Master's Thesis

European Master in System Dynamics

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The Diabetes Type 2 Patient Journey

Modelling the diabetes type 2 patient journey and the extent to what LaM can reduce the total societal costs associated with diabetes type 2 in The Netherlands

In collaboration with:

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TNO innovation for life

Abstract

Diabetes mellitus (DM) is a complex, metabolic disorder and the number of individuals suffering from DM is dramatically increasing worldwide, resulting in an increasing burden on society and rising health care costs. DM is preceded by prediabetes. Roughly, prediabetes patients suffer either from Impaired Fasting Glucose (IFG) or Impaired Glucose Tolerance (IGT). Without treatment, the body becomes unable to regulate the blood glucose levels and the patient develops diabetes mellitus type 1 (T1DM) patient or diabetes mellitus type 2 (T2DM) patient. Both increasing the risks of cardiovascular diseases, eye disorders, and kidney disorders. Furthermore, the relevant literature suggests that 9 out of 10 of the total DM population suffer from T2DM and that T2DM patients can be reversed. Therefore, there is an urgent need to understand how to reduce this increasing burden on society. In response, Dutch research organization TNO developed personal care program Lifestyle as a Medicine (LaM). The present study aims to gain a clear understanding of the T2DM patient journey and the development of the total societal costs associated with T2DM. Additionally, the present study would like to contribute to the T2DM policy-making process. A system dynamics model is developed to gain insights in the development of the normoglycemic population, the undiagnosed prediabetes population, the diagnosed prediabetes population (IFG), the diagnosed prediabetes population (IGT), and the T2DM population. System dynamics is an appropriate tool, as it supports a system's understanding and it allows for scenario analysis upfront real-life implementation and evaluation of intervention programs. After the model is considered robust, several scenarios are used to examine the potential of LaM as an intervention program and/or a prevention program, in terms of normoglycemic growth, recovered T2DM patients, and potential reduction of total societal costs. The simulation of the Current Policy projects an increase in normoglycemic population, but also an increase in T2DM population and thus, an increase in total societal costs. When LaM program is implemented, either as an intervention program or a prevention program, the results suggest a significant increase in normoglycemic population, decrease in both the T2DM population and the total societal costs. In terms of recovered T2DM patients and potential reduction of total societal cost, the policy option Intervention + Prevention (IFG) + Prevention (IGT) is most effective and the Current Policy is observed to be the least effective. In terms of recovered T2DM patients, both the policy option Intervention + Prevention (IFG) and the policy option Intervention + Prevention (IGT) are observed second most effective. In terms of reduction of total societal costs, a combination of LaM as an intervention program and a prevention program focused on

recovering one of the two prediabetes populations is observed to be second most effective. The results support the present study's suggestion of shifting from intervention programs to prevention programs.

Acknowledgements

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List of Abbreviations

Bi	Balancing feedback loop i
BMI	Body Mass Index
CBP	Centraal Planbureau (Agency for Economic Policy Analysis)
CBS	Centraal Bureau voor de Statistiek (Statistics Netherlands)
CGI	Combined Glucose Tolerance
CLD	Causal Loop Diagram
DiHAG	Diabetes Huisartsen Adviesgroep (Dutch College of General Practitioners focused on Diabetes)
dl	Deciliter
DM	Diabetes Mellitus
DT	Delta Time
Dx PreD Popn	Diagnosed Prediabetes Population
IFG	Impaired Fasting Glucose
IGT	Impaired Glucose Tolerance
IVA-benefits	Inkomensvoorziening Volledig Arbeidsongeschikten (Return to Work Fully Disabled Benefits)
KPMG	Klynveld Peat Marwick Goerdeler
LaM	Levensstijl als Medicijn (Lifestyle as a Medicine)
mg	Milligram
NCEP-ATP II	National Cholesterol Education Program Adult Treatment Panel III
NGT	Normal Glucose Tolerance
NHG	Nederlandse Huisartsen Genootschap (Dutch College of General Practitioners)
Ri	Reinforcing feedback loop i
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and Environment)
SFD	Stock and Flow Diagram
T1DM	Type 1 Diabetes Mellitus
T2DM	Type 2 Diabetes Mellitus

TNO	Toegepast Natuurwetenschappelijk Onderzoek (Applied Scientific Research)
Undx PreD Popn	Undiagnosed Prediabetes Population
UWV	Uitvoeringsinstituut Werknemersverzekeringen (Employee Insurance Agency)
WC	Waist Circumference
WGA-benefits	Werkhervatting Gedeeltelijk Arbeidsgeschikten Uitkeringen (Return to Work Partially Disabled Benefits)
WIA-benefits	Wet, Werk en Inkomen Uitkeringen (Work and Income Benefits)

1. Introduction

1.1. Problem Formulation

Diabetes mellitus (DM) is a complex, metabolic disorder (Boles, Kandimalla, & Reddy, 2017, p. 3) and the number of individuals suffering from DM is dramatically increasing worldwide, from over 360 million individuals to over 500 million individuals in 2030 (Verdile, Fuller, & Martins, 2015, p. 23). This results in an increasing burden on society and rising health care costs (Dall et al., 2010, p. 1). Also, in The Netherlands there is talk of an emerging epidemic, as over the years the total population of DM patients is expected to dramatically increase to approximately 7.6% of the total Dutch population by 2025 (Baan et al., 2009, p. 36; CBS, 2017a; Seidell, 2000, p. S5). Additionally, the health care costs are expected to increase with 47.3 billion euros from 2000 to 2025 (Badir, 2014, p. 2). Therefore, there is an urgent need to explore how this rising burden on society can be reduced.

