**Goal 3: Ensure Healthy Lives and Promote Well-Being for all at all Ages (by Reducing the Global Maternal Mortality Ratio)**

**Sarah Mashhadi, Evans Anane, Aman Prasad Shrestha**

**Executive summary**

The scope of this study is identifying an effective strategy to achieve Goal 3 of United Nations Sustainable Development Goals (SDGs) to help the government of Zambaqui to align its national development plan with the 2030 Agenda. The special focus here is reducing the maternal mortality and ensuring that the number of skilled birth attendance pregnancy and childbirth increases. The maternal mortality is a result of complications before (pregnancy), during and after delivery. Unavailable, inaccessible, and unaffordable health services besides the illiteracy and poverty drive the maternal mortality further. In developing countries with the highest maternal mortality rates, a mother’s death is much more than an emotional disaster, often leading to long-term social and economic breakdown, both for her close family and the community. Therefore, it has critical importance to investigate the problem and design policies to implement by the government to take the maternal mortality under control. In Zambaqui, access to basic health care is very poor and the transportation to the health centres in emergencies is relatively difficult. People are mostly uneducated and the family’s income is not growing over time. The majority of deliveries are at home and the maternal mortality rate is considerably higher than the average maternal mortality rate of the world. The recommended policy after analysis of the problem with system dynamics modelling is to construct new health centres to increase the access to the basic health care to 100% and equip the health centres with at least one ambulance. Along with, the skilled health care personnel should be increased to ensure that each pregnant woman can receive help and information by skilled health personnel. The Zambaqui Government should consider required an extra expenditure for implementing these policies in the health sector expenditure.

**Introduction**

When a woman is pregnant with her first child, it’s exciting to think about holding the baby for the first time and all the beautiful moments they will have together. But it can also be scary since pregnancy and childbirth is unpredictable. Many soon-to-be moms worry about childbirth, anesthesia, and complications. It is even normal to consider the chances of dying.

Pregnant women can die because of the complications during and following pregnancy and childbirth. Most of these complications which develop during pregnancy are preventable or treatable if pregnant women are examined regularly. About 75% of all maternal deaths are resulted due to the following major complications (Keskin et al, 2018):

* Severe bleeding (mostly bleeding after childbirth)
* Infections (usually after childbirth)
* High blood pressure during pregnancy (pre-eclampsia and eclampsia)
* Complications from delivery
* Unsafe abortion

The remainder is caused by or associated with diseases such as malaria, and AIDS during pregnancy.

Because of these complications associated with pregnancy and child delivery and resulting in a considerable number of pregnant women deaths, there is a need to focus on reducing maternal mortality. When a woman dies from anything having to do with pregnancy, it is called maternal mortality or maternal death. According to the World Health Organization (WHO), maternal death can happen while a woman is pregnant, during labour and delivery, or in the 42 days after childbirth or the termination of pregnancy. If a woman passes away from an accident or a health issue that doesn't have anything to do with the pregnancy, then it is not considered a pregnancy-related death.

WHO defines the maternal mortality rate as the ratio of the recorded (or estimated) number of maternal deaths by total recorded (or estimated) number of live births in the same period and multiplying by 100,000 2). Maternal mortality has a lot of contributing factors which can be categorized as follows per review of the literature: Lack of access to the health care, inadequate skilled health care personnel, lack of information, poverty, and cultural practices. Factors such as a few numbers of the health centres, ambulances and poor road infrastructure increase the number of the child deliveries at home which can lead to more maternal mortality (Girum and Wasie, 2017).

Due to the complications in pregnancy and child delivery, thousands of women die every year and a large proportion of them are from the developing countries (Figure 1). The African continent has the highest maternal deaths in the world which is approximately 62% of all maternal deaths worldwide (Kalipeni et. al, 2017).

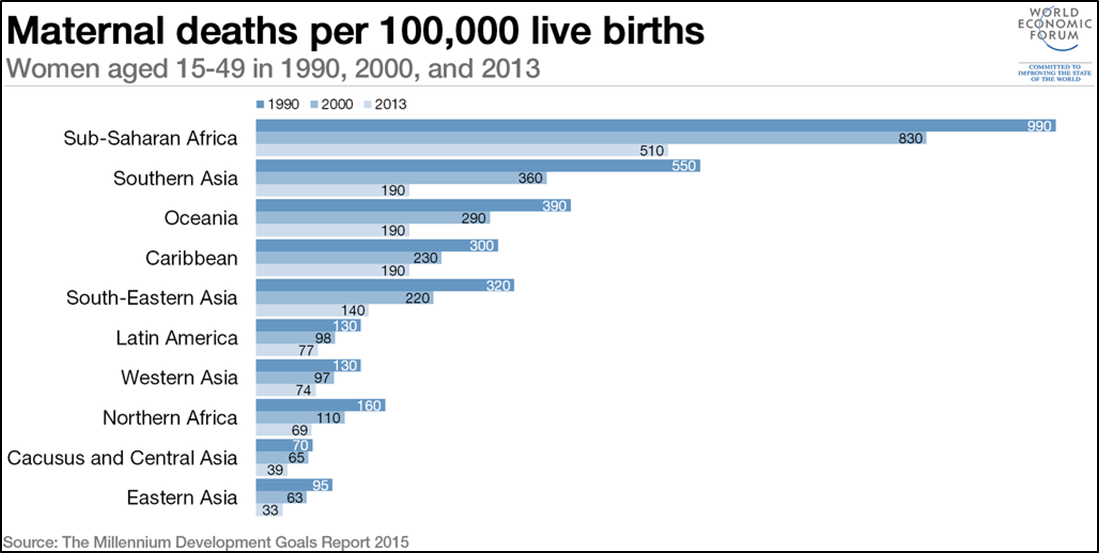


Figure 1: Maternal death per 100,000 live births in women aged 15-49 in 1990, 2000 and 2013, according to the Millennium Development Goals Report 2015.

