Modeling Diabetes Prevalence in the UAE

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Abstract

In the last two decades the UAE population is suffering from the increasing levels of the type-two diabetes. In contrast to diabetes type-one, type-two develops gradually from unhealthy lifestyle choices and can be prevented by primarily adjusting these factors. Nevertheless, if no actions are taken, the percentage of people suffering from diabetes will continue to increase in the near future. This paper presents a system dynamics model as an analytic tool that captures the current situation in the UAE and assesses the prevalence of diabetes type-two under a set of potential health-related policy options that are intended to control the disease.

Keywords: system dynamics; diabetes type-two; lifestyle choices; health policies; UAE.

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1 Introduction

The epidemic of type-two diabetes is evident globally, shortening lives and straining the financial resources of health care systems. Especially in the UAE, the prevalence of type-two diabetes is the second highest in the world, i.e. 19% of the population between ages of 20 to 70 [1]. If no action is taken and the current trends continue, by 2020 an estimated 32 percent of the adult population, between ages of 20 to 79, including both UAE nationals and expatriates, may have diabetes or prediabetes at a possible cost of $8.52 USD billion. There is evidence that medical costs attributable to diabetes and prediabetes in the UAE will increase to $1.04 USD billion by 2020, representing a 58 percent increase from an estimated $657 USD million in 2010 [2, 3].

Fortunately, the toll of diabetes can be reduced by early, aggressive intervention. Screening tests, lifestyle changes, and disease management can help prevent type-two diabetes and for those who already have diabetes, can reduce the risk of developing deadly complications, such as heart and kidney disease, nerve damage, blindness and limb amputation[4]. Curbing the UAE's epidemic of diabetes and prediabetes should include collaboration between the government's public health agencies, nonprofit organizations and the private sector. The way forward begins with designing and implementing culturally-appropriate, community-based initiatives for diabetes prevention and control in the UAE, drawing on and adapting what has worked in other parts of the world.

In this paper we develop a system dynamics model to represent the current situation in the UAE and to predict and analyze the prevalence dynamics of diabetes type-two under different policies. UAE is an interesting country to address this problem not only because of its high prevalence but also for its limited health policies implemented currently. Therefore, we consider a system dynamics approach as the most appropriate in order to describe the existing situation and to analyze the impacts of future policies.

The contribution of this paper is the in depth analysis of the variables that affect the growth of diabetes type-two and the implementation in a country that urgently needs to restructure its policies. In Section 2, an overview of the disease mechanism is described whereas in Section 3, the problem definition is presented, including the causal loop diagram. The stock and flow model is developed in Section 4. In Section 5 the results are analyzed and finally in the last section the main conclusions are drawn.

2 Background and Overview

Understanding of diabetes condition is crucial in addressing the current problematic situation. In this section, we give a simplified explanation of the disease mechanisms, the causes, and the potential consequences.

2.1 Diabetes

Upon the intake of sugars and starches, the body changes them rapidly into glucose, which is the main source of body energy. Liver also produces some glucose but the majority of it is gained through the digestion process. In order glucose to be taken up by the body cells and be burnt to produce energy, insulin has to be released. Insulin is a hormone (part of the endocrine system) produced by the beta cells in the pancreas and acts as a key to unlock the body's cells so that blood sugar can be stored and burnt in them. In fact, diabetes mellitus, or simply diabetes, is a metabolic disease in which a person has a state of high blood sugar.

High blood sugar levels can be caused either because the amount of insulin released by the pancreas does not meet the amount of sugar in the blood or because the insulin available is not functioning well (low efficiency), or both. Thus, sugar and starch accumulate in the blood and urine, and the byproducts of alternative fat metabolism disturb the acid–base balance of the blood, causing a risk of convulsions, severe complications in the long term or even coma. Figure 1 describes this mechanism in the context of system dynamics. The stocks used are "sugar in the blood" and "insulin released in the blood". The model shows that the sugar conversion rate is triggered by the insulin released in the blood, where the rate of releasing the insulin itself depends on the ability of the pancreas to produce insulin when the sugar in the blood is high (the glucose level increases after any carbohydrates food intake).

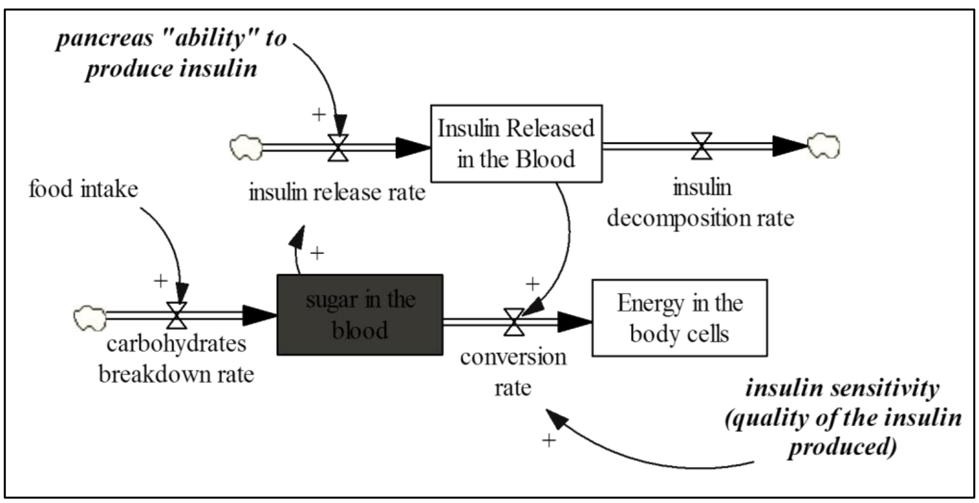

Figure 1: Diabetes Mechanism, using System Dynamics

There are three main types of diabetes mellitus (DM) [5]:

- Type-one DM results from the pancreas failure to produce insulin, and presently requires the person to inject insulin. This type of diabetes has a sudden onset and develops mostly in children.

- Type-two DM results from insulin resistance, a condition in which cells fail to use insulin properly, sometimes combined with an absolute insulin deficiency. This type of diabetes has a gradual onset due to lifestyle factors, genetics, or aging and develops mostly in adults.
- The third main form, gestational diabetes occurs when pregnant women without a previous diagnosis of diabetes develop a high blood glucose level. It may precede development of type-two diabetes.

The first two types are chronic conditions that cannot be cured.

An important state before the development of diabetes type-two is the Pre-diabetes. In the pre-diabetic stage some but not all of the diagnostic criteria for diabetes are met. It is often described as the “gray area” between normal blood sugar and diabetic levels. If the condition is detected early enough, the development of type-two diabetes can be prevented or delayed [6].

2.2 Causes and Complications

The onset of type-one diabetes is not related to lifestyle and the causes are not known (prevention of developing the disease is infeasible). On the other hand, type-two diabetes is due primarily to lifestyle factors especially eating habits, physical activity and smoking. Thus, whereas the prevention of developing diabetes type-one is infeasible in case of type-two, there are ways to prevent it. Diabetes without proper treatments can cause many complications. Acute complications include diabetic ketoacidosis, or hyperosmolar coma. Serious long-term complications include cardiovascular disease, chronic renal failure, and diabetic retinopathy, i.e. retinal damage [4].

