilty_control_Policy_switch = 1
 fractional_death_rate_of_females_15_to_49_due_other_reasons =
 GRAPH(TIME)
 (1990, 0.00805), (1995, 0.00528), (2000, 0.0044), (2005, 0.0033), (2010, 0.001)
 Fraction_of_females_who_are_sterile = 0.3
 Fraction_of_married_women__15_to_49 = GRAPH(TIME)
 (1990, 0.9), (1995, 0.75), (2000, 0.697), (2005, 0.655), (2010, 0.643)
 goal_of_contraceptives = 0.99
 Marital_sterility_factor = 1.18
 Maternal_mortality_ratio_simulated =
 (Indirect__agravated_causes_of__marternal_deaths+direct__agravated_cause
 s_of_maternal_deaths+Abortion_deaths)/Total_Live_Births*100000
 Mean_Duration_of_Postpartum_Amenorrhoea_1 = GRAPH(TIME)
 (1990, 19.0), (1995, 19.0), (2000, 18.5), (2005, 17.0), (2010, 16.4)
 MW_at_Risk_of_pregnacy = Total__Fecund_females*Contraceptives
 policy_time = 2014

pregnancy_duration1 = 9/12
 probability_of_conception = 0.5
 Proportion_of_Married_Women_Currently_Using_Contraceptives =
 GRAPH(TIME)
 (1990, 0.1), (1995, 0.15), (2000, 0.25), (2005, 0.28), (2010, 0.3)
 proportion_of_non_pregnant_women_15_to_49_married =
 Non_pregnant_Females_in_reproductive_age__15__to_49*Fraction_of_married_women__15_to_49
 recovery_period1 = 4/12
 still_birth_fraction = 0.009
 {1/year}
 Survival_fraction = GRAPH(TIME)
 (1990, 0.907), (1995, 0.922), (2000, 0.941), (2005, 0.961), (2010, 0.963)
 TFR_Historical_data = GRAPH(TIME)
 (1990, 7.10), (1995, 6.90), (2000, 6.50), (2005, 6.20), (2010, 5.60)
 Time_to_use_Contraceptives_policy = GRAPH(TIME)
 (1990, 34.0), (1995, 33.5), (2000, 32.0), (2005, 22.0), (2010, 14.0), (2015, 8.00),
 (2020, 4.00)
 Total_deaths_of_females_between_15_to_49 =
 Abortion_deaths+Indirect_aggravated_causes_of_maternal_deaths+direct_aggravated_causes_of_maternal_deaths+deaths_due_to_other_reasons
 Total_Live_Births = BirthsS_1[Females]+BirthsS_1[Males]
 Total_Fecund_females =
 proportion_of_non_pregnant_women_15_to_49_married*(1-Fraction_of_females_who_are_sterile)

(e) model 4: midwives subsector



Equations.

$Midwives(t) = Midwives(t - dt) + (Recruitment_rate + Midwives_recruitment_rate - Retiring_rate - Attrition_rate) * dt$

INIT Midwives = 9000

INFLOWS:

Recruitment_rate =

Total_health_workers_to_be_recruited*Midwives_Recruitment_fraction

Midwives_recruitment_rate = if((time>2014)

and(policy_switch_of_recruiting_midwives_1=1))THEN

(Desired_additional_midwives_1)ELSE(0)

OUTFLOWS:

Retiring_rate = Midwives/Average_time_for_retirement_in_Uganda

Attrition_rate = Midwives*Attrition_fraction_1

annual_fraction_of_females_who_attends_health_units = GRAPH(TIME)

(1990, 0.38), (1995, 0.39), (2000, 0.4), (2005, 0.41), (2010, 0.42)

Attrition_fraction_1 = GRAPH(TIME)

(1990, 0.48), (2000, 0.5), (2010, 0.57)

Average_midwife_per_Mothers_per_year = 3.33*365

Average_time_for_retirement_in_Uganda = 60

Desired_additional_midwives_1 = stock_adjustment_rate-

SMTH1((Retiring_rate+Attrition_rate),16)