In recent years, significant development has been made, but notable challenges remain. Sexual and reproductive health care is not accessible by many women around the world. According to the reports by UNICEF, about 800 women die every day from complications related to pregnancy and childbirth. In Eastern Asia, Northern Africa and Southern Asia, maternal mortality has reduced to around one-third. But developing regions still have maternal mortality ratio 14 times higher than the developed regions. Countries have now united behind a new target for even further decrease in maternal mortality as one of the targets of SDGs Goal 3 (Figure 2) is to reduce the global maternal mortality ratio to less than 70 per 100,000 live births by 2030, with minimizing the number of countries having a maternal mortality rate of more than twice the global average. According to the United Nations Sustainable Development Goals, if all babies are delivered with the assistance of a skilled birth attendant the maternal mortality will be reduced substantially. Medical doctors, nurses or midwives are accounted as the skilled health care personnel.

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Figure 2: Goal 3 of SDGs, ensure healthy lives and promote well-being for all at all ages, by reducing the global maternal mortality ratio, from the UN website.

**Model Introduction and Documentation**

The maternal mortality in Zambaqui, a developing country in Africa (Figure 3), is investigated here by use of the system dynamics modelling and by considering the major effective factors on the maternal mortality rate. Complete information about the model variables is in the appendix.

Figure 3: Zambaqui map, a virtual developing country in Africa.

The variable ***Maternal Mortality Rate*** in the model is affected by the ***Fraction of Total Delivery at Health Centres, PC Real Disposable Income, Average Adult Literacy Rate, Skilled Healthcare Personnel Coverage*** and ***Average Number of the Infected Fertile Women.*** Based on the elasticity of the ***Maternal Mortality Rate*** to these variables, the effects of them have been defined (Table 1).

Even though causes of maternal mortality are health-related complications, unavailable, inaccessible, and unaffordable health services drive maternal mortality rate. Therefore, if the ***Fraction of Total Delivery at Health Centres*** increases, the maternal mortality will decrease. If the health centres are accessible equally for the whole country and in reasonable quality, the ***Fraction of Total Delivery at Health Centres*** will increase. To maximize the potential benefits of maternity care services, pregnant women need to be able to physically get to health facilities in a timely manner. In most of sub–Saharan Africa, transport represents a major practical barrier. So, ***Fraction of Total Delivery at Health Centres*** is affected by ***Access to Basic Health Care, Ambulances*** and ***km of Roads per Million ha.***

Table 1: List of the elasticities used for the calculation of effects of different variables.

|  |  |
| --- | --- |
| **List of Elasticities Used in the Model** | **Value** |
| Elasticity of Maternal Mortality Rate to Delivery at Health Centre | -0.3 |
| Elasticity of Maternal Mortality Rate to Skilled Health Personnel Coverage | -0.25 |
| Elasticity of Maternal Mortality Rate to PC Real Disposable Income | -0.1 |
| Elasticity of Maternal Mortality Rate to Average Adult Literacy Rate | 0.1 |
| Elasticity of the Maternal Mortality Rate to Average Infected Fertile Women | 0.5 |
| Elasticity of Fraction of Total Delivery at Health Centres to Access to Basic Health Care | 0.32 |
| Elasticity of Transportation to Health Centres to Road per Million ha | 0.3 |
| Elasticity of Transportation to Health Centres to Ambulance | 0.3 |

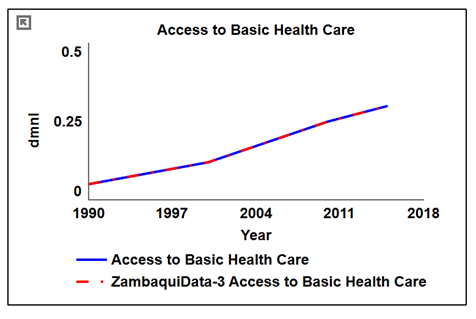
Evidence shows that early and regular attendance of antenatal care and delivery in a health facility under the supervision of trained personnel is associated with improved maternal health outcomes. The highest number of maternal deaths has been reported in countries where women are least likely to deliver their babies with the assistance of skilled practitioners, such as a nurse, midwife, doctor and other health workers. Therefore, the effect of attendance by health care personnel should be considered. A variable of ***Skilled Healthcare Personnel Coverage*** has been introduced in the model which is defined as the ratio of the ***Skilled Healthcare Personnel*** to the ***Pregnant Women.*** This coverage shows how many birth attendants are available for each pregnant woman. Higher coverage shows more accessible to health personnel.The ***Skilled Healthcare Personnel*** is fed by the ***Graduation Rate*** of ***Healthcare Trainees***.

Socioeconomic risk factors almost always accompany the growth and development of maternal mortality related conditions. Literacy and poverty are important socioeconomic effective factors on maternal mortality.

Poverty is often identified as a major barrier to human development. It is also a powerful brake on accelerated progress toward the Millennium Development Goals. Poverty is also a major cause of maternal mortality, as it prevents many women from getting proper and adequate medical attention and limit their access to quality health care due to their inability to afford good antenatal care. Also, poverty causes that women do not have access to proper food and it affects their lifestyle. It causes many diseases before and during pregnancy and makes a higher risk for maternal mortality (Lanre-Abass, 2008). It is the reason that the ***Effect of the PC Real Disposable Income to the Maternal Mortality Rate*** has been designed in the model.

Literate women are less likely to experience poverty, more likely to maintain adequate nutritional status and make decisions with respect to health and well-being, access and use information, and have fewer children. These improvements in female literacy can reduce maternal mortality (Pillai et al., 2013). The ***Effect of the Average Adult Literacy Rate to the Maternal Mortality Fraction*** has been designed in the model to show the effect of the literacy on maternal mortality.

Mothers who are HIV positive are also 10 times more likely to die than mothers who are HIV negative (Lathrop et al., 2014). So, the effect of the mother’s infection should be considered during the investigating of the ***Maternal Mortality Rate*** and ***Effect of the Infection of the Fertile Women on the Maternal Mortality Rate*** has been created in the model.

**Base Run Description**

***Access to Basic Health Care*** is increasing from 5% in 1990 to about 32% in 2018. Figure 4 shows a good calibration between the simulated ***Access to Basic Health Care*** and the Zambaqui data. Despite the increasing trend, access to basic health care is still low in Zambaqui because just 32% of the population has access to basic health care. This low number can show the unequal distribution of the health centres in the country and the lack of access to the health centres in some rural and remote areas.