2.3 Literature Review

In [7], a system dynamics model was built to address the gap of analytics tools in capturing the dynamic complexity of chronic diseases, as well as to help improve existing strategies for addressing the prevalence of diabetes. However, the model was calibrated for a country that had already strong policies regarding diabetes prevention. Additionally, in order to reach a more accurate analysis, factors that affect lifestyle and public awareness should be further developed.

In [8, 9], the author also recommends the use of system dynamics approach to represent the diabetes situation and to test possible interventions. Zhang uses the same approach with [7] to model the existing situation in a region in Canada. Despite the fact that the model was initially structured in the past to model a situation in a different geographic area, it was suitable to model the different population even using similar data for the initial values of parameters in his model. Nevertheless, he acknowledges the limitations of the policies recommended because of the long time horizon needed to be implemented and to turn successful. We notice that the long time horizon might become even longer if the model is implemented in a country with less developed policies related to diabetes. Moreover, Zhang highlights the lack of additional metrics of the burden of diabetes, e.g. the cost produced by diabetes.

Useful conclusions can be drawn using system dynamics simulation modeling such as in [10], where Jones et al. indicate the inability of diabetes control efforts alone to reduce diabetes-related deaths in the long term. In the current study, an extended version of the model developed in [7] is presented. The objective is to address the gaps found in the literature review and to examine the dynamics in a special case study with high prevalence and weak health policies, i.e. the UAE.

3 Problem Definition

The problematic behavior to be analyzed is the rise of diabetes type-two in the UAE. As show in Figure 2, since 1990 the rise of diabetes type-two in the UAE has been significant [11, 12, 13]; if nothing changes, estimates show that around 2040 one out of three adults in the UAE will suffer from the disease [14].

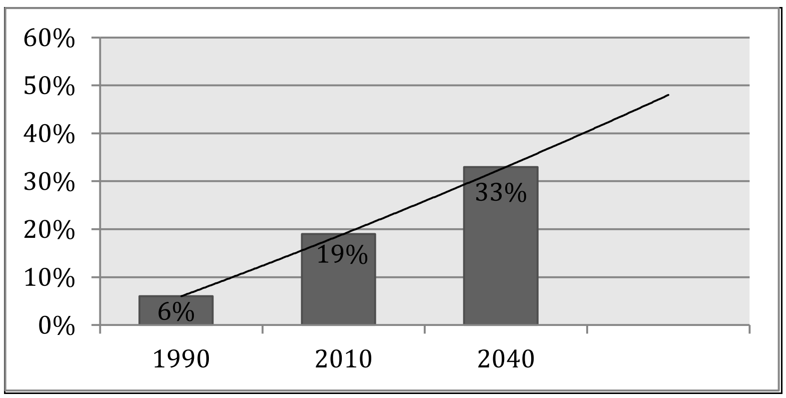

Figure 2: Prevalence Rate of Diabetes in UAE

As far as the effects are concerned, diabetes does not only affect the individual’s quality of life but it also imposes high healthcare cost on UAE government. These costs accumulate with the rise of the number of diabetics. As a matter of fact, in 2010 around 40% of total medical expenditures were for diabetes healthcare [2]. The rate of diabetics developing complications became significantly high, which imposes another indirect cost in terms of reduced productivity. The system dynamics model we develop evaluates the policy options available on how effectively they reduce the rates of diabetes type-two in the UAE.

3.1 Important Concepts and Variables

Identification of the causes that contribute to the high prevalence of diabetes and its social and economic impacts is the first step in order to understand the dynamics of its spread. Our model focuses on the important risk factors related to the lifestyle of individuals in the UAE. The main variables needed to describe diabetes prevalence model and its boundaries are listed on Table 1, and the highlighted ones are the most important for the upcoming discussion.

Table 1: Stock and Flow Model Boundary Chart List (highlighted variables are the most critical for the current study)

Type	Endogenous Variables	Exogenous Variables	Excluded
Stocks	Total Population Normoglycemic Population Undiagnosed Pre-diabetic Population Diagnosed Pre-diabetic Population Undiagnosed Diabetic Population without Complication Diagnosed Diabetic Population without Complication Undiagnosed Diabetic Population with Complication Diagnosed Diabetic Population with Complication		Population Categorized based on Gender and Age
Flows	Growth Rate Developing Prediabetes Recovery from Undiagnosed Prediabetes Recovery from Diagnosed Prediabetes Developing Diabetes from Undiagnosed Prediabetes Developing Diabetes from Diagnosed Prediabetes Developing Complications of Undiagnosed Diabetes Developing Complications of Diagnosed Diabetes Death Rate of Normoglycemics Death Rate of Undiagnosed Prediabatics Death Rate of Diagnosed Prediabatics Death Rate of Undiagnosed Diabetics (Controlled) Death Rate of Diagnosed Diabetics (Controlled) Death Rate from Uncontrolled Undiagnosed Diabetes Death Rate from Uncontrolled Diagnosed Diabetes Diagnosis of Prediabetes Diagnosis of Diabetes Diagnosis of Diabetes through Complications	Average Population Growth Rate Diagnosis Rate	
Auxiliary Variables	Risk of Diabetes Smoking Obesity/Overweight Healthy Diets Physical Activities		Other Risks of Diabetes (i.e. Genetic Factor)
	Direct Cost of Diabetes Ratio of Diabetics	Cost of Diabetes Per Capita	Indirect Cost of Diabetes
	Patient Advocacy	Willingness to Advocate	
	Average Annual Medical Check-ups Diagnosis	Recommended Annual of Medical Check-ups Delay in Diagnosis	
	Public-driven Awareness Awareness Health Literacy	Policy-driven Awareness	
	Self-Management of Diabetes Perception of Severity of Diabetes	Probability of Diabetes-related Death Delay in Recovery Average Death Rate from Other Causes Average Time to Develop Diabetes Average Time to Develop Pre-diabetes Average Time to Develop Complications	
Tables	Effect of Awareness on Smoking Effect of Awareness on Obesity Effect of Awareness on Healthy Diets Effect of Awareness on Physical Activity		

	Effect of Medical Checkups on Diagnosis		

The system dynamics model that we developed is comprehensive enough to test practical policies without disaggregating the population into demographical categories. The model is based on some assumptions, for simplification, and does not explicitly depict the following effects:

1. The effect of aging of the population, which affects death rates as well as prediabetes and diabetes onset rates (Figure 3)

2. The effect of changing the racial and ethnic composition.

3. The effect of the differences between genders in terms of vulnerability to develop the disease, i.e. according to the World Health Organization, women in the UAE are more likely to have prediabetes than men (Figure 3) [15].

4. The genetic factor associated with diabetes is not depicted. As a matter of fact, there is some clinical evidence that peninsular Arabs share a genetic tendency to insulin resistance; which is a condition that if it persists, it can trigger the development of diabetes in the future [3].