DM is a disorder that evolves over time and it can be defined in two stages. First, individuals suffer from prediabetes, that is having higher blood glucose levels than normal, but below the threshold defined for DM (Bansal, 2015, p. 296). Prediabetes patients can be roughly distinguished as either suffering from Impaired Fasting Glucose (IFG) or Impaired Glucose Tolerance (IGT) (Nathan et al., 2007, p. 753). Without treatment, the body becomes unable to regulate the blood glucose levels and the patient becomes diabetic, either suffering from diabetes mellitus type 1 (T1DM) or diabetes mellitus type 2 (T2DM) (Boles et al., 2017, p. 3). Both types increase the risks of cardiovascular diseases, eye disorders, and kidney disorders (Poortvliet, Schrijvers, & Baan, 2017, p. 12). According to Boles et al. (2017, p. 3), T1DM patients suffer from an insulin deficiency and thus, making the patient insulin dependent. In contrast with T1DM patients, T2DM patients suffer from an insulin resistance and/or insulin deficiency, which is the result of a metabolic imbalance for which no single cause has been identified yet (Boles et al., 2017, p. 3). According to Boles et al. (2017, p. 3), scientists and health professionals argue that the development of T2DM is influenced by the interaction of heritable risk factors and non-heritable risk factors. Boles et al. (2017, p. 3) suggest that non-heritable risk factors are modifiable and hence, assuming that individuals are able to make sustainable lifestyle changes, T2DM patients can be helped to permanently lower their blood glucose levels to normal levels (Petersen et al., 2005, p. 603). A process referred to as reversing the T2DM patient (Boles et al., 2017, p. 8). As 90% of the DM population consists of T2DM patients (“Suiker in perspectief,” 2013), recovering T2DM patients can have positive implications for society.

Therefore, several intervention programs focused on reversing T2DM patients have been developed. Among others, Simons et al. (2016, p. 341) and Dutch research organization TNO (2017, p. 6) are advocates of such intervention programs, because of high expected chances of implementing sustained behavior changes. In response, TNO has developed an intervention program called Lifestyle as a Medicine (LaM). T2DM is a complex, heterogeneous, metabolic disorder (Boles et al., 2017, p. 3) and thus one optimal treatment does not exist (Baan et al., 2009, p. 90; Expert E, personal communication, April 11, 2017). Therefore, LaM is based upon understanding and measuring individual differences in resilience of the metabolic system which allows for a better prediction of treatment effectiveness (Wopereis et al., 2009, p. 11) and therefore the potential to provide better personalized health advice to increase treatment effectiveness (Celis-Morales et al., 2016, p. 8; Expert A, personal communication, February 13, 2017; Expert E, personal communication, April 11, 2017). It is expected that this type of intervention program is less costly than traditional treatment methods, as by reversing T2DM patients, the total number of T2DM patients will decrease and their quality of life will increase. In turn, this will result in a gradual decrease in the need for medication and an increase of labor productivity (TNO, 2017, p. 19; Van der Wal, 2011, p. 4). Consequently, the healthcare costs are expected to be reduced.

In commission of TNO, Dutch consultancy agency Vintura provided high-level insights into the costs and benefits of implementing LaM as an intervention program to treat and reverse T2DM patients while aiming to achieve permanent lifestyle changes and thus, improve their quality of life (TNO, 2017, p. 19). Vintura compared costs associated with T2DM under the Current Policy versus when LaM would be implemented as an intervention program and suggested a large potential cost reduction (TNO, 2017, p. 13). The costs considered in the Vintura business case are costs compensated by the health insurer (Keurentjens, Van Ommen, Van Dijken, & Molema, 2016). However, costs associated with T2DM concern multiple stakeholders. Therefore, the present study is concerned with the total societal costs associated with T2DM. The stakeholders considered are the public authorities, the patient, and the health insurer. Additionally, assuming that all T2DM patients and all prediabetes patients are employed, the employer is considered a stakeholder. In addition, Vintura only considered the T2DM population and disregarded the prediabetes population when determining the potential of LaM, because of an active health care law in The Netherlands (de Zorgverzekeringswet in Dutch) (Expert A, personal communication, February 13, 2017). This law states that once the patient is diagnosed, financial resources will become available for treatment (Nederlandse

Zorgautoriteit, n.d.). Consequently, treatment for a prediabetes patient is relatively more expensive than treatment of a diabetes patient. However, by only focusing on the T2DM population, the Dutch society is fighting the consequences instead of reducing the causes. Hence, the present study argues that recovery programs should focus on the prediabetes population as well. Additionally, for prediabetes patients, the disease is still in its early phase and thus, less drastic lifestyle changes are needed (Expert D, personal communication, March 8, 2017). When lifestyle treatment is focused on the prediabetes population, it could potentially result in long-term societal cost reductions. Therefore, the present study argues a shift from intervention to prevention.

Despite having access to several intervention programs and knowledge on the effect of T2DM on total societal costs in the Netherlands, no policy on reversing T2DM patients or prediabetes patients is being implemented in the Dutch health care system yet (Expert E, personal communication, April 11, 2017). A clear understanding of the T2DM patient journey, from being healthy to becoming diabetic, and how the total societal costs associated with T2DM develop, can support decision makers to change the current policy. Therefore, a system dynamics model will be developed to understand the T2DM patient journey and the development of the total societal costs associated with T2DM, for the T2DM population and both prediabetes populations. Furthermore, the present study may contribute in creating awareness of the effectiveness of non-medicinal remedies for T2DM patients and prediabetes patients. Additionally, the resulting insights might contribute to the T2DM policy-making processes. Therefore, the present study will present possible scenarios over time for mutual awareness and decision support, in advance of real-life action programs.