Figure 4: Changes in **Access to Basic Health Care**

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Description generated with very high confidenceHowever, the number of ***Ambulances*** is increasing from 1990 to 2018 but the access to the ambulances is poor and according to the changes in ***Working Ambulance per Health Centre*** in 2018 one ambulance should cover about 40 health centres. Clearly, people cannot account on the ambulances in emergency situations. The only available data is that Zambaqui had 21 ambulances in 2014 and the result of the model verifies that (Figure 5).

Figure 4: Changes in **Working Ambulance per Health Centre.**

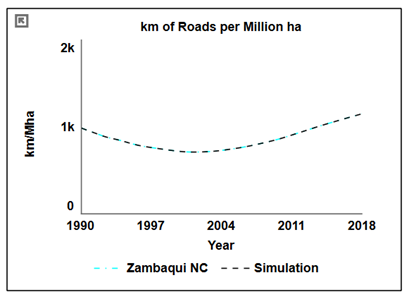
The ***km of Roads per Million ha*** reaches to 1150 km/Mha in 2018 which is much lower than the road density in developed countries such as Norway (3000 km/Mha) and even the developing countries such as Nigeria (2100 km/Mha). A good calibration exists between the simulated ***km of Roads per Million ha*** and Zambaqui data (Figure 6).

Figure 5: Changes in **km of Roads per Million ha.**

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Description generated with very high confidenceTherefore, in Zambaqui the health centres have not distributed equally in the country, the health centres are not equipped with even one ambulance and the roads are in low quality and low density. These conditions lead a major portion of the deliveries are at home. Figure 7 shows the ***Fraction of Total Delivery at Health Centres*** is 25% which can be interpreted that the majority of the women do not go to the health centres for the delivery.

Figure 6: Changes in **Fraction of Total Delivery at Health Centres.**

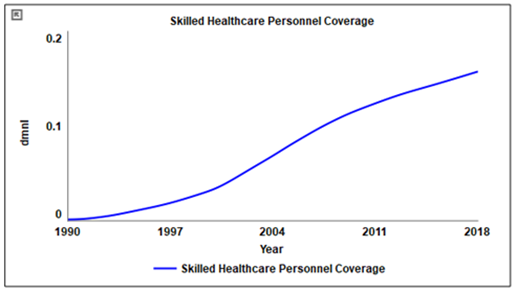
The ***Skilled Healthcare Personnel Coverage*** has also an increasing trend but in 2018 just 16% of the pregnant women can be attended by existing skilled health care personnel in comparison to the average 70 skilled personnel for 100 pregnant women in the world (Figure 8).

Figure 7: Changes in **Skilled Healthcare Personnel Coverage**

The ***Average Adult Literacy Rate*** reaches to just about 33% in 2018 which shows that most of the population are not literate. ***PC Real Disposable Income*** is decreasing in the period of 1990 to 2018 and means that no improvement has been made to decrease the poverty in Zambaqui (Figure 9).

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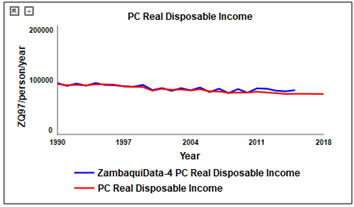
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Figure 8: Changes in **Average Adult Literacy Rate** and **PC Real Disposable Income**.

Figure 10 shows that the ***Maternal Mortality Rate*** is decreasing by time (from 0.01 in 1990 to 0.0052 in 2018). In the current condition that people are not educated, they have low income and child deliveries are mainly at home without the help of skilled birth attendance, the maternal mortality rate is considerably higher than the average maternal mortality in the world (0.002).

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Figure 9: Changes in **Maternal Mortality Rate** and **Dead Women due to the Maternal Mortality**.

**Description of Alternative Scenarios and Analysis of Results**

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Description generated with very high confidenceMaternal mortality is widely accepted as an important indicator of the sociocultural, political and economic philosophy of society. The figure shows one example of the effects of maternal mortality on the economy of a country. It is important to focus on the economic influences of maternal mortality rate on Gross Domestic Product (GDP) as a key economic indicator of the development. Different studies also have demonstrated that maternal mortality has a statistically significant negative effect on GDP (Kirigia et.al, 2006). The CLD in Figure 11 consists of 6 reinforcing loops which show the relationship between Goal 3 and other sectors. The mortality of mothers causes a reduction in the active labour force. Lower labour force decreases the GDP. Lower GDP means a lower expenditure for the health, education and roads and lower PC real disposable income. In this situation, the access of the people to the basic health care decreases and at the same time there is not enough ambulances and functioning roads in the country and there will be a lack of the skilled personnel in the health centres. Therefore, people are less educated, they have lower income and it is not easy to go to the health centres. As a result, the number of deliveries at home increases which leads to more maternal mortality.

Figure 10: Causal Lopp Diagram (CLD)

**Recommended Policies**

According to the results of the modelling, the maternal mortality in Zambaqui is considerably higher than the average maternal mortality in the world. For achieving the Goal 3 of SDGs and reducing the maternal mortality to an acceptable level, two policies are recommended here, and the results are compared. The policy deadline is set as 2030 to be in accordance with the 2030 Agenda for SDGs.

**Policy 1: Increasing the Skilled Healthcare Personnel Coverage**

This policy is based on the increasing the ratio of the skilled health care personnel to the pregnant women or the ***Skilled Healthcare Personnel Coverage*** because if the deliveries are attendant by doctors, midwives and nurses the risk of the maternal mortality decreases considerably. The current coverage in Zambaqui is 22% which is very low comparing to developed countries in the world. For having more skilled health care personnel, the Zambaqui government needs to spend extra expenditure on training the required personnel.

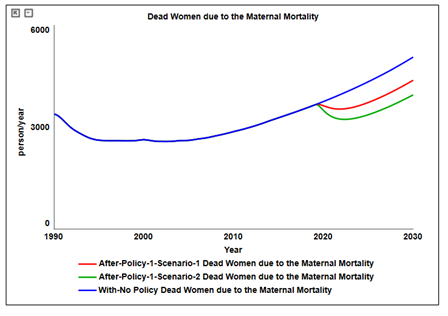
**Scenario 1-Policy 1**

The coverage goal in this scenario is 50% which means that 1 skilled personnel is attending 2 pregnant women. Figures 12 shows the changes in the model behaviour after applying this policy. The ***Maternal Mortality Rate*** decreases from 0.00524 to 0.00466 in 2030 after implementing the scenario 1 and the extra required an expenditure for this scenario is 2,929,580,000 ZQ/year.