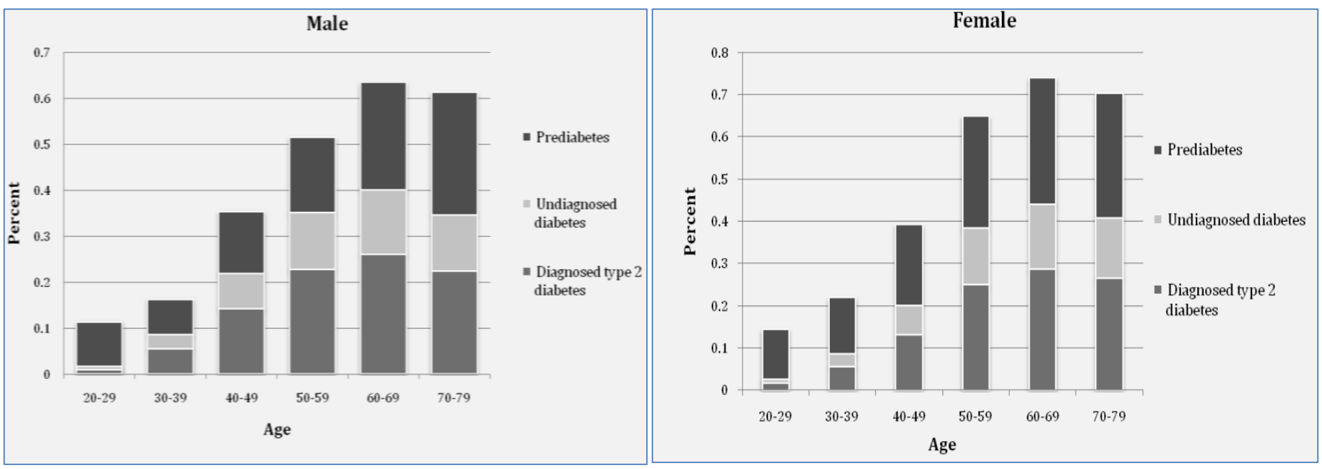

Figure 3: Prevalence of diabetes in the UAE based on gender and age [17]

In section 4.2., we introduce some additional assumptions, related to our model.

3.2 Time Horizon

The time horizon studied should capture a time period when the dynamics of the rise of diabetes will be revealed. The initial time of the simulation is set at 1990 where the percentage of diabetic people in UAE was as low as 6%. Since 1990 [16], the economic success of UAE has led to an increase in fast food and less exercise, which has negatively affected public health. As a result, nowadays the prevalence of diabetes also soared to well over 20% [17].

The World Health Organization forecasts that deaths connected to diabetes will have been double by the year 2030 [15]. Thus, it is useful to simulate the model in a time horizon extended more than 20 years from today. Therefore, we capture the long term effects of policies until 2040.

3.3 Causal Loop Diagram

The Causal Loop Diagram in Figure 4 (next page) shows the main loops that contribute to dynamics of the prevalence of diabetes. Few stocks are also shown in the diagram to allow for a better understanding of the dynamics. The stocks of population are shown as Healthy Population, Population with Risk of Diabetes and Diabetic Population, without any disaggregation based on diagnosis. However, there are other variables in the model characterize the importance of diagnosis, e.g. early diagnosis of prediabetes and detection of diabetes-related risks. The stock of healthy population is for people who didn't develop diabetes and they are also less likely to develop it. On the other hand, the stock of population with risk of diabetes includes those who either have the potential to develop diabetes or are already pre-diabetic. The last stock is for the diabetic population without disaggregation based on the control of diabetes and its complications. Population flows from the stock of healthy population to the stock of population with risk of diabetes with the flow rate of developing the risk of diabetes, and also flows from the stock of population with risk of diabetes to the stock of diabetics with the flow rate of diabetes onset. Another point to mention with regard to the flow rates is the birth inflow rate, which only flows to the stock of the healthy population; as diabetes type 2 develops gradually and postnatally. Hence, all newborns are included in the stock of healthy population. Also, death outflows are shown for each stock, where this rate increases for diabetics if they develop complications.

The most important reinforcing loop is the misperception loop (R1), which depicts the unwillingness of the population to adopt the necessary lifestyle changes to prevent diabetes, as they don't not perceive the disease as severe as it could be; thus, increasing the risk of diabetes and eventually diabetes onset. Other reinforcing loops are related to the cost of diabetes; either direct costs by the medical expenditures (R3) that rises with diabetes-related complications (R2), or indirect costs characterized by the reduced productive capacity due to early mortality and low productivity of diabetics (R4 & R5).

For the balancing loops, awareness is presented as the public perception about the widespread of diabetes which is formed with some delay (B1), or the awareness through policies that comes from patient advocates (B2). Both loops increase the total awareness among population, which encourage them to do medical checkups and adopt healthy lifestyle; hence decreasing the risk of diabetes. Also, through patient advocacy, medical checkups are more doable by improving access to health care (B3).