Expected_mothers_per_year =

Main_maternal_mortality_ratio_sector.Pregnant_wemen+Main_maternal_mor

tality_ratio_sector.Females_in_Postpartum_period+Main_maternal_mortality_r

atio_sector.aborted_and_miscarried_wemen

Historical_data_for_Total_health_workers_in_General_per_year =

GRAPH(TIME)

(1990, 892), (1997, 977), (2003, 1000), (2010, 1110)

midwives_gap = midwives_goal-Midwives

midwives_goal =

Average_midwife_per_Mothers_per_year*Expected_mothers_per_year

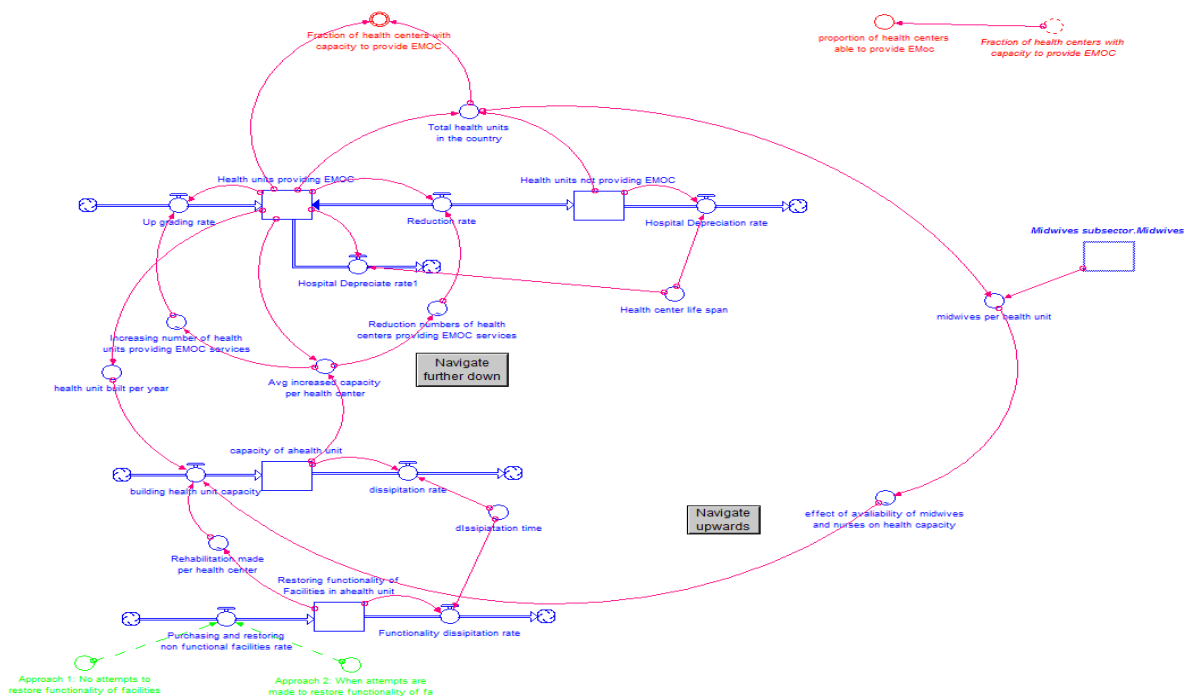
Midwives_Mothers_ratio =

Number_of_women_who_attend_hospitals_for_maternal_services/Midwives

Midwives_Recruitment_fraction = 0.5

Number_of_women_who_attend_hospitals_for_maternal_services =
 (Main_maternal_mortality_ratio_sector.Pregnant_wemen+Main_maternal_mortality_ratio_sector.aborted_and_miscarriaged_wemen+Main_maternal_mortality_ratio_sector.Females_in_Postpartum_period)*annual_fraction_of_females_who_attends_health_units
 policy_switch_of_recruiting_midwives_1 = 1
 Stock_adjustment = midwives_gap/Stock_adjustment_time_1
 stock_adjustment_rate = SMTH1(Recruitment_rate,2)+Stock_adjustment
 Stock_adjustment_time_1 = 5
 Total_health_workers_retiring =
 Historical_data_for_Total_health_workers_in_General_per_year/Average_time_for_retirement_in_Uganda
 Total_health_workers_to_be_recruited = Total_health_workers_retiring

(f) Model 5: health centers with capacity to provide EMOc services subsector.