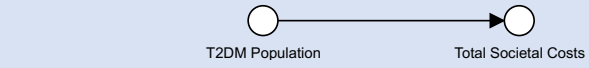
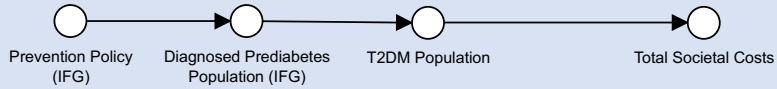
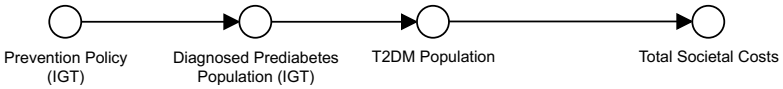
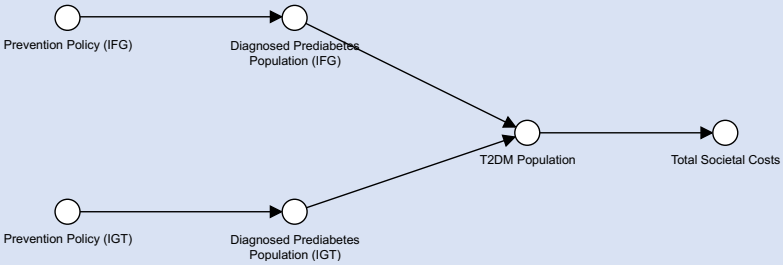
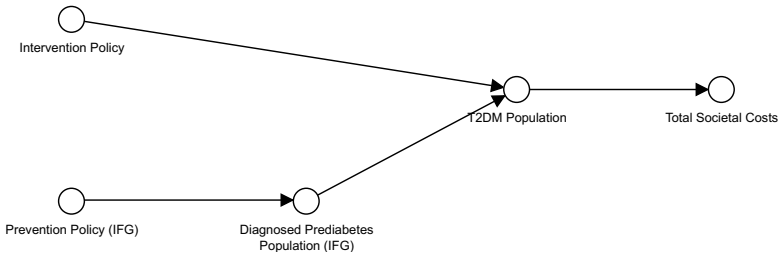
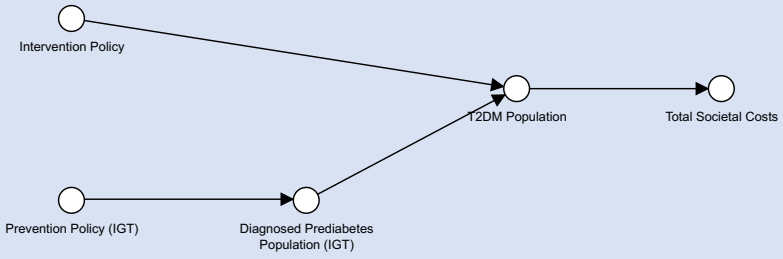
Hence, the research objective is to develop a system dynamics model to gain insights in the role of LaM in reducing the total societal costs associated with T2DM, creating awareness of the effectiveness of T2DM intervention programs and prevention programs, and contributing to the T2DM decision-making processes. Subsequently, the research question is:

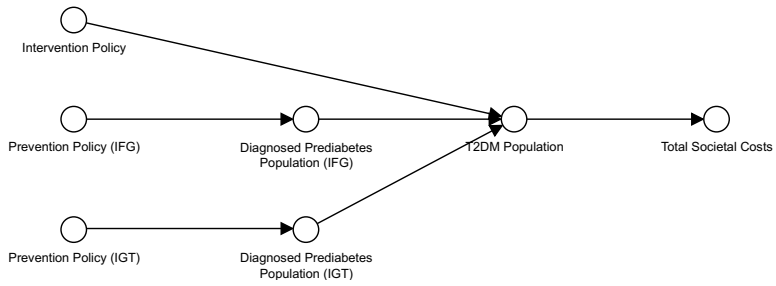
To what extent does LaM change the development of the T2DM population and reduce the total societal costs associated with T2DM in comparison with the current situation in The Netherlands?

To be able to examine the effect of implementing LaM as an intervention program, information is needed on the development of the prediabetes populations, the T2DM

population, and the total societal costs associated with T2DM under the Current Policy. Additionally, it is interesting to examine the development of the T2DM population and the total societal costs associated with T2DM when LaM is implemented as a prevention program. Furthermore, the effect of a simultaneous implementation of policy option LaM as an intervention program and a prevention program will be examined as well. A brief overview of the policy options is presented in Table 1 below.

Table 1 – Overview of Policy Options

Current Policy	
Intervention Policy	
Policy Option: Prevention (IFG)	
Policy Option: Prevention (IGT)	
Policy Option: Prevention (IFG + IGT)	
Policy Option: Intervention & Prevention (IFG)	
Policy Option: Intervention & Prevention (IGT)	

Policy Option: Intervention & Prevention (IFG) & Prevention (IGT)	

To support answering the research question, the following sub-questions will be addressed:

A – How do the T2DM population and the total societal costs associated with T2DM develop in case of a continuation of the current situation in the Dutch health care system?

B – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM intervention program in the Dutch health care system?

C – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as a prevention program (IFG) in the Dutch health care system?

D – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as a prevention program (IGT) in the Dutch health care system?

E – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as a prevention program LaM (IFG + IGT) in the Dutch health care system?

F – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as both an intervention program and a prevention program (IFG) in the Dutch health care system?

G – *How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as both an intervention program and a prevention program (IGT) in the Dutch health care system?*

H – *How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as an intervention program LaM, a prevention program LaM (IFG), and a prevention program (IGT) in the Dutch health care system?*

1.2. Approach

System dynamics has proven to be a successful tool to gain insights in complex, social systems (Forrester, 1961, p. 49) in multiple research fields, such as the housing association market (Vennix, 1996, p. 241) and food security programs in Sub-Saharan Africa (Kopainsky, Tröger, Derwisch, & Ulli-Beer, 2012). However, its application to gain an understanding in of the total societal costs of T2DM is so far limited. Therefore, system dynamics will be applied to develop a simulation model to gain insights in the development of the Dutch T2DM patient journey under the Current Policy, under LaM as an intervention policy, under LaM as several prevention policies, and under policy options that combine LaM as intervention program and prevention program. It is considered an appropriate method for identifying important leverage points in complex problems (Guariguata et al., 2016, p. 1). Additionally, it allows for an examination of possible interventions in advance of real-life implementation and subsequent evaluation (Homer, Hirsch, Minniti, & Pierson, 2004, p. 202), which would otherwise be too costly. The model will be based upon models developed by Jones et al. (2006) and Gelevert (2012). Jones et al. (2006, p. 488) have studied and modeled T2DM as an emerging health issue in the United States. Gelevert (2012, p. 4-5) has developed an unvalidated system dynamics model to simulate the effect of T2DM interventions to cost-effectively reduce the number of T2DM patients in The Netherlands.

To develop a system dynamics model, a thorough understanding of the core concepts of this complex, social issue is crucial. These concepts are addressed in chapter 2. Chapter 3 elaborates on the methods used and addresses the role of feedback governing the system's behavior. Chapter 4 provides an overview of the T2DM patient journey model. Chapter 5 is concerned with the model's validation process. The results from conducting scenario analyses are presented in chapter 6. Chapter 7 summarizes the most important insights resulting from

the present study. The Master's Thesis is concluded by reflecting on the study's limitations and by providing recommendations for future research in chapter 8.