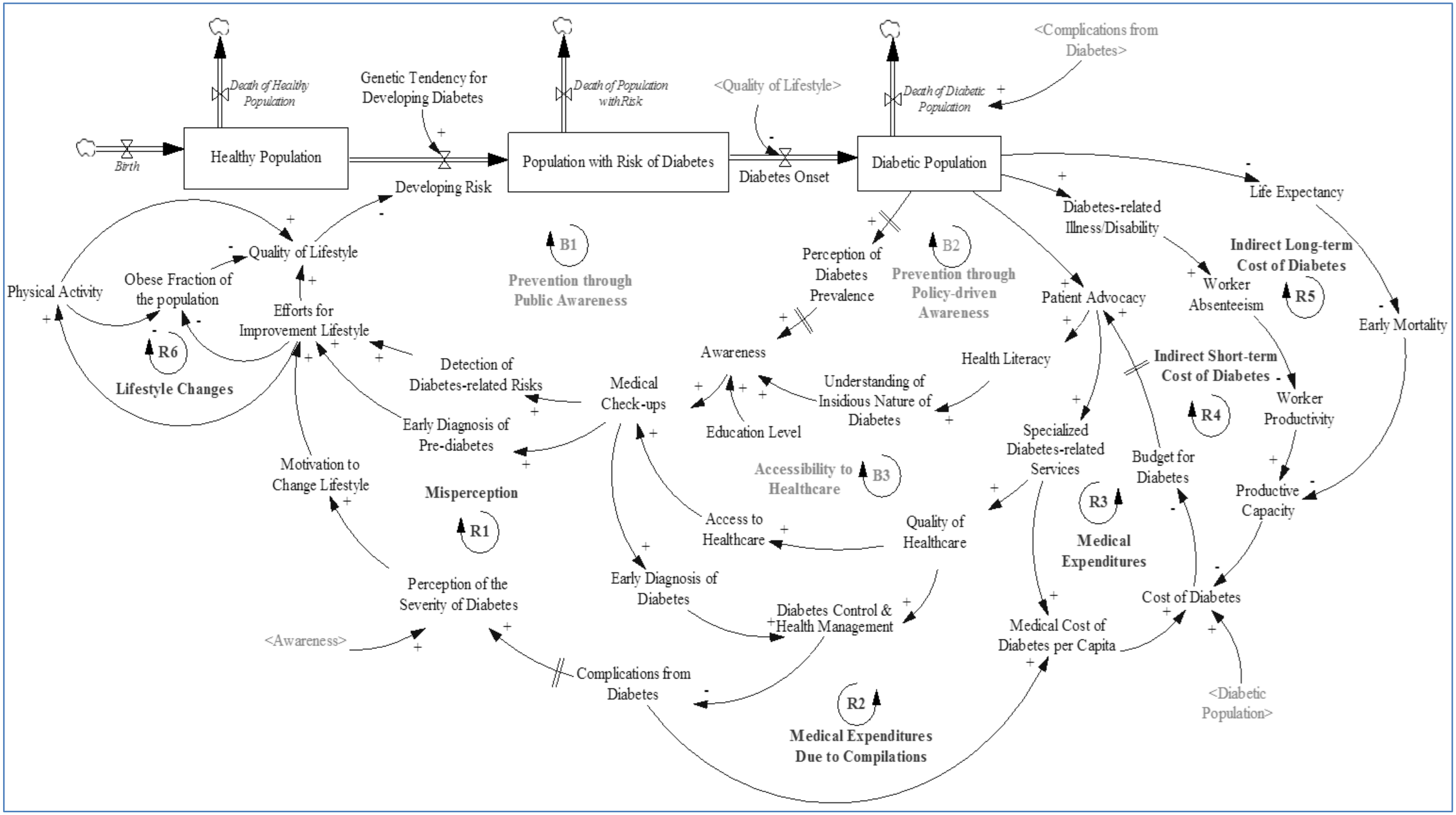

Figure 4- Causal Loop Diagram for the Prevalence of Diabetes in the UAE

4 Model Description

The Stock and Flow Structure (Figure 5) is based on the variables shown in Table 1. The dynamics of the model are also based on the main concepts introduced by the casual loop diagram.

4.1 Stock and Flow Model

Regarding the stocks, the population is subdivided into seven stocks which are based on diagnosis and the states of prediabetes and diabetes, as follows:

1. Normoglycemic Population
2. Undiagnosed Pre-diabetic Population
3. Diagnosed Pre-diabetic Population
4. Undiagnosed Diabetic Population without Complication
5. Diagnosed Diabetic Population without Complication
6. Undiagnosed Diabetic Population with Complication
7. Diagnosed Diabetic Population with Complication

Disaggregating the population based on diagnosis is very essential, since patient Advocacy is more operational for those who are diagnosed, in terms of received healthcare. Also, the self-management of diabetes does not take place for the undiagnosed diabetics, which increases the risk of developing complications.

For the loops, one of the key balancing loops that, explicitly shown in the diagram, is the prevention of diabetes, by encouraging lifestyle change through awareness (B1) or medical check-ups for an early diagnosis of diabetes or prediabetes (B2). Other loops are diabetes control through patient advocacy (B3), and the perception formed by people about the severity of diabetes (B4).

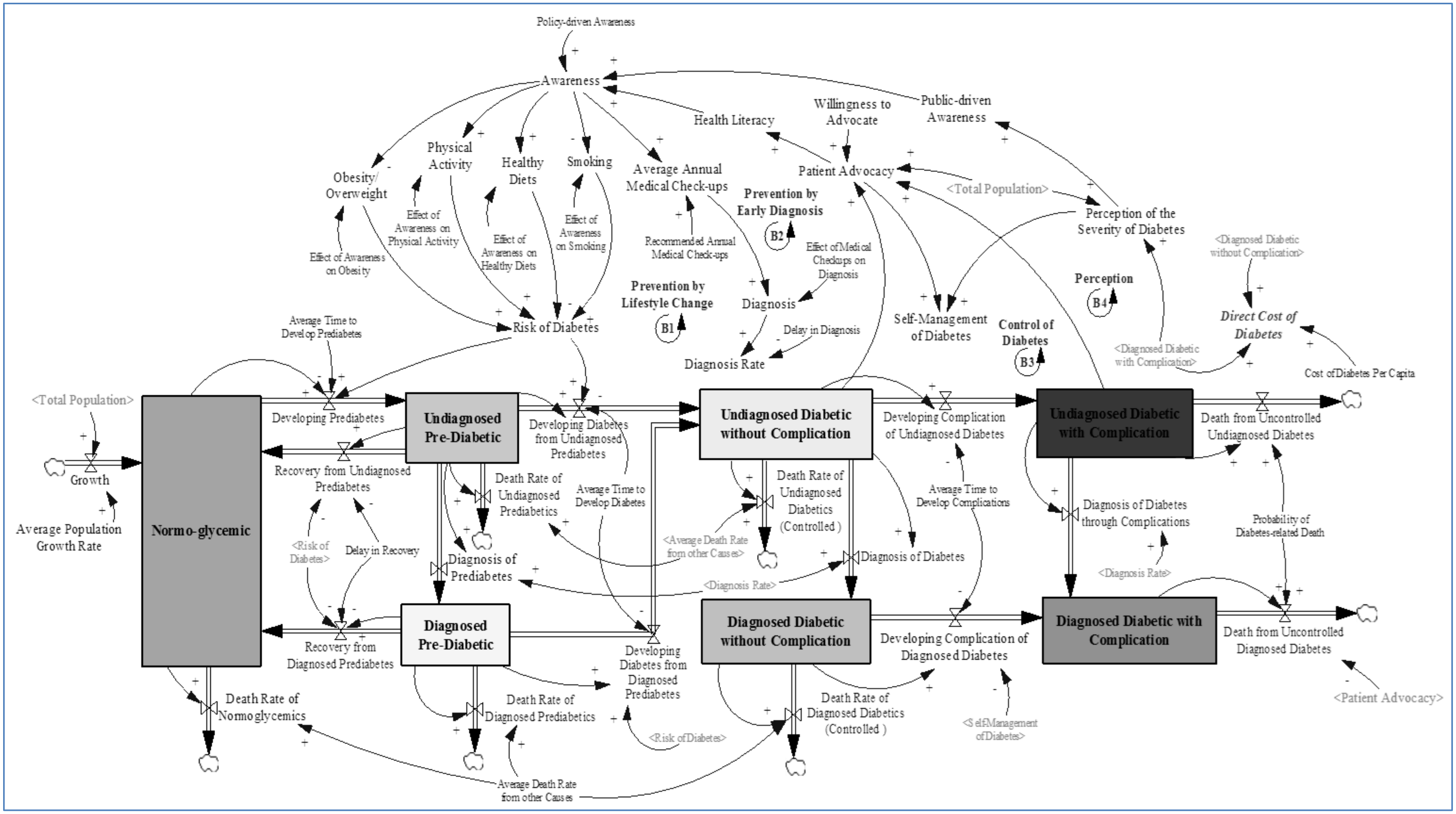

Figure 5: Stock and Flow Model for the Prevalence of Diabetes in the UAE

For the variables, the risk of diabetes, which is endogenous, is measured by the lifestyle factors that could trigger diabetes onset, and this variable positively affects the following flows:

1. Developing Prediabetes
2. Developing Diabetes from Undiagnosed Prediabetes
3. Developing Diabetes from Diagnosed Prediabetes
4. Developing Complications of Undiagnosed Diabetes
5. Developing Complications of Diagnosed Diabetes

And negatively affect the following flows:

1. Recovery from Undiagnosed Prediabetes
2. Recovery from Diagnosed Prediabetes

When the risk of diabetes is still high, diagnosis based on the frequency of medical check-ups is not as critical as lowering the risk factors of either recover from prediabetes, or avoid diabetes-related complications.