Equations,

$$\text{capacity_of_ahealth_unit}(t) = \text{capacity_of_ahealth_unit}(t - dt) + (\text{building_health_unit_capacity} - \text{dissipation_rate}) * dt$$

INIT capacity_of_ahealth_unit =

Health_units_providing_EMOC+Health_units_not_providing_EMOC

INFLOWS:

building_health_unit_capacity =

Rehabilitation_made_per_health_center*health_unit_built_per_year*effect_of
_avaliability_of_midwives_and_nurses_on_health_capacity

OUTFLOWS:

dissipitation_rate = capacity_of_ahealth_unit/dlssipiatation_time

Health_units_not_providing_EMOC(t) = Health_units_not_providing_EMOC(t -
dt) + (Reduction_rate - Hospital_Depreciation_rate) * dt

INIT Health_units_not_providing_EMOC = 799

INFLOWS:

Reduction_rate =

Health_units_providing_EMOC*Reduction_numbers_of_health_centers_providi
ng_EMOC_services

OUTFLOWS:

Hospital_Depreciation_rate =

Health_units_not_providing_EMOC/Health_center_life_span

Health_units_providing_EMOC(t) = Health_units_providing_EMOC(t - dt) +
(Up_grading_rate - Reduction_rate - Hospital_Depreciate_rate1) * dt

INIT Health_units_providing_EMOC = 399

INFLOWS:

Up_grading_rate =

Health_units_providing_EMOC*Increasing_number_of_health_units_providing_
EMOC_services

OUTFLOWS:

Reduction_rate =

Health_units_providing_EMOC*Reduction_numbers_of_health_centers_providi
ng_EMOC_services

Hospital_Depreciate_rate1 =

Health_units_providing_EMOC/Health_center_life_span

Restoring_functionality_of_Facilities_in_ahealth_unit(t) =

Restoring_functionality_of_Facilities_in_ahealth_unit(t - dt) +
(Purchasing_and_restoring_non_functional_facilities_rate -
Functionality_dissipitation_rate) * dt

INIT Restoring_functionality_of_Facilities_in_ahealth_unit = 50

INFLOWS:

Purchasing_and_restoring_non_functional_facilities_rate =
Approach_1:_No_attempts_to_restore_functionality_of_facilities*0+Approach_2:_When_attempts_are_made_to_restore_functionality_of_fa*100
{building/year}

OUTFLOWS:

Functionality_dissipation_rate =

Restoring_functionality_of_Facilities_in_ahealth_unit/dissipation_time

Approach_1:_No_attempts_to_restore_functionality_of_facilities = 1

Approach_2:_When_attempts_are_made_to_restore_functionality_of_fa = 0

Avg_increased_capacity_per_health_center =

capacity_of_ahealth_unit/Health_units_providing_EMOC

dissipation_time = 60

effect_of_availability_of_midwives_and_nurses_on_health_capacity =

GRAPH(midwives_per_health_unit)

(0.00, 0.00), (2.33, 0.5), (4.67, 0.76), (7.00, 1.00), (9.33, 1.58), (11.7, 1.88), (14.0, 2.00)

Fraction_of_health_centers_with_capacity_to_provide_EMOC =

Health_units_providing_EMOC/Total_health_units_in_the_country

Health_center_life_span = 50

health_unit_built_per_year = Health_units_providing_EMOC

Increasing_number_of_health_units_providing_EMOC_services =

GRAPH(Avg_increased_capacity_per_health_center)

(0.00, 0.032), (25.0, 0.045), (50.0, 0.168), (75.0, 0.4), (100, 0.4)

midwives_per_health_unit =

Midwives_subsector.Midwives/Total_health_units_in_the_country

proportion_of_health_centers_able_to_provide_EMOC =

Fraction_of_health_centers_with_capacity_to_provide_EMOC*100

Reduction_numbers_of_health_centers_providing_EMOC_services =

GRAPH(Avg_increased_capacity_per_health_center)

(0.00, 0.082), (25.0, 0.054), (50.0, 0.037), (75.0, 0.023), (100, 0.016)