**Scenario 2-Policy 1**

In scenario 2, the ***Skilled Healthcare Personnel Coverage*** is further increased to 100% which means that each pregnant woman can be supported by one skilled health care personnel. As Figure 12 shows, the Maternal Mortality Rate decreases from 0.00524 to 0.00406 in 2030 after scenario 2. The extra required expenditure for this policy is 13,965,000,000 ZQ/year.

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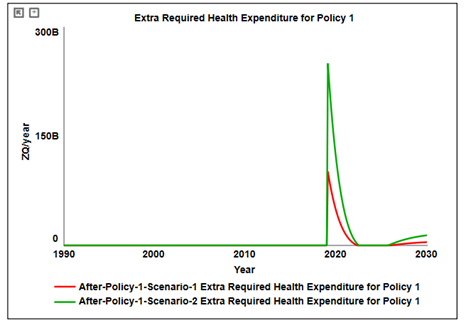
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Figure 11: Changes in **Maternal Mortality, Dead Women Due to Maternal Mortality, Skilled Health Care Personnel Coverage** and **Extra Required Health Expenditure** after policy 1 (Scenarios 1 and 2).

**Policy 2**

Policy 2 is targeted at increasing ***Access to Basic Health Care*** and ***Ambulance*** during antenatal care, child delivery and emergency to transfer pregnant women to improved health facilities. The source of funding for this policy is the extra required health expenditure afforded by the Zambaqui government. This extra required expenditure has been calculated in the model and linked to the government sector model. The goal is to increase ***Access to Basic Health Care*** by 100% by building required health centres and equipping the health centres by one ambulance. As health centres increases, the number of ambulances should increase at the same time. By this policy the coverage area of the health centres increases. In the current situation, only 33% of the population have access to the health centres and the goal of policy 2 makes it accessible to 100% of the population.

Figure 13 shows the result of implementing Policy 2. The ***Maternal Mortality Rate*** decreases from 0.00524 in 2030 to 0.00359 after implementing Policy 2. The extra required an expenditure for this policy for purchasing ambulances is 13,965,000,000 ZQ/year and for health centres construction is 89,722,100,000 ZQ/year.

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Figure 12: Changes in **Access to Basic Health Care, Working Ambulance per Health Center and Maternal Mortality Rate** after policy 2.

**Comparison of two policies**

If more skilled personnel are covering the pregnant women or more health centres are constructed and equipped with the ambulances the maternal mortality will be decreased. Figure 14 shows that Policy 2 is more expensive to implement than Policy 1. Our suggested policy here is to combine the policies 1 and 2 and implement them at the same time. The expenditure of the Policy 1 is much lower than the required extra expenditure for the Policy 2 and their combination causes more decrease in the maternal mortality rate reaching to 0.003 without any significant change in the expenditures. In addition, if new health centres are constructed and new ambulances are purchased but enough doctors, nurses and midwives are not available to help the pregnant women the policy cannot reach the goal perfectly. Tables 2 and 3 compare the changes in ***Maternal Mortality Rate*** and required an extra expenditure for with and without policy conditions. As Figure 14 shows the extra required expenditure has a sharp increase at the beginning of the policy implpementaion but by closing the gap and achieveing the goal this exoenditure decreases considerably. It should be considered that this extra expenditure is different from the usual expenditure used for health sector. It is noticeable that the applying these two policies are not just beneficial for the pregnant women but for all the people of the country because the health centres are more accessible for all the population, there are more ambulances for emergency situations and people can receive help from doctors and skilled personnel easier than before.

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Figure 13: Comparsion of changes in ***Dead Women Due to Maternal Mortality, Required Health Expenditure*** and ***Maternal Mortality Rate*** for before policy and after policies 1 and 2 and the combination of two policies.

Table 2: Comparison of ***Maternal Mortality Rate*** with and without policies.

|  |  |
| --- | --- |
| Policy | Maternal Mortality Rate |
| Without Policy | 0.0052 |
| With Policy 1 Scenario 1 | 0.0047 |
| With Policy 1 Scenario 2 | 0.0041 |
| With Policy 2 | 0.0036 |
| Combination of Policy 1 and Policy 2 | 0.0030 |

Table 3: List of the required extra expenditure for different policies.

|  |  |
| --- | --- |
| Policies | Extra Expenditure for Different Policies (ZQ/year) |
| Policy 1 Scenario 1 (With 50% Skilled Health Care Coverage Goal) | 2,929,580,000 |
| Policy 1 Scenario 2 (With 100% Skilled Health Care Coverage Goal) | 13,965,000,000 |
| Policy 2 Purchasing Ambulance | 12,565,500,000 |
| Policy 2 Construction of Health Centres | 89,722,100,000 |
| Total | 119,182,180,000 |

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**Appendix**

Goal\_3:

Ambulances(t) = Ambulances (t - dt) + (Purchasing - Depreciation) \* dt {NON-NEGATIVE}

INIT Ambulances = 1

UNITS: ambulance

Documentation: The stock of ambulance is defined by the difference between the inflow of purchasing the ambulance and the outflow of depreciation of the ambulance over the time of its use.

INFLOWS:

Purchasing = DELAYN (Expenditure for Purchasing Ambulances/ Price of One Ambulance, Time to Purchase, 2) {UNIFLOW}

UNITS: ambulance/Year

Documentation: The inflow purchasing is the outcome of the total expenditure of purchasing the ambulance over the price per ambulance and time taken to purchase the ambulance with delay.

OUTFLOWS:

Depreciation = Ambulances/ Life Time of the Ambulance {UNIFLOW}

UNITS: ambulance/Year

Documentation: The outflow is the result of the ambulance over its lifetime.

Healthcare Trainees(t) = Healthcare Trainees (t - dt) + (Training Rate – Graduation Rate – Dropout Rate) \* dt {NON-NEGATIVE}

INIT Healthcare Trainees = 45

UNITS: person

Documentation: The stock of healthcare trainees changes by the difference of the training rate, graduation rate and dropout rate.

INFLOWS:

Training Rate = Expenditure for the Healthcare Personnel Training/ Cost of Training per Healthcare Personnel {UNIFLOW}

UNITS: person/year

Documentation: The training rate is defined as the ratio of expenditure on training to the cost of training.