2. Theoretical foundation

2.1. The Metabolic Disorder

2.1.1. Diabetes Mellitus (DM)

DM is an important research topic because poor glucose management can result in blindness, kidney failure, amputation(s), and cardiovascular diseases. The two main types of DM are diabetes mellitus type 1 (T1DM) and diabetes mellitus type 2 (T2DM) (Boles et al., 2017, p. 3). T1DM occurs as "an autoimmune disease where autoreactive T cells of the immune system attack the insulin secreting pancreatic islets of Langerhans" (Boles et al., 2017, p. 3). This results in patients suffering from an insulin deficiency and consequently becoming insulin dependent. In contrast with T1DM, T2DM patients suffer from insulin resistance, insulin deficiency, or a combination of both (Boles et al., 2017, p. 4). Tabák et al. (2009, p. 2216) defined T2DM "by a fasting glucose of 7·0 mmol/L or more or a 2-h postload glucose of 11·1 mmol/L or more.".

T2DM is a complex and progressive disease. If the fasting glucose or 2-h postload glucose is higher than the blood glucose levels of healthy individuals but lower than the standard set to receive the diagnosis DM, the individual is referred to as prediabetic or having prediabetes (Bansal, 2015, p. 296; Boles et al., 2017, p. 1; Expert B, personal communication, February 17, 2017). Graph A and graph B in Figure 1 show the glucose trajectories of healthy individuals versus T2DM patients. The blue line in both graphs shows that for T2DM patients, the fasting glucose and the 2-h blood glucose is increasing over the years, whereas the green line representing the non-DM population remains stable over the years (Tabák et al., 2009, p. 2218). Hence, the T2DM patient first suffers from prediabetes before developing T2DM.

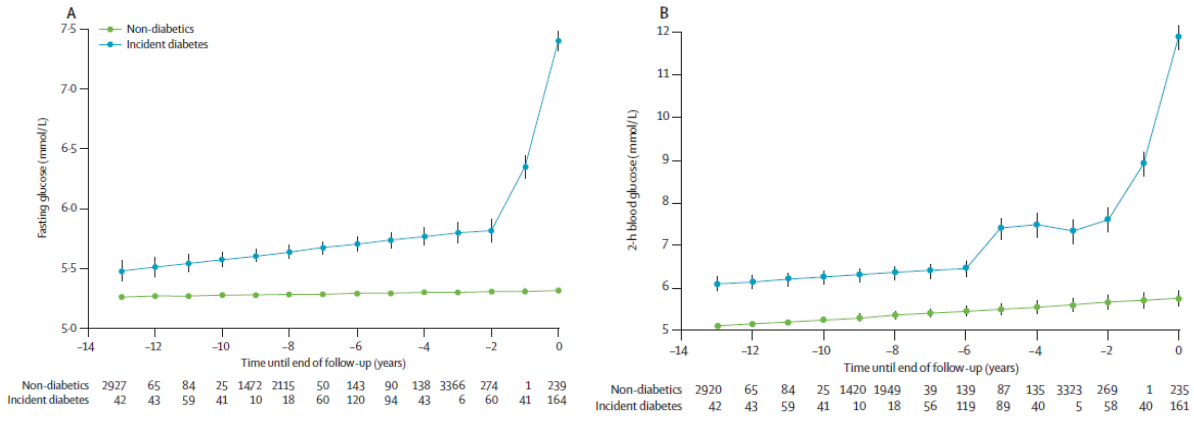


Figure 1 – Fasting (A) and 2-h Postload (B) Glucose Trajectories before Diagnosis of Diabetes or The End of Follow-Up (Tabák et al., 2009, p. 2217).

2.1.2. Prediabetes

The metabolic abnormality in prediabetes that precedes T2DM can be categorized into undiagnosed prediabetes and diagnosed prediabetes. In contrast with diagnosed prediabetes patients, individuals suffering from undiagnosed prediabetes are not aware of their condition. Diagnosed prediabetes can be roughly distinguished as impaired fasting glucose (IFG) and impaired glucose tolerance (IGT) (Nathan et al., 2007, p. 753). Nathan et al. (2007, p. 735) defined IFG and IGT by looking at "an elevated fasting plasma glucose concentration" and "an elevated 2-h plasma glucose concentration", respectively. An IFG-patient suffers from the liver incorrectly responding to the hormone insulin and consequently releasing too much glucose into the bloodstream (Territory Organisations, 2012). An IGT-patient suffers from the opposite issue of having too little insulin being released into the bloodstream and/or the produced insulin does not work properly (Territory Organisations, 2012). However, these definitions of IFG and IGT assume an overlap between the two categories, which is referred to as Combined Glucose Intolerance (CGI) (Jing et al., 2014, p. 809). Nathan et al. (2007, p. 754) developed criteria to be able to study the characteristics of IFG and IGT separately, which are referred to as isolated IFG (FPG:100–125 mg/dl and the 2-h value <140 mg/dl) and isolated IGT (2-h value of 140–199 mg/dl and the fasting level <100 mg/dl). An overview of the criteria and the plasma glucose concentration of individuals suffering from IFG and IGT are presented in Figure 2 and Figure 3 respectively (Nathan et al., 2007, p. 754). Nathan et al. (2007, p. 754) use the abbreviation NGT to refer to individuals with normal glucose tolerance or to refer to individuals from the normoglycemic population. The present study considers individuals of the normoglycemic population to be healthy individuals.

Table 1—*Classification of glucose tolerance states*

State	FPG level (mg/dl)	2-h plasma glucose in OGTT (mg/dl)*
IFG	100–125	<200
Isolated IFG	100–125	<140
IGT	<126	140–199
Isolated IGT	<100	140–199
Combined IFG/IGT	100–125	140–199
NGT	<100	<140

Figure 2 – Criteria of NGT, IFG, IGT, and CGI by Nathan et al. (2007, p. 754).