Another important variable is awareness. Awareness comes either through patient advocacy or people perception, thus presenting delay, or the direct intervention of the government, considered as a policy-driven awareness. The exogenous variables are the willingness to advocate, i.e. supporting current patients and improving healthcare, the policy-driven awareness by decision and policy makers, and recommended medical check-ups. The first two are treated as dimensionless quantities and range from 0 to 1, where 0 depicts total lack of it and 1 highest level of it. These are the exogenous variables that will be changed in our analysis of the dynamics in the upcoming section to test for different policies. Another exogenous variable is the cost of diabetes per capita, which is estimated to be a constant of $1150 USD per year and assumed to be constant throughout the analysis.

4.2 Assumptions

Additional assumptions are made for the growth rate, which flows into the stock of Normoglycemic only assuming all immigrants are healthy, and also the stocks for diabetics with complications are assumed to have an outflow of death only due to diabetes. An assumption is made for the medical cost for treatment or management of diabetes, which is fixed for all different stages, i.e. healthcare of diabetic with complication is more costly than the one with controlled diabetes. Also, we have assumed that currently people do as many medical check-ups per year as recommended.

As far as the fraction of overweight population is taken to be 70% as a baseline average, based on the World Health Organization data, about 73% of adult women and 66% of men are overweight or obese in the UAE [15]. Additionally, the demographical information about UAE is taken from Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat. Moreover, the cost of awareness is excluded in the model, since our interest is mainly the prevalence of the disease and partially about its effect on the medical expenditures.

For UAE in particular, obesity combined with physical inactivity significantly increases the risk of developing the disease. With reference to Booz Allen Hamilton and Ipsos Study about Diabetes-Related Behaviors and Attitudes in UAE, awareness among UAE population about diabetes is estimated to be fair. However, the study shows that female and less educated population are less aware of diabetes; given the fact that women tend to have a higher probability of developing diabetes than men, especially if they have once developed gestational diabetes during pregnancy. Also, among those who tried to change their lifestyle to decrease the risk of diabetes, there is lack of understanding about adequate prevention measures. The study also suggests that the unhealthy behaviors can be effectively decreased by the proper quick intervention to increase awareness [2]. Thus, our model runs under the assumption that all the risk factors of diabetes only changes through awareness, which can educate the population about diabetes, encourage them to adopt a healthy lifestyle, and do regular medical check-ups. Only then early diagnosis is possible, which is a key factor in controlling the disease and decreasing the possibility of developing complications in the future.

5 Model Analysis

Using the stock-and-flow structure, we develop a functioning model and run simulations to capture the dynamics of diabetes prevalence. In the model described, there are three exogenous variables, i.e. Willingness to Advocate, Policy Driven Awareness and Recommended Annual Medical Check-Ups, that could be affected by certain policies. Thus, in the partial model tests, different values are chosen for these variables to demonstrate their effect to the behavior of the system.

5.1 Simulation Results-Integrated Policy Analysis

Table 2: Table of Different Scenarios

	Willingness to advocate	Policy Driven Awareness	Recommended Annual Medical Check-Ups
a. Existing (UAE)	***1***	***0.5***	***1***
b. No willing to advocate	0	0.5	1
c. No medical check-ups	1	0.5	0
d. No Policy Awareness	1	0	1
e. Recommended	1	0.9	2
f. Best efforts	1	1	4

The first test, Table 2-test a, describes the existing situation in UAE. It is assumed that the government is willing to advocate and it has a moderate strategy concerning policies to raise awareness. Finally, it recommends one medical check-up per year.

The next three tests, Table 2-tests b, c and d, are run to analyze the sensitivity of the model in each one of the three exogenous variables. Thus, the variables are set to zero and the rest values are kept equal to the base scenario of UAE.

Finally, two more tests are conducted. In Table 2-test e, a recommended policy is run in order to examine its result. The values are set slightly high but they are still feasible. There is willingness to advocate and an aggressive policy to increase awareness. Moreover, the government recommends two annual medical check-ups per year. As far as the last test, Table 2-test f, concerns, all three values are set to their highest point in order to demonstrate the potential range of the impact of the proposed policies in the model.

The results of the simulation present notable dynamics of the model and demonstrate the intended rationality of the decision rules for each factor in the model. Regarding the ratio of diabetic people (Figure 6), it is mainly affected by policy-driven awareness. When policy-driven awareness is set at 0, the ratio reaches as high as 46% in 2040. The second main factor is the willingness of the government to advocate. If there is no willing at all to advocate then the ratio reaches to 36% in 2040. An interesting aspect of the model is the similarity in behavior between the scenarios of recommending no medical check-ups with the existing situation of UAE. As expected, the ratio of diabetics slightly increases for the recommended policy; whereas for the best effort policy, the ratio is almost constant throughout the years.