OUTFLOWS:

Graduation Rate = Healthcare Trainees/ Average Time to Graduate {UNIFLOW}

UNITS: person/year

Documentation: The outflow of the stock is the graduation rate. It means the number of trainees graduating over the period.

Dropout Rate = Healthcare Trainees\* Dropout Fraction {UNIFLOW}

UNITS: person/year

Documentation: The rate of dropout is calculated through the number of healthcare trainees’ times the dropout fraction.

Skilled Healthcare Personnel(t) = Skilled Healthcare Personnel (t - dt) + (Graduation Rate - Retirement) \* dt {NON-NEGATIVE}

INIT Skilled Healthcare Personnel = 270

UNITS: person

Documentation: According to the data provided, initially there are 90 health centres and each centre has 3 personnel including 2 nurses and 1 doctor which becomes totally 270 skilled personnel.

INFLOWS:

Graduation Rate = Healthcare Trainees/ Average Time to Graduate {UNIFLOW}

UNITS: person/year

Documentation: This inflow is the outcome of the health trainees over the time it takes to graduate.

OUTFLOWS:

Retirement = Skilled Healthcare Personnel/ Average Working Duration Before Retirement {UNIFLOW}

UNITS: person/year

Documentation: The outflow is the skilled healthcare personnel over the average time duration of working before retirement.

Ambulance Adjustment Rate = Number of Ambulance Gap/ Time\_to\_Achieve\_the\_Policy\_2\_Goal

UNITS: ambulance/year

Documentation: The adjustment rate is the rate which decreases the gap between the desired number of ambulance and the current number of ambulances.

Average Infected Fertile Women = POP.Women in Fertile Age\* Fertile Women Fraction with HIV

UNITS: person/year

Documentation: About 60% of fertile women in Zambaqui are HIV positive. It is calculated with the multiplication of the fertile age women to 0.6.

Average Time of Abortion = 0.15

UNITS: year

Documentation: In 2003, the Centres for Disease Control and Prevention (CDC) reported that 26% of reported legal induced abortions in the United States were known to have been obtained at less than 6 weeks' gestation, 18% at 7 weeks, 15% at 8 weeks, 18% at 9 through 10 weeks, 10% at 11 through 12 weeks, 6% at 13 through 15 weeks, 4% at 16 through 20 weeks and 1% at more than 21 weeks. Average Time of Abortion is calculated based on this data.

Average Time of Pregnancy = 0.725

UNITS: year

Documentation: The pregnancy time can vary from 6 to 9 month. The average in a year is calculated here.

Average Time to Graduate = 5

UNITS: year

Documentation: It is the average time for the graduation of the skilled healthcare trainees.

Average Working Duration Before Retirement = 30

UNITS: year

Documentation: It is the average time before the skilled healthcare trainees retire from the work.

Cost of Training per Healthcare Personnel = 160000

UNITS: ZQ97/person

Documentation: It is the total cost of individuals who is trained to be health care personnel.

Dead Women due to the Maternal Mortality = Live Birth\* Maternal Mortality Rate

UNITS: person/year

Documentation: It is the result of the multiplication of live birth to the maternal mortality rate. This equation is based on the definition of the Maternal Mortality Rate.

Desired Expenditure for Purchasing Ambulances = Desired Purchasing Rate\* Price of One Ambulance

UNITS: ZQ97/year

Documentation: It is the required expenditure for purchasing ambulance according to the Policy-2 goal of the ambulance to health centre ratio.

Desired Expenditure for the Healthcare Personnel Training = Desired Training Rate\* Cost of training per Healthcare Personnel

UNITS: ZQ97/year

Documentation: It is the required expenditure for training skilled personnel according to the Policy-1 goal of skilled personnel coverage.

Desired Fraction of the Health Expenditure for Transportation = Desired Health Centres Transportation Expenditure/ (GOV.Health Expenditure/GDP.GDP Deflator)

UNITS: dmnl

Documentation: The expenditure for purchasing the ambulances is a fraction of the health expenditure. The desired fraction of the health expenditure which is required for the purchasing ambulances to reach the goal of policy 2.

Desired\_Fraction\_of\_the\_Healthcare\_Expenditure\_Using\_for\_the\_Healthcare\_Personnel\_Training = Desired\_ Expenditure\_ for \_the\_ Healthcare\_ Personnel\_ Training\* GDP.GDP\_ Deflator/ GOV.Health\_ Expenditure

UNITS: dmnl

Documentation: It is the desired fraction of healthcare expenditure used for the training healthcare personnel to reach the goal of policy 1.

Desired\_ Graduation\_ Rate = Skilled \_Healthcare \_Personnel\_ Adjustment Rate+ Retirement

UNITS: person/year

Documentation: It is the sum of the adjustment rate of skilled health personnel and retirements.

This rate is defined based on the goal of policy 1.

Desired\_ Health \_Centres \_Transportation \_Expenditure = Desired\_ Expenditure for\_ Purchasing \_Ambulances+ Running\_ Cost\_ of\_ the \_Ambulance\_ Services

UNITS: ZQ97/year

Documentation: It is the sum of the desired expenditure for purchasing the ambulance and the maintenance cost of the ambulance.

Desired\_ Healthcare \_Trainees = Desired \_Graduation \_Rate\* Average \_Time \_to \_Graduate

UNITS: person

Documentation: This is the required number of trainees to reach the goal of policy 1 to increase the skilled health care personnel coverage.

Desired Number \_of \_the \_Ambulances = Desired \_Working \_Ambulances/ Proportion\_ of \_Working \_Ambulance

UNITS: ambulance

Documentation: The desired number of ambulances to reach the policy 2 goals of having one ambulance for each health centre.

Desired\_ Purchasing \_Rate = Ambulance\_ Adjustment \_Rate+ Depreciation

UNITS: ambulance/year

Documentation: The sum of ambulance adjustment rate and the depreciation of the ambulance results in the desired rate in which the ambulance is purchased.

Desired\_ Training\_ Rate = Healthcare \_Trainees \_Adjustment \_Rate+ Dropout \_Rate+ Graduation \_Rate

UNITS: person/year

Documentation: We generally expect all the other flows to continue as is, and we should take them into account to prevent the steady state error.