Rehabilitation_made_per_health_center =

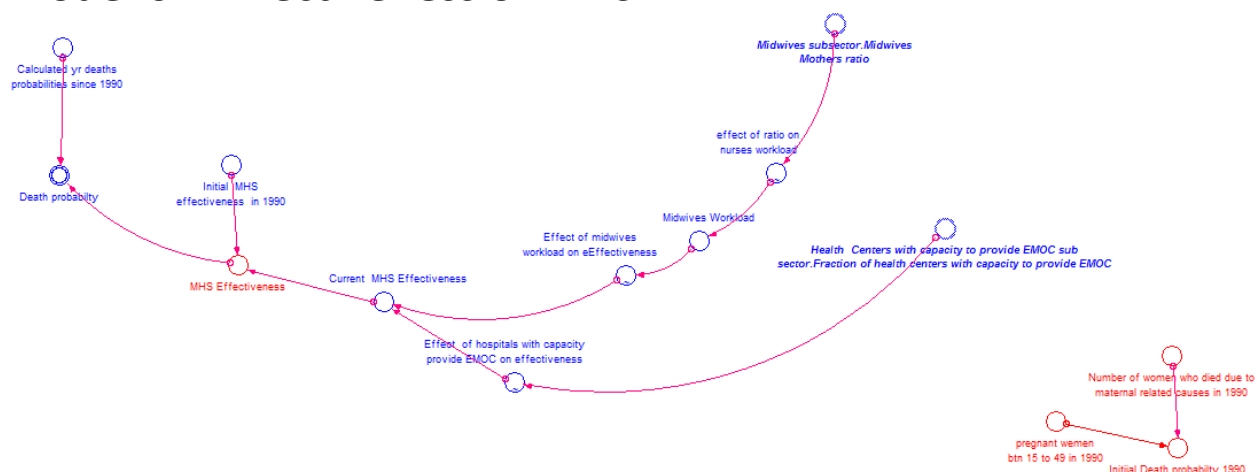
GRAPH(Restoring_functionality_of_Facilities_in_ahealth_unit)

(0.00, 0.137), (25.0, 0.962), (50.0, 2.27), (75.0, 5.09), (100, 8.28)

Total_health_units_in_the_country =

Health_units_providing_EMOC+Health_units_not_providing_EMOC

Model 6: Effectiveness of MHS.



Equations.

Calculated_deaths_probabilities_since1990_up_to_2010 = GRAPH(TIME)
 (1990, 0.683), (1995, 0.682), (2000, 0.6), (2005, 0.54), (2010, 0.42)

Current_MHS_Effectiveness =

Effect_of_hospitals_with_capacity_provide_EMOC_on_effectiveness*Effect_of
 _midwives_workload_on_eEffectiveness

Death_probabilty =

Calculated_deaths_probabilities_since1990_up_to_2010*MHS_Effectiveness

Effect_of_midwives_workload_on_eEffectiveness =

GRAPH(Midwives_Workload)

(0.00, 1.55), (0.5, 1.41), (1.00, 1.07), (1.50, 0.519), (2.00, 0.371)

effect_of_ratio_on_nurses_workload =

GRAPH(Midwives_subsector.Midwives_Mothers_ratio)

(0.00, 0.00), (0.5, 0.5), (1.00, 1.00), (1.50, 1.70), (2.00, 2.50)

Effect_of_hospitals_with_capacity_provide_EMOC_on_effectiveness =

GRAPH(Health_Centers_with_capacity_to_provide_EMOC_sub_sector.Fraction
 _of_health_centers_with_capacity_to_provide_EMOC)

(0.00, 1.01), (2.33, 1.07), (4.67, 1.16), (7.00, 1.25), (9.33, 1.34), (11.7, 1.40), (14.0,
 1.50)

Initial_MHS_effectiveness__in_1990 = 0.004

Initial_Death_probabilty_1990 =

Number_of_women_who_died_due_to_maternal_related_causes_in_1990/pre
 gnant_wemen__btn_15_to_49_in_1990

MHS_Effectiveness =

Initial__MHS_effectiveness__in_1990/Current__MHS_Effectiveness

Midwives_Workload = effect_of_ratio_on__nurses_workload

Number_of_women_who_died_due_to_maternal_related_causes_in_1990 =
600

pregnant_wemen__btn_15_to_49_in_1990 = 878