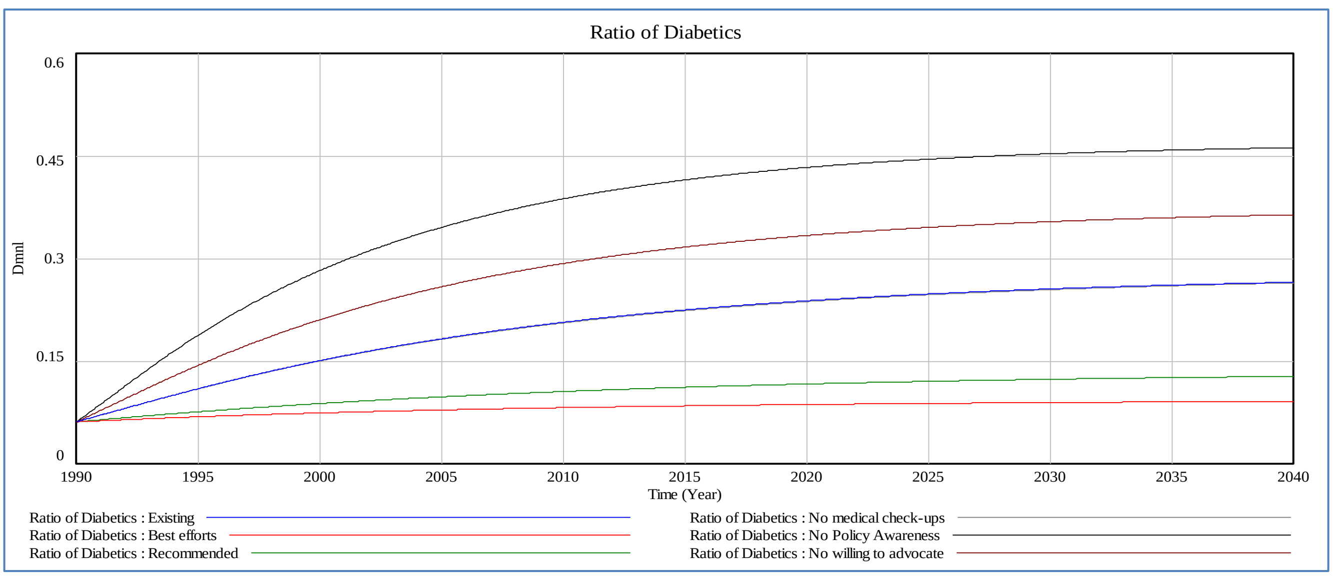

Figure 6- Ratio of Diabetics – Simulation Results

Awareness is a key variable in our model, since it is the main factor affecting the ratio of diabetics. We can notice in Figure 7, by comparing awareness and the ratio of diabetics, that the higher the awareness, the lower the ratio will be. Thus, best efforts model run and recommended model run have the highest percentages of awareness. On the other hand, no policy-driven awareness model run and no willingness to advocate model run have the lowest percentage of awareness.

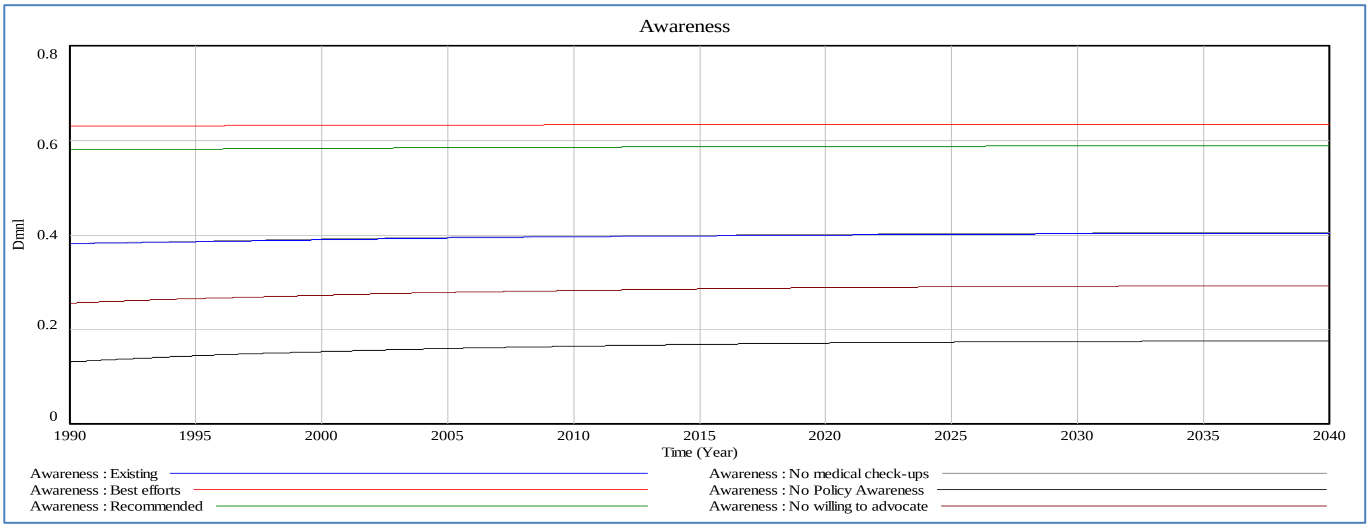

Figure 7- Awareness – Simulation Results

With regards to the direct cost of diabetes (Figure 8), the results of the simulation are proportional to the ratio of diabetic people; since the cost is affected directly by the diabetic diagnosed population multiplied by the cost of diabetes per capita which remains constant.

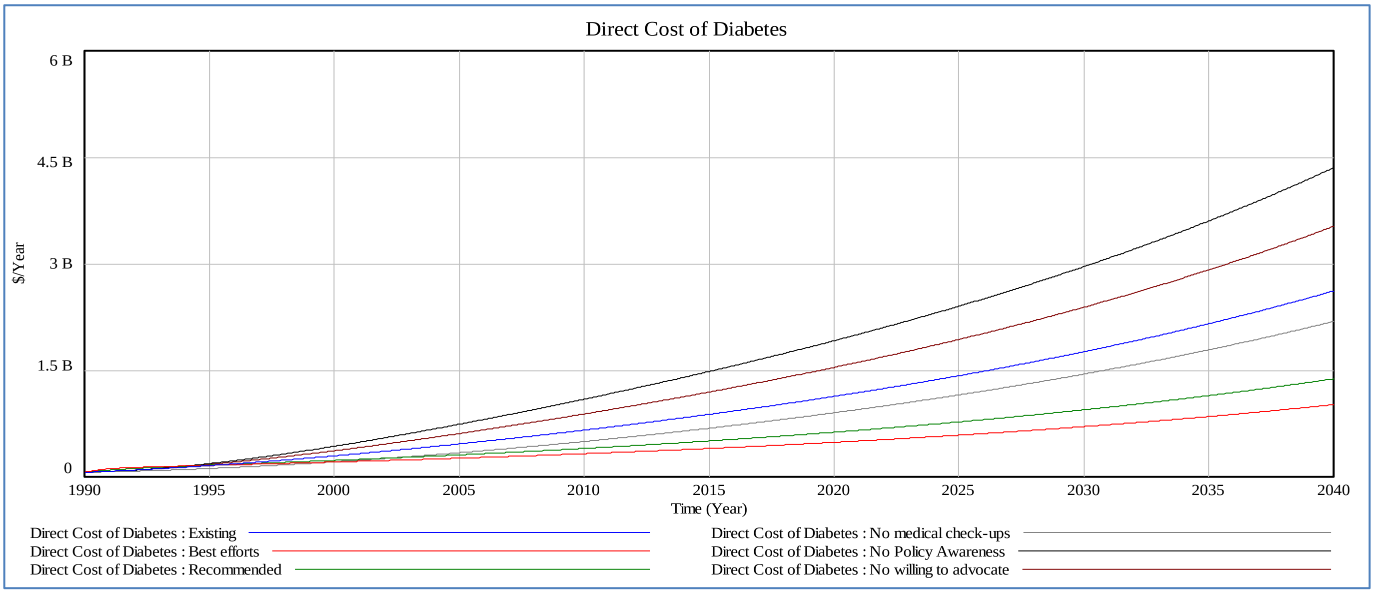

Figure 8- Direct Cost of Diabetes – Simulation Results

Furthermore, diagnosis rate is playing a key role in the model (Figure 9). The diagnosis rate sharply increases in the case of best efforts where the medical check-ups are set at 4 per year and reaches a very low value in the case where no medical check-ups are recommended. Another point to highlight is the behavior of the rate under all the scenarios throughout the time horizon. The rate remains almost constant since it is a function of variables which are given a constant value. With reference to our model, Diagnosis rate is the fraction of diagnosis over the delay of diagnosis. Additionally, Diagnosis depends on constant variables throughout the time horizon examined.