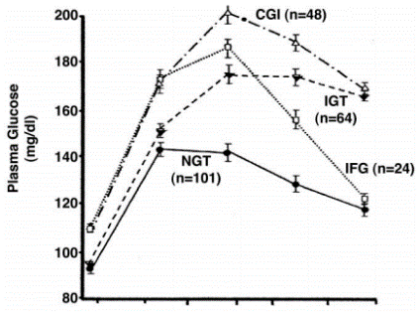


Figure 3 – Plasma Concentration of Individuals with NGT, IFG, IGT, and CGI (Nathan et al., 2007, p. 754).

Although T2DM occurs due to a metabolic imbalance for which a single cause is not yet identified (Boles et al., 2017, p. 3; Tabák et al., 2009, p. 2219), researchers argue that T2DM

and prediabetes results from an interaction of heritable risk factors, such as genetics, and non-heritable risk factors, such as lack of physical exercise (Boles et al., 2017, p. 4; Homer et al., 2014, p. 1; Kandimalla et al., 2017, p. 1). The non-heritable risk factors indicate the possibility of T2DM patients and diagnosed prediabetes patients to be reversed to healthy individuals.

2.1.3. The Role of Obesity

Loos and Janssens (2017, p. 535) argued that most individuals develop T2DM as a consequence of suffering from a metabolic syndrome or obesity. According to Baan et al. (2009, p. 14), fat-cells are less sensitive to insulin, when compared with other cell types such as muscle cells. Obesity might therefore lead to T2DM. According to the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) (Wilson, 2005, p. 3066), an individual suffers from a metabolic syndrome when at least three of the following traits are present: "an increased waist circumference, blood pressure elevation, low HDL cholesterol, high triglycerides, and hyperglycemia". It is noted that one of the symptoms of obesity is also an increased waist circumference (Schokker, Visscher, Nooyens, van Baak, & Seidell, 2007, p. 104).

Obesity is defined as "the state in which the accumulation of fat has occurred to such an extent that the health of the individual is impaired" (Leong & Wilding, 1999, p. 222). Obesity occurs because of the combination of an unhealthy lifestyle and a genetic susceptibility for gaining weight (Loos & Janssens, 2017, p. 540). To determine if an individual is obese, Dutch Statistics Agency CBS (2016c) uses the Body Mass Index (BMI; in $\frac{kg}{m^2}$). BMI is a measuring standard which provides an indication for the ideal bodyweight in kilograms concerning the individual's height in meters (Lemmens, Brodsky, & Bernstein, 2005, p. 1082). CBS (2016c) determines an individual as obese when their BMI is 25 or over. However, fat distribution plays a major role in the development of T2DM, as fat distributed around the abdomen and the viscera causes more harm than fat distributed more peripherally (Leong & Wilding, 1999, p. 222). Therefore, Leong and Wilding (1999, p. 222) used waist circumference (WC) in addition to BMI to determine the obese population. Using the WC measurement, the magnitude of the abdominal fat tissue is reflected in relationship to the individual's height and weight (Ness-Abramof & Apovian, 2008, p. 402; Taylor, Jones, Williams, & Goulding, 2000, p. 490). The WC defines individuals as being obese, when the waist circumference is over 94 cm and over 80 cm, for men and women respectively (Wang, Rimm, Stampfer, Willett, & Hu, 2005, p. 506). Even though both BMI and WC are measures to estimate central adiposity,

Leong and Wilding (1999, p. 222) and Wang et al. (2005, p. 560) prefer the WC over BMI, as the WC is simpler and it appears to be a better predictor of the risk of T2DM. That is, when compared to the BMI measurement, the WC identified approximately an extra 1% of the individuals to be at risk of developing T2DM (Wang et al., 2005, p. 561).

Furthermore, individuals developing obesity also develop a higher insulin resistance and, as a consequence, eventually need insulin therapy (Swinnen, Hoekstra, & De Vries, 2009, p. 19; TNO, 2017, p. 2). Together with two internists from two Dutch hospitals, the Heart Foundation and the Dutch Diabetes Association suggest that 1 out of 3 obese individuals will develop T2DM (Nederlandse Hartstichting & Diabetes Fonds, 2011). Therefore, in developing intervention programs for T2DM, it is of great importance to consider the role of obesity.

2.2. Trends

Worldwide 366 million individuals suffer from DM with an expected increase to 552 million individuals in 2030 (Kandimalla, Thirumala, & Reddy, 2017, p. 2). Similarly in The Netherlands, the number of DM patients has increased from 160,000 individuals in 1990 to 740,000 individuals in 2007, and is expected to increase to 1.3 million individuals by 2025 (Baan et al., 2009, p. 36). It is assumed that 9 out of 10 individuals of the total DM population suffers from T2DM ("Suiker in perspectief," 2013) (Figure 4) . CBS (2017b) has published data concerning the number of T2DM patients in 2013, 2014, 2015, and 2016, which also shows a less drastic but still increasing T2DM population (Figure 5). As CBS is perceived to be the most reliable resource from which a relevant dataset can be obtained, the present study will consider the trend in T2DM population published by CBS (2017b) as reference mode of behavior. The reference mode of behavior describes the dynamic problem (Bianchi, 2016, p. viii).

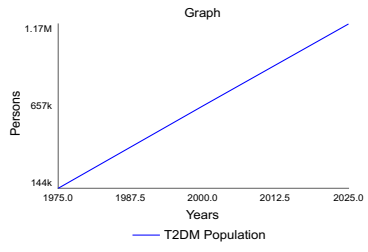


Figure 4 – Trend T2DM Population (Baan et al., 2009, p. 36)

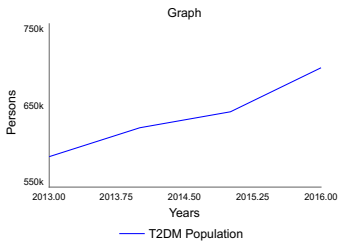


Figure 5 – Trend T2DM Population (CBS, 2017b)

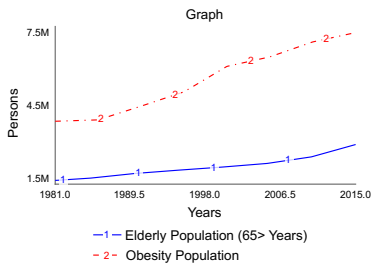


Figure 6 – Trend Elderly Population and Obesity Population

Both datasets exhibit an increasing T2DM population, which is a result of two factors. Besides the effect of obesity (Loos & Janssens, 2017, p. 535), an increasing aging population in The Netherlands results in an increasing T2DM population (CBS, 2017a) (Figure 6), as it is common for insulin resistance to increase with age (Yakaryilmaz & Öztürk, 2017, p. 279). Furthermore, Baan et al. (2009, p. 9) argue that more patients are registered as T2DM patient since 2009, as a result of increasing awareness of T2DM in general practices. However, researchers disagree on the degree to which the T2DM population has increased. Some researchers argue about a 34% increase (Volksgezondheidenzorg.info, 2018), others state a 30% increase (RIVM, 2016), and again other studies discuss about an approximate 14% increase (Baan et al., 2009, p. 36).