Desired Working \_Ambulance \_per \_Health\_ Centre = 1

UNITS: centre/ambulance

Documentation: The desired working ambulance per health centre is 1 which is the goal of the policy 2 to have one ambulance for each health centre.

Desired Working Ambulances = HLT. Health Centres\* Desired \_Working \_Ambulance\_ per\_ Health Centre

UNITS: ambulance

Documentation: This equation shows that the number of health centre times the desired working ambulance per health centres results in a desired working ambulance.

Dropout\_ Fraction = 0.01

UNITS: dmnl/year

Documentation: It is the rate of dropout fraction of the healthcare trainees.

Effect\_of\_the\_Access\_to\_Basic\_Health\_Care\_on\_Fraction\_of\_Total\_Delivery\_at\_Health\_Centres = (HLT.Access\_to\_Basic\_Health\_Care/ INIT(HLT.Access\_to\_Basic\_Health\_Care))^ Elasticity\_of\_Maternal\_Mortality\_to\_Access\_to\_Basic\_Health\_Care

UNITS: dmnl

Effect\_of\_the\_Average\_Adult\_Literacy\_Rate\_to\_the\_Maternal\_Mortality\_Fraction = (EDU.Average\_Adult\_Literacy\_Rate/ INIT(EDU.Average\_Adult\_Literacy\_Rate))^ Elasticity\_of\_the\_Maternal\_Mortality\_Fraction\_to\_the\_Average\_Adult\_Literacy\_Rate

UNITS: dmnl

Effect\_of\_the\_Delivery\_at\_Health\_Centres\_on\_Maternal\_Mortality\_Rate = (Fraction\_of\_Total\_Delivery\_at\_Health\_Centres/ INIT(Fraction\_of\_Total\_Delivery\_at\_Health\_Centres))^ Elasticity\_of\_Maternal\_Mortality\_to\_Delivery\_at\_Health\_Centre

UNITS: dmnl

Effect\_of\_the\_Infection\_of\_the\_Fertile\_Women\_on\_the\_Maternal\_Mortality\_Rate = (Average\_Number\_of\_the\_Infected\_Fertile\_Women/ INIT(Average\_Number\_of\_the\_Infected\_Fertile\_Women))^ Elasticity\_of\_the\_Maternal\_Mortality\_Fraction\_to\_The\_Number\_of\_the\_Infected\_Fertile\_Women

UNITS: dmnl

Effect\_of\_the\_PC\_Real\_Disposable\_Income\_to\_the\_Maternal\_Mortality\_Rate = (HHS.PC\_Real\_Disposable\_Income/ INIT(HHS.PC\_Real\_Disposable\_Income))^ Elasticity\_of\_the\_Maternal\_Mortality\_Fraction\_to\_the\_PC\_Real\_Disposable\_Income

UNITS: dmnl

Effect\_of\_the\_Skilled\_Healthcare\_Personnel\_Coverage\_on\_the\_Death\_in\_Hospital = (Skilled\_Healthcare\_Personnel\_Coverage/ INIT(Skilled\_Healthcare\_Personnel\_Coverage))^ Elasticity\_of\_the\_Death\_in\_Hospital\_to\_the\_Skilled\_Healthcare\_Personnel\_Coverage

UNITS: dmnl

Effect\_of\_the\_Skilled\_Healthcare\_Personnel\_on\_Maternal\_Mortality\_Rate = (Skilled\_Healthcare\_Personnel\_Coverage/ INIT(Skilled\_Healthcare\_Personnel\_Coverage))^ Elasticity\_of\_Maternal\_Mortality\_Fraction\_to\_the\_Skilled\_Healthcare\_Personnel\_Coverage

UNITS: dmnl

Effect\_of\_the\_the\_Road\_per\_Million\_ha\_on\_Transportation = (IFR.km\_of\_Roads\_per\_Million\_ha/ INIT(IFR.km\_of\_Roads\_per\_Million\_ha))^ Elasticity\_of\_Transportation\_to\_the\_Road\_per\_Million\_ha

UNITS: dmnl

Effect\_of\_the\_Transportation\_on\_Fraction\_of\_Total\_Delivery\_at\_Health\_Centres = Effect\_of\_the\_Working\_Ambulance\_per\_Health\_Centre\_on\_Transportation\* Effect\_of\_the\_the\_Road\_per\_Million\_ha\_on\_Transportation

UNITS: dmnl

Effect\_of\_the\_Working\_Ambulance\_per\_Health\_Centre\_on\_Transportation = Relative\_Working\_Ambulance\_per\_Health\_Centre^ Elasticity\_of\_Transportation\_to\_the\_Access\_to\_Ambulance

UNITS: dmnl

Elasticity\_of\_Maternal\_Mortality\_Fraction\_to\_the\_Skilled\_Healthcare\_Personnel\_Coverage = -0.15

UNITS: dmnl

Elasticity\_of\_Maternal\_Mortality\_to\_Access\_to\_Basic\_Health\_Care = 0.32

UNITS: dmnl

Elasticity\_of\_Maternal\_Mortality\_to\_Delivery\_at\_Health\_Centre = -0.3

UNITS: dmnl

Elasticity\_of\_the\_Death\_in\_Hospital\_to\_the\_Skilled\_Healthcare\_Personnel\_Coverage = -0.25

UNITS: dmnl

Elasticity\_of\_the\_Maternal\_Mortality\_Fraction\_to\_the\_Average\_Adult\_Literacy\_Rate = -0.1

UNITS: dmnl

Elasticity\_of\_the\_Maternal\_Mortality\_Fraction\_to\_The\_Number\_of\_the\_Infected\_Fertile\_Women = 0.5

UNITS: dmnl

Elasticity\_of\_the\_Maternal\_Mortality\_Fraction\_to\_the\_PC\_Real\_Disposable\_Income = -0.1

UNITS: dmnl

Elasticity\_of\_Transportation\_to\_the\_Access\_to\_Ambulance = 0.3

UNITS: dmnl

Elasticity\_of\_Transportation\_to\_the\_Road\_per\_Million\_ha = 0.3

UNITS: dmnl

Expenditure\_for\_Purchasing\_Ambulances = MAX(0, Health\_Centres\_Transportation\_Expenditure- Running\_Cost\_of\_the\_Ambulance\_Services)

UNITS: ZQ97/year

Expenditure\_for\_the\_Healthcare\_Personnel\_Training = IF Policy\_1\_Status=0 THEN (GOV.Health\_Expenditure\* Fraction\_of\_the\_Healthcare\_Expenditure\_Using\_for\_the\_Healthcare\_Personnel/ GDP.GDP\_Deflator) ELSE (GOV.Health\_Expenditure\* Desired\_Fraction\_of\_the\_Healthcare\_Expenditure\_Using\_for\_the\_Healthcare\_Personnel\_Training/ GDP.GDP\_Deflator)

UNITS: ZQ97/year

Documentation: This is the normal expenditure (before any policy) which the government spends for the health care personnel training.