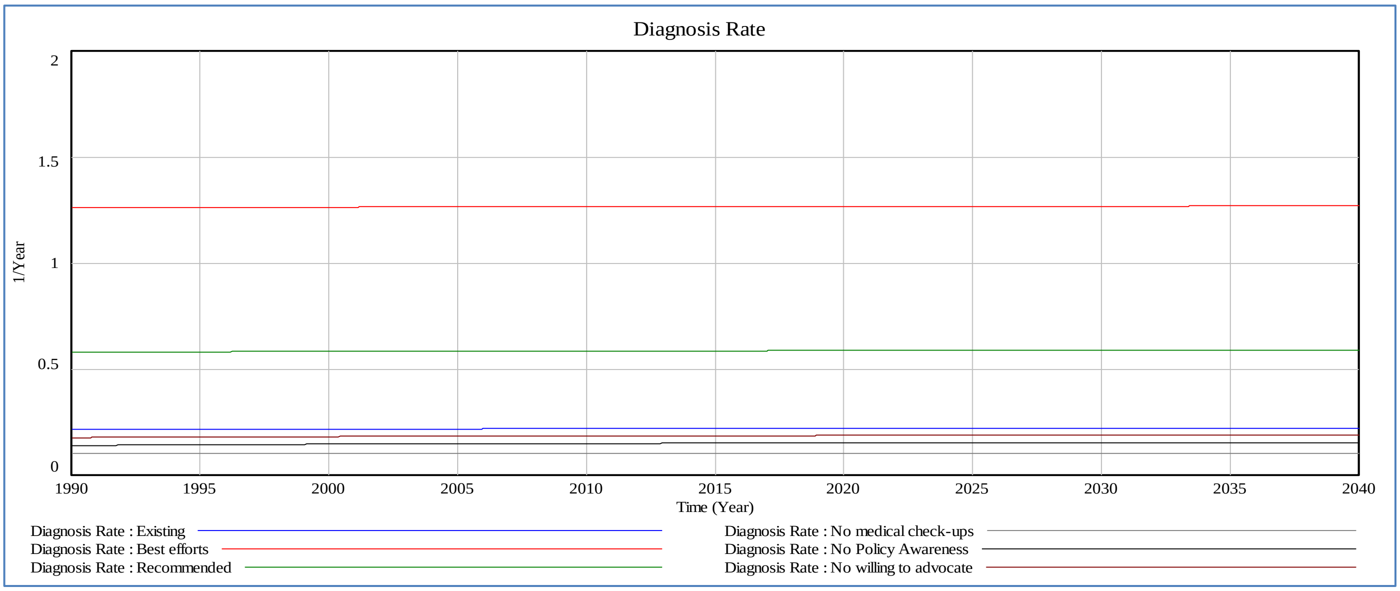

Figure 9- Diagnosis Rate – Simulation Results

Finally, interesting dynamics of the model are driven by the disaggregation of diagnosed and undiagnosed diabetic population (Figure 10). Undiagnosed were separated from diagnosed since the difference in the rates of developing complications and its relative consequences should be revealed. As shown in the graph above, the rate of developing complications is less for diabetic people who are diagnosed compared to those who are not diagnosed yet as they do not control it.

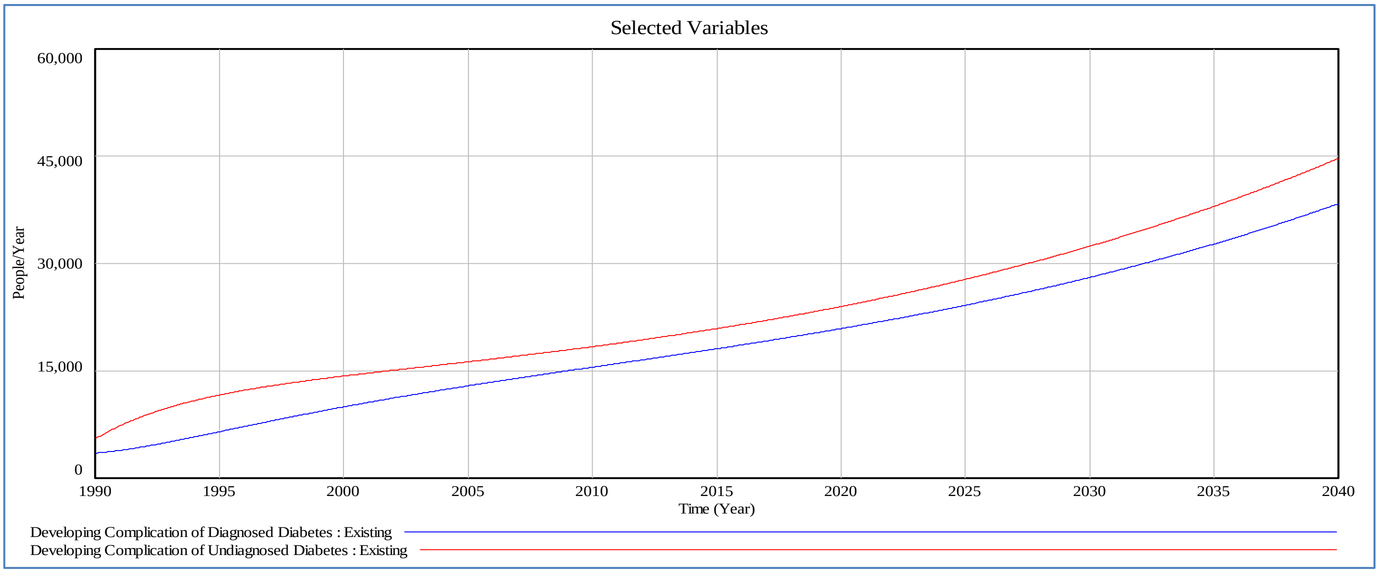

Figure 10- Developing Complications of Diagnosed and Undiagnosed Diabetics for UAE – Current Situation

5.2 Discussion

From the study presented we infer that awareness is the key factor to prevent the rise of diabetes. In Figure 6, the ratio of diabetics over the total population given and is mostly affected by the level of Awareness among the individuals. When awareness is low, the ratio of diabetics obtains its highest value by the end of the time horizon examined; almost double. The willingness to advocate from the side of the government also plays an important role given the fact that when there is no willingness the ratio is presented to be higher compared to the existing one almost 33 percent. Finally, the ratio of diabetics is less sensitive to the change of the number of recommended medical check-ups per yea, given the fact that also in the baseline scenario (existing situation) is appeared to be low equal to only 1 per year.