Moreover, as the prediabetes phase precedes the onset of T2DM, this population is expected to increase in the future as well (Bansal, 2015, p. 296). However, little data is published on the expected trend of prediabetes in The Netherlands. According to OptimaleGezondheid (2014), an organization concerned with providing lifestyle advice, 950,000 individuals are in risk of developing T2DM of which 200,000 individuals are unaware of their condition. The present study considers those individuals to be the diagnosed prediabetes population, both IFG and IGT, and the undiagnosed prediabetes population, respectively. De Vegt et al. (2001, p. 2111) argue that the incidence of IFG and IGT in The Netherlands is 33% and 33.8%, respectively.

2.3. Reversing T2DM Patients

Boles et al. (2017, p. 8), Petersen et al. (2005, p. 607), TNO (2017, p. 5), and Tuomilehto et al. (2001, p. 1348) suggested that T2DM patients might be reversed by making long-term behavioral changes to restore normal blood glucose levels. These recovery programs are focused on providing treatment with limited use of insulin, as early routine use of insulin therapy can have negative consequences such as increased mortality, weight gain, increased risks of cancer, and hypoglycemia (Lebovitz, 2011, p. S226). Hypoglycemia is the occurrence of the blood glucose level dropping below the normal blood glucose level (Funnell, 2016).

Currently, the most common treatment method for T2DM is diet change recommendations, increased physical activity and, if necessary, insulin therapy ("Diabetes type 2," n.d.). Several intervention programs have been developed to improve the effectiveness of current therapy to ensure T2DM patients to be long-term reversed to healthy individuals (Boles

et al., 2017, p. 8). The intervention programs range from programs focusing on improving current treatment according to the NHG-standard (de Nederlandse Huisartsen Genootschap Standaard in Dutch) (Baan et al., 2009, p. 61), programs focused on reevaluating screening methods resulting in earlier intervention possibilities, and setting up the DiHAG (Diabetes Huisartsen Advies Groep in Dutch) (Baan et al., 2009, p. 59). Other programs are focused on the effects of personalized nutrition (Celis-Morales et al., 2016, p. 8) or the effect of physical exercise (Teixeira-Lemos, Nunes, Teixeira, & Reis, 2011, p. 2). The NHG is a health standard to provide a protocol for diagnosis and to ensure the quality of treatment (Baan et al., 2009, p. 61). The DiHAG (Diabetes Huisartsen Advies Groep in Dutch) is a general practice specialized in treating T2DM patients (DiHAG, n.d.). The process of reversing T2DM patients is defined as decreasing the failure to produce insulin by the beta cells of the islets of Langerhans of the pancreas by long-term decreasing high blood glucose levels to normal levels again (Boles et al., 2017, p. 3). Researchers advocate reversing T2DM patients because of two reasons. First, the chances of sustainable healthier lifestyle behavior increases because of treatment being implemented in the patients' lives (Simons et al., 2016, p. 341). Second, research suggests costs associated with T2DM decrease as the need for insulin and medical treatment is reduced (Simons et al., 2016, p. 340; TNO, 2017, p. 13).

However, treatment effectiveness is highly dependent on the patient's intrinsic motivation to deliberately make lifestyle changes because such coaching is outside of the general practitioner's role (Expert B, personal communication, February 17, 2017). Hence, the patient either needs to seek support elsewhere or try to recover without the support from professionals. As a consequence, some experts are skeptical about the success rate of recovery programs because of the crucial role of the patient's environment in achieving success (Ershow, 2009, p. 729; Expert A, personal communication, February 13, 2017; Expert B, personal communication, February 17, 2017; Expert D, personal communication, March 8, 2017). Additionally, an American study suggests that only approximately 20% of the individuals are capable of maintaining long-term weight loss, which challenges the underlying assumption that individuals can make long-term behavioral changes (Wing & Phelan, 2009, p. 225S).

Furthermore, regarding the treatment effectiveness of LaM, the present study suggests a shift from focusing on recovering the T2DM population to recovering both diagnosed prediabetes populations to effectively reduce the number of T2DM patients. Another alternative to improve the success ratio of LaM could be by focusing on recovery of the populations simultaneously. Currently, LaM as an intervention program is focused on reversing

T2DM patients. However, T2DM is a progressive disease and thus, for prediabetes patients, the disease is still in its early phase. Additionally, when compared to a T2DM patient, prediabetes patient has practiced an unhealthy lifestyle for a shorter period of time as the onset time for prediabetes is shorter. Hence, it is arguable that less drastic lifestyle changes are needed. Additionally, it could be argued that treatment at an earlier state is likely to be more successful (Expert E, personal communication, April 11, 2017).

2.4. Global emergence of T2DM

2.4.1. The United States

Jones et al. (2006) studied the patient journey in the United States and subsequently translated this dynamic process into a system dynamics model (Figure 7). The model is interpreted to be concerned with DM, as it is not apparent whether Jones et al. (2006) studied DM or T2DM in particular. The structure of the model shows how patients transition between the following phases of the disease: *People with Normal Glycemic Levels*, *People with Undiagnosed Prediabetes*, *People with Diagnosed Prediabetes, People with Undiagnosed, Uncomplicated Diabetes*; *People with Diagnosed, Uncomplicated Diabetes; People with Undiagnosed, Complicated Diabetes;* and *People with Diagnosed Complicated Diabetes* (Jones et al., 2006, p. 488).