Extra\_Required\_Health\_Centres\_Transportation\_Expenditure\_After\_Policy\_2 = IF Policy\_2\_Status=1 THEN MAX(0, (Desired\_Fraction\_of\_the\_Health\_Expenditure\_for\_Transportation- Fraction\_of\_the\_Health\_Expenditure\_for\_Transportation)\* GOV.Health\_Expenditure) ELSE 0

UNITS: ZQ/year

Documentation: Purchasing extra ambulances for policy 2 needs extra expenditure.

Extra\_Required\_Health\_Expenditure\_for\_Policy\_1 = IF(Policy\_1\_Status=1) THEN MAX (0, (Desired\_Fraction\_of\_the\_Healthcare\_Expenditure\_Using\_for\_the\_Healthcare\_Personnel\_Training- Fraction\_of\_the\_Healthcare\_Expenditure\_Using\_for\_the\_Healthcare\_Personnel)\* GOV.Health\_Expenditure) ELSE 0

UNITS: ZQ/year

Documentation: The goal of policy 1 is increasing skilled health care personnel. For reaching this goal, the government should spend extra expenditure on training the new personnel.

Fertile\_ Women\_ Fraction \_with \_HIV = 0.6

UNITS: dmnl/year

Documentation: It is the constant fraction that shows the proportion of HIV infected women among the total fertile women.

Fraction of \_the \_Health\_ Expenditure \_for\_ Transportation = 0.001

UNITS: dmnl

Documentation: It is the constant fraction of the health expenditure which is spent on transportation in normal condition and with no implemented policy.

Fraction\_of\_the\_Healthcare\_Expenditure\_Using\_for\_the\_Healthcare\_Personnel Training = 0.05

UNITS: dmnl

Documentation: It is the constant fraction of the health expenditure which is spent for health personnel training in normal condition and with no implemented policy.

Effect\_of\_the\_Transportation\_on\_Fraction\_of\_Total\_Delivery\_at\_Health\_Centres\* Effect\_of\_the\_Access\_to\_Basic\_Health\_Care\_on\_Fraction\_of\_Total\_Delivery\_at\_Health\_Centres

UNITS: dmnl

Health\_Centre\_Coverage\_per\_Ambulance = HLT.Health\_Centres/ Working\_Ambulances

UNITS: centre/ambulance

Documentation: this number shows that each ambulance should give service to how many hospitals.

Health\_Centres\_Transportation\_Expenditure = IF Policy\_2\_Status=0 THEN (GOV.Health\_Expenditure/ GDP.GDP\_Deflator)\* Fraction\_of\_the\_Health\_Expenditure\_for\_Transportation ELSE (GOV.Health\_Expenditure/ GDP.GDP\_Deflator)\* Desired\_Fraction\_of\_the\_Health\_Expenditure\_for\_Transportation

UNITS: ZQ97/year

Documentation: It is the expenditure which is spent on purchasing and maintaining the ambulances in normal condition and with no implemented policy.

Healthcare \_Trainees \_Adjustment \_Rate = Healthcare \_Trainees \_Gap/ Healthcare \_Training \_Adjustment \_Time

UNITS: person/year

Documentation: It is the rate of closing gap between the current condition and the goal of policy 1.

Healthcare\_ Trainees \_Gap = Desired \_Healthcare\_ Trainees- Healthcare \_Trainees

UNITS: person

Documentation: The healthcare trainee gap is the difference between the desired healthcare trainees and healthcare trainees.

Healthcare\_ Training \_ Adjustment\_ Time = 1

UNITS: year

Initial\_ running \_Cost\_ of\_ the\_ Ambulance\_ Services = 130000

UNITS: ZQ97/ambulance/year

Documentation: It is the initial running cost of the ambulance service. There was no data available for Zambaqui and the data of Kenya has been used.

Life \_ Time\_ of\_ the \_Ambulance = 10

UNITS: year

Documentation: It is assumed that the service time of an ambulance is 10 years after which it should be replaced

Live \_ Birth = Total\_ Delivery\* (1-Stillbirth\_Rate)

UNITS: person/year

Documentation: The total deliveries consist of both stillbirth and live birth.

Maternal\_ Mortality \_Rate = 0.0099\* Effect\_of\_the\_Delivery\_at\_Health\_Centres\_on\_Maternal\_Mortality\_Rate\* Effect\_of\_the\_Skilled\_Healthcare\_Personnel\_on\_Maternal\_Mortality\_Rate\* Effect\_of\_the\_Average\_Adult\_Literacy\_Rate\_to\_the\_Maternal\_Mortality\_Fraction\* Effect\_of\_the\_PC\_Real\_Disposable\_Income\_to\_the\_Maternal\_Mortality\_Rate\* Effect\_of\_the\_Infection\_of\_the\_Fertile\_Women\_on\_the\_Maternal\_Mortality\_Rate

UNITS: dmnl

Documentation: The initial value (the data for Kenya has been used) times effect of the delivery at health centres on maternal mortality rate, effect of the skilled healthcare personnel on maternal mortality rate, effect of the average adult literacy rate to the maternal mortality fraction, effect of the pc real disposable income to the maternal mortality rate and effect of the infection of the fertile women on the maternal mortality rate.

Number\_ of\_ Ambulance \_Gap = Desired \_Number \_of\_ the\_ Ambulances- Ambulances

UNITS: ambulance

Percentage \_of \_all\_ pregnancies\_ ending \_in \_abortion = 0.2

UNITS: dmnl

Documentation: According to reports, 20% of all pregnancy ends up in abortion.