What is important to be highlighted regarding the validity of the developed model, is the level of convergence between the results generated from our model and the historical-real data collected through literature review and studies regarding the prevalence of the disease. Comparing the behavior of the endogenous variables examined i.e. Ratio of diabetics, Diagnosis Rate, Direct Cost of Diabetes and Awareness among individuals, it is clear that the gap between the reference mode i.e. real case so far, historical data obtained from literature review regarding the prevalence of the disease in the country, and the modeled one is not big and in some cases it is even zero. For instance, the results generated from our model in case of Ratio of Diabetics or Awareness, are exactly the same with the ones in the respective real ones. Based on this, the confidence for the level of validity of our results and model in general increases.

Moreover, it can be easily concluded from results of the simulation that awareness is the key factor to prevent the rise of diabetic population. Hence, the government should focus on increasing awareness as much as possible. Through awareness, all the variables that affect the risk of diabetes are mainly influenced.

In terms of policies and initiatives that have already been taken from the UAE authorities, several campaigns have been taken place in the emirates so far with the objective to increase awareness and motivate the population to change their lifestyle and reduce the risk of diabetes. Few of these initiatives are presented below:

"Beat Diabetes":

- Launched in 2009 by Landmark Group aims to create awareness & educate people about the condition
- Beat Diabetes Walkathon (in 2010 over 25,000 participants)
- Conducted free blood glucose tests for over 30,000 people

"Diabetes-Knowledge-Action":

- Launched in 2007 under the patronage of Her Highness Sheikha Fatima bin Mubarak
- Imperial College London Diabetes Center's award-winning public health awareness campaign
- ICLDC has offered diabetes prevention, education and treatment to more than 177,000 people

"Know Diabetes":

- Free medical checkups, presentations, educational games for children and other events were run for one week until November 14 2009, the World Diabetes day
- A Know Diabetes team conducted medical check-ups for 45 corporate houses

However, more actions should be taken in order to tackle the problem of diabetes in UAE efficiently. First of all, the government should organize more public health awareness campaigns. For instance, events like "Beat Diabetes" and "Diabetes-Knowledge-Action" mentioned above could be organized more frequently. Moreover, educational games for children are considered to be very important as also including lectures concerning the severity of diabetes in school curriculum. The focus on the young generation would lead not only to increased awareness but also to early diagnosis, as they represent the population that would be susceptible to diabetes in the future. Furthermore, recommended annual check-ups could be increased in order to mitigate the rise of the percentage of diabetics. This could be done either by setting policies that would motivate people to conduct more medical check-ups, or by arranging interactive medical check-ups events, e.g. events with free on-site blood glucose level test.

6 Conclusions

In this paper a System Dynamics model was developed to capture the different dynamics of the prevalence of type-two diabetes in the UAE and the impact of the basic variables on its growth. Different scenarios were tested in order the sensitivity of the prevalence of the disease to be evaluated under changes of the important variables such as Willingness to Advocate, Policy Driven Awareness and number of Recommended Annual check-ups. In the second section an overview of the disease characteristics was presented, necessary in order to understand its mechanism and its causes whereas in Section 3 the problem definition was presented, including the causal loop diagram. The stock and flow model was developed in Section 4. From the different scenarios tested in Section 5, the highest impact of the people's Awareness compared to others variables was depicted. Given the fact that awareness is mostly driven by policies that could be potentially applied, an effective strategy could be developed to the direction of increase the Awareness of people regarding the mechanism and severity of the disease. The current study offers insights that could potentially change the current estimates that present an increasing diabetic ratio in the UAE. Thus, actions should be taken in order to tackle the problem efficiently. Moreover, the impact that the size of diabetic population combined with the level of awareness on the future behavior of the diabetic ratio is explicitly shown. It is clear that in case of the UAE, where the size of population suffering from the disease is high and the awareness is low, the prevalence of diabetes type-two is expected to increase significantly in the next years, given the higher delays and inertia of the system that are developed. Finally, the validity of the model and its contribution is also highlighted by the level of convergence between the results generated and the real data obtain through literature review.

7 References

[1] International Diabetes Federation. 2013. IDF Diabetes Atlas, Sixth Edition. [online] Available at: http://www.idf.org/atlasmap/atlasmap [Accessed: 30 Nov 2013].

[2] Booz Allen Hamilton, "Exploring the Growing Challenge of Diabetes across the GCC and within the United Arab Emirates", 2012

[3] United Health Group, "Diabetes in the UAE: Opportunity or Crisis", 2010

[4] American Diabetes Association. 2013. Diabetes Statistics. [online] Available at: http://www.diabetes.org/diabetes-basics/diabetes-statistics/ [Accessed: 30 Oct 2013].

[5] William's textbook of endocrinology (12th edition). Philadelphia: Elsevier/Saunders. pp. 1371–1435

[6] American Medical Network. 2013. Pre-Diabetes. [online] Available at: http://www.health.am/db/more/pre_diabetes/ [Accessed: 26 Nov 2013].

[7] Homer Jack, Andrew Jones, Don Seville, Joyce Essien, Bobby Milstein, and Dara Murphy, "The CDC's Diabetes Systems Modeling Project; Developing a New Tool for Chronic Disease Prevention and Control", 22nd International Conference of the System Dynamics Society, July 25-29, 2004 (Oxford, England)

[8] Grassmann, W., Zhang, J., Dyck, R., Osgood, N. 2012. "A System Simulation Model for Type 2Diabetes in the Saskatoon Health Region", International conference of the System Dynamics Society, St. Gallen, Switzerland, 18pp, July 22-25, 2012

[9] J. Zhang, "A System Simulation Model for Type 2 Diabetes in the Saskatoon Health Region", M. Sc. Thesis, Department of Computer Science, University of Saskatchewan, July 2011.

[10] Andrew P. Jones, Jack B. Homer, Dara L. Murphy, Joyce D. K. Essien, Bobby Milstein, Donald A. Seville. "Understanding Diabetes Population Dynamics through Simulation Modeling and Experimentation", American Journal of Public Health, 2006 96:3, 488-494

[11] Health Authority Abu Dhabi, "Health Statistics", 2006

[12] Health Authority Abu Dhabi, "Health Statistics", 2010

[13] Health Authority Abu Dhabi, "Health Statistics", 2011

[14] Fikri M., "The Magnitude of Diabetes in UAE: National Diabetes Strategy and Achievements", MENA Diabetes Leadership Forum, 2010

[15] United Nations, Department of Economic and Social Affairs. 2013. World Population Prospects: The 2012 Revision. [online] Available at: http://esa.un.org/unpd/wpp/index.htm [Accessed: 30 Nov 2013].

[16] UAE University, Al-Ain UAE, "Measuring the Health of the Nation: United Arab Emirates Health and Lifestyle Survey 2000", UAEHALS2000

[17] UAE National Diabetes Committee, "National Diabetes Guidelines", United Arab Emirates, 2009