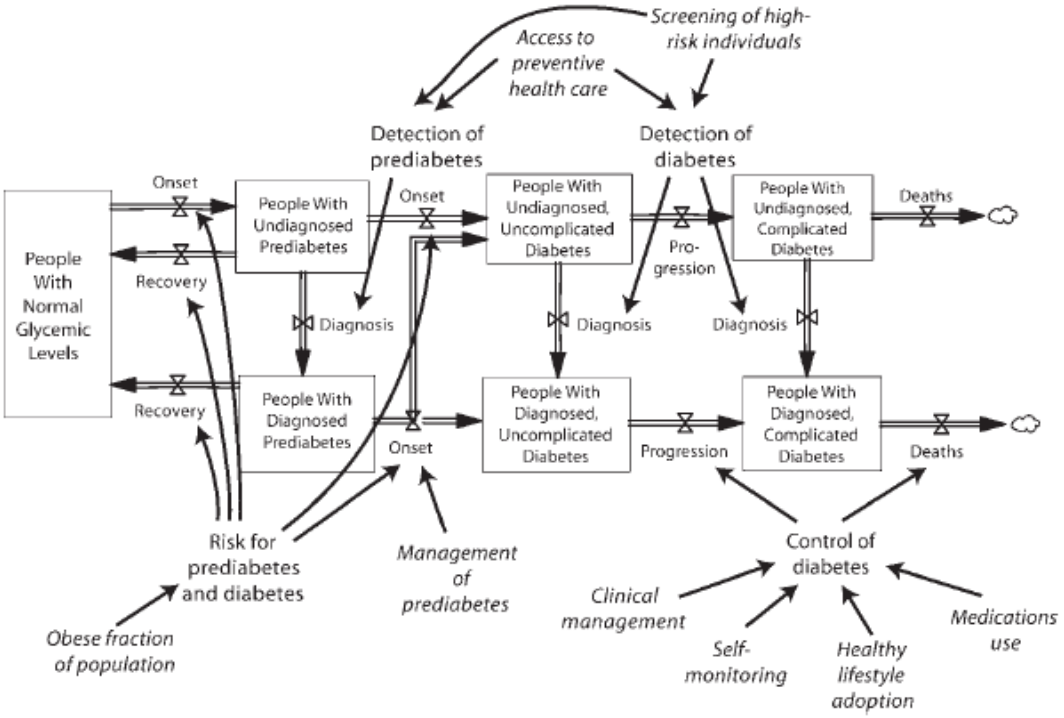


Figure 7 – System Dynamics Model on DM in the United States (Jones et al., 2006, p. 489)

Individuals suffering from prediabetes, either undiagnosed or diagnosed, are defined by suffering from impaired glucose tolerance and/or suffering from impaired fasting glucose (Jones et al., 2006, p. 488). The transition from undiagnosed to diagnosed is indicated with the flow *Diagnosis* (Jones et al., 2006, p. 488). An individual suffers from uncomplicated DM when certain testing criteria are met, but there are no detectable signs of failure in eyesight, failure in the blood circulation of feet, kidney failure, or failure of other organs yet. In contrast with uncomplicated DM, the individual does show symptoms when suffering from complicated DM (Jones et al., 2006, p. 488). Both populations may decrease as a result of *Deaths* (Jones et al., 2006, p. 489). A *Recovery* flow is added to indicate a decrease in the number of people suffering from prediabetes where individuals revert to healthy individuals again (Jones et al., 2006, p. 488).

2.4.2. The Netherlands

In commission of TNO, Gelevert (2012) built a system dynamics model displaying the development of T2DM in The Netherlands based on the Jones et al. (2006) model. The Gelevert model (2012) was developed to understand the influences causing T2DM to be able to simulate the effect of P4-interventions (Gelevert, 2012, p. 5). A simplified version of the Gelevert model (2012) is presented in Figure 8. The full model is presented in Appendix 1. P4 interventions are interventions resulting from "Proeftuin", a program concerned with cost-effectively reducing the number of T2DM patients and the associated cardiovascular complications (Gelevert, 2012, p. 5). P4-interventions are focused on intervening via Personalized, Predictive, Preventive, and Participatory care (Gelevert, 2012, p. 5).

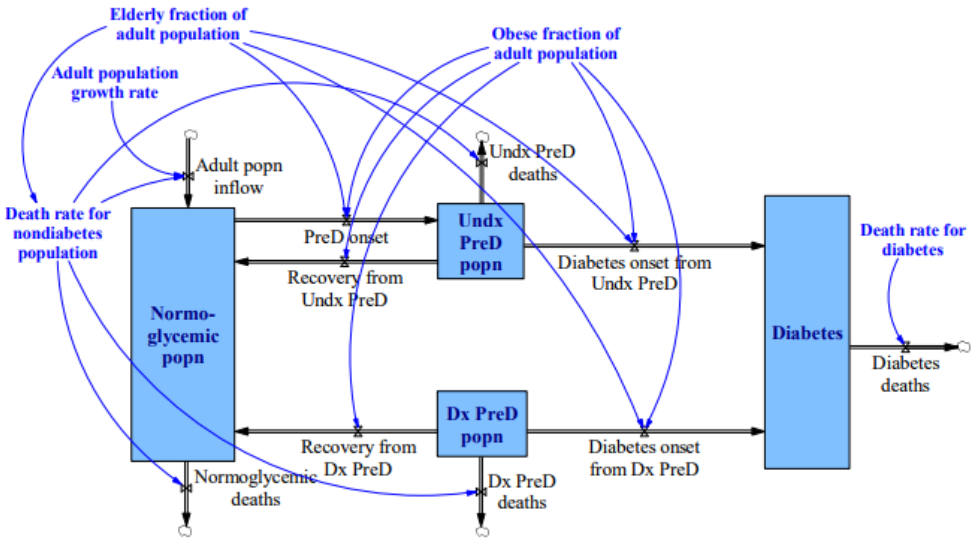


Figure 8 – System Dynamics Model on T2DM in The Netherlands (Gelevert, 2012, p. 13)