Policy\_1\_Start\_Time = 2019

UNITS: year

Policy\_1\_Status = IF(Policy\_1\_Switch=1) AND (Policy\_1\_Start\_Time<TIME) THEN (1) ELSE (0)

UNITS: dmnl

Policy\_2\_Status = IF(Policy\_2\_Switch=1) AND (Policy\_2\_Start\_Time<TIME)THEN (1) ELSE (0)

UNITS: dmnl

Pregnant Women = POP.Birth\* (Average\_ Time\_ of\_ Pregnancy\* (1-Percentage\_of\_all\_pregnancies\_ending\_in\_abortion)+ (Average \_Time\_ of\_ Abortion\* Percentage \_of\_ all \_pregnancies \_ending \_in \_abortion))

UNITS: person

Documentation: The total birth times the average time of pregnancy and abortion gives the number of pregnant women. 20% of pregnancies end to abortion and remaining to continue till delivery. The abortion time and average pregnancy time has been defined earlier.

Price\_ of \_One \_Ambulance = 5100000

UNITS: ZQ97/ambulance

Documentation: This data was available for Zambaqui in USD and by using the exchange rate and GDP deflator converted to ZQ97/ambulance.

Proportion\_ of\_ the\_ Running\_ Cost \_Covered = MIN(1, Health\_ Centres \_Transportation \_Expenditure/ Running \_Cost \_of \_the \_Ambulance \_Services)

UNITS: dmnl

Documentation: While calculating the proportion of the running cost covered the minimum of 1 or the value that results of the dividing the health centres transportation expenditure overrunning cost of the ambulance services.

Proportion\_of\_Working\_Ambulance = SMTHN(Proportion\_of\_the\_Running\_Cost\_Covered, Time\_for\_Expenditure\_to\_Effect\_the\_Working\_Ambulances, 1, 1 )

UNITS: dmnl

Relative \_ Health \_Centre \_per \_Ambulance = Health \_Centre \_Coverage \_per \_Ambulance/ INIT(Health \_ Centre \_ Coverage \_per \_Ambulance)

UNITS: dmnl

Documentation: The working ambulance over the initial working ambulance per health centre gives the relative working ambulance per health centre.

Relative\_ Working \_Ambulance \_per \_Health \_Centre = Working \_Ambulance \_per \_Health\_ Centre/ INIT(Working\_ Ambulance \_per \_Health \_ Centre)

Documentation: The working ambulance over the initial working ambulance per health centre gives the relative working ambulance per health centre.

UNITS: dmnl

Running\_ Cost\_ of\_ the\_ Ambulance \_Services = Ambulances\* Initial\_ running\_ Cost \_of \_the \_Ambulance\_ Services\* Relative\_ Health \_Centre \_per\_ Ambulance

UNITS: ZQ97/year

Documentation: The total number of ambulance times the initial running cost of the ambulance service times relative health centre per ambulance gives the total amount of cost it takes for running the ambulance service.

Skilled\_ Healthcare \_Personnel\_ Adjustment\_ Rate = Skilled \_Healthcare \_Personnel \_Gap/ Time\_to\_Achieve\_the\_Policy\_1\_Goal

UNITS: person/year

Documentation: The rate of closing gap between the desired and current skilled health care personnel to reach the goal.

Skilled\_ Healthcare\_ Personnel\_ Coverage = Skilled\_ Healthcare\_ Personnel/ Pregnant\_ Women

UNITS: dmnl

Documentation: The coverage is defined by as the ratio of the skilled healthcare personnel to the pregnant women. It is assumed that if the pregnant women have access to the doctors, nurses and midwives and examined regularly, the maternal mortality will be decreased. This coverage shows that how many birth attendants is available for each pregnant woman.

Skilled\_ Healthcare \_Personnel\_ Coverage\_ Goal = 0.5

UNITS: dmnl

Documentation: It shows the goal of policy 1 which is increasing the skilled health care personnel coverage.

Skilled\_ Healthcare \_Personnel\_ Gap = Skilled \_Healthcare\_ Personnel \_Goal- Skilled\_ Healthcare\_ Personnel

UNITS: person

Documentation: The difference between skilled healthcare personnel goal and the current skilled healthcare personnel.

Skilled\_ Healthcare \_Personnel\_ Goal = Pregnant \_Women\* Skilled\_ Healthcare \_Personnel\_ Coverage \_Goal

UNITS: person

Documentation: The pregnant women times skilled healthcare personnel coverage goal defines the goal of skilled healthcare personnel. It gives the ration of skilled health personnel to pregnant women.

Stillbirth \_Rate = 0.03

UNITS: dmnl

Documentation: It is the constant fraction and the data was given for the Zambaqui.

Time\_ for \_Expenditure \_to \_Effect \_the \_Working \_Ambulances = 1

UNITS: year

Documentation: This depicts that it takes 1 year for expenditure to affect the working ambulance.

Time\_to\_Achieve\_the\_Policy\_1\_Goal = 3

UNITS: year

Time\_to\_Achieve\_the\_Policy\_2\_Goal = 3

Total \_Delivery = POP.Birth\*(1-Twins\_Birth\_Fraction\_to\_the\_Total\_Birth)+POP.Birth\*Twins\_Birth\_Fraction\_to\_the\_Total\_Birth/2

UNITS: person/year

Documentation: The number of deliveries and the number of births is very similar in Zambaqui. We assumed both as the same number given the poor statistics in Zambaqui. Twins would comprise 2 births per delivery.

Twins\_ Birth \_Fraction \_to \_the \_Total \_Birth = 0.035

UNITS: dmnl

Documentation: According to the reports, 3.5% of the deliveries are twins.

Working \_Ambulance \_per \_Health \_Centre = Working \_Ambulances/ HLT. Health \_Centres

UNITS: ambulance/centre

Documentation: It is calculated through the number of working ambulances over the number of health centres.

Working\_ Ambulances = Ambulances\* Proportion\_ of\_ Working \_Ambulance

UNITS: ambulance

Documentation: The total ambulance times the proportion of working ambulances gives the value of the current working ambulances.

(The model has 109 (109) variables (array expansion in bracket).

In this module and 0 additional modules with 0 sectors.

Stocks: 3 (3) Flows: 6 (6) Converters: 100 (100)

Constants: 35 (35) Equations: 71 (71) Graphical: 0 (0)

There are also 70 expanded macro variables.

}

Introduce all the variables and equations in the appendix