Gelevert (2012, p. 9) distinguished the T2DM population in four groups: individuals (>20 years) with normal blood glucose levels (Normoglycemic Popn), individuals (>20 years) suffering from undiagnosed prediabetes (Undx PreD Popn), individuals (>20 years) suffering from diagnosed prediabetes (Dx PreD Popn), and individuals (> 20 years) suffering from T2DM. In contrast with Jones et al. (2006), Gelevert (2012) did not distinguish between complicated T2DM and uncomplicated T2DM. According to Gelevert (2012, p. 9), the number of healthy individuals change over time by an inflow of individuals turning 20 years old (Adult Popn inflow) and an outflow of *Diabetes deaths*. The number of undiagnosed prediabetics changes because of individuals experiencing first symptoms of T2DM, undiagnosed prediabetics becoming T2DM patient, and undiagnosed prediabetes patients passing away (PreD onset, Diabetes onset from Undx PreD, and Undx PreD deaths, respectively) (Gelevert, 2012, p. 10). Then, an individual is diagnosed (PreD Diagnosis) and recruited to the diagnosed prediabetes population (Dx PreD Popn) (Gelevert, 2012, p. 10). The diagnosis rate is missing in Figure 8. The diagnosed prediabetes population also changes because of *Diabetes onset from Dx PreD* and *Dx PreD deaths*. Hence, the T2DM population recruits individuals via *Diabetes onset from Undx PreD* and *Diabetes onset from Dx PreD*. The T2DM population decreases because of *Diabetes deaths* (Gelevert, 2012, p. 10). Furthermore, Gelevert (2012, p. 10) assumes that only prediabetes patients can be reversed to healthy individuals and thus, individuals are recruited to the normoglycemic population via *Recovery from Undx PreD* and *Recovery from Dx PreD* (Gelevert, 2012, p. 10).

Furthermore, Gelevert (2012, p. 11) considers four factors affecting the emergence of T2DM in The Netherlands, which are marked blue in Figure 8. First, the effect of an aging population (Elderly fraction of adult population). Second, the effect of obesity on the emergence of T2DM (Obese fraction of adult population). Individuals are considered obese when their BMI is 25 or over (Gelevert, 2012, p. 11). Gelevert (2012, p. 11) defined the obese fraction as the total obese population as a proportion of the total Dutch population. Third, the effect of population growth is considered (Adult growth rate). Fourth, the T2DM death rate is assumed twice as high when compared to the normoglycemic population (Death rate for diabetes and Death rate for nondiabetes population, respectively) (Gelevert, 2012, p. 11).

2.5. Lifestyle as a Medicine (LaM)

2.5.1. The Program

The intervention program developed by TNO is called Lifestyle as a Medicine (LaM). TNO is

a Dutch research organization dedicated to combine available knowledge and innovation to improve the Dutch society and the society's well-being (TNO, 2016, p. 3). LaM aims to improve quality of life by reversing T2DM patients to healthy individuals by using and individual's lifestyle as a medicine (TNO, 2017, p. 19). When participating in the LaM program, it is expected that participants will experience more energy, empowerment, a delay in the occurrence of complications and comorbidities, and a significant decrease in the use of medication (TNO, 2017, p. 19). LaM is considered successful when participants do not need blood glucose-related medication any longer, both now and in the future (TNO, 2017, p. 10). The long-term expected success rate is 40% (TNO, 2017, p. 10). TNO intends to reach this success by bringing parties together that use lifestyle as a medicine to be able to jointly offer personalized care programs (Expert E, personal communication, April 11, 2017). Personalized care treatment programs are important, because of two factors. First, T2DM is a complex, heterogeneous metabolic disorder (Boles et al., 2017, p. 3). Second, the success of intervention programs is dependent on the willingness and determination of the individual to make sustainable lifestyle changes (Expert B, personal communication, February 17, 2017; Expert D, personal communication, March 8, 2017). Consequently, the effectiveness of treatment programs is different for each individual suffering from T2DM or prediabetes, either IFG or IGT. For example, patient X benefits from coaching, while patient Y benefits from making diet adjustments (Blanco-Rojo et al., 2015), whereas patient Z benefits from a combination of treatment methods (Expert E, personal communication, April 11, 2017). LaM defined personalized care by determining what caused the development of T2DM on an individual basis for each patient.

2.5.2. The Vintura Business Case: Costs of T2DM

Vintura is a Dutch consultancy agency, that, in commission of TNO, developed a business case to provide high level insights in costs and benefits of implementing LaM as an intervention program (TNO, 2017, p. 3). The Vintura business case is focused on reducing costs arising from T2DM compensated by the health insurer rather than those arising from prediabetes, as a consequence of an active health care law in The Netherlands (De Zorgverzekeringswet in Dutch) (Expert A, personal communication, February 13, 2017). The health care law states that monetary support is only available to diagnosed patients. However, as prediabetes is not recognized as a disease yet, only T2DM patients qualify (Nederlandse Zorgautoriteit, n.d.).

Vintura conducted a literature review and expert interviews seeking to imitate possible real-life scenarios using a static, mathematical model (Keurentjens et al., 2016; TNO, 2017, p. 3). The costs associated with T2DM are determined by distinguishing the T2DM patients based on medication type: oral medication, injecting less than 40 units of insulin per day, and injecting more than 40 units of insulin per day (Keurentjens et al., 2016). The total costs are determined by costs resulting from medication, direct medical costs, complications and comorbidities, labor, and lifestyle programs costs (TNO, 2017, p. 8) (Figure 9). Costs resulting from the use of medication are the costs from having insulin therapy (TNO, 2017, p. 9). Direct medical costs are concerned with costs of primary care, hospitalization, and being admitted to a nursing home (TNO, 2017, p. 9). Costs of complications and comorbidities are based on costs of ischemic heart diseases, myocardial infarcts, heart failures, strokes, amputations, loss of eyesight, and kidney failures (TNO, 2017, p. 9). Labor costs are based on costs resulting from loss of labor productivity or becoming disabled due to poorly managed blood glucose levels (TNO, 2017, p. 9). Additionally, lifestyle costs are costs resulting from executing LaM (Keurentjens et al., 2016). That is, starting and following up the LaM intervention program (TNO, 2017, p. 9). Each expense is determined by the average costs and the development of costs throughout the course of T2DM (TNO, 2017, p. 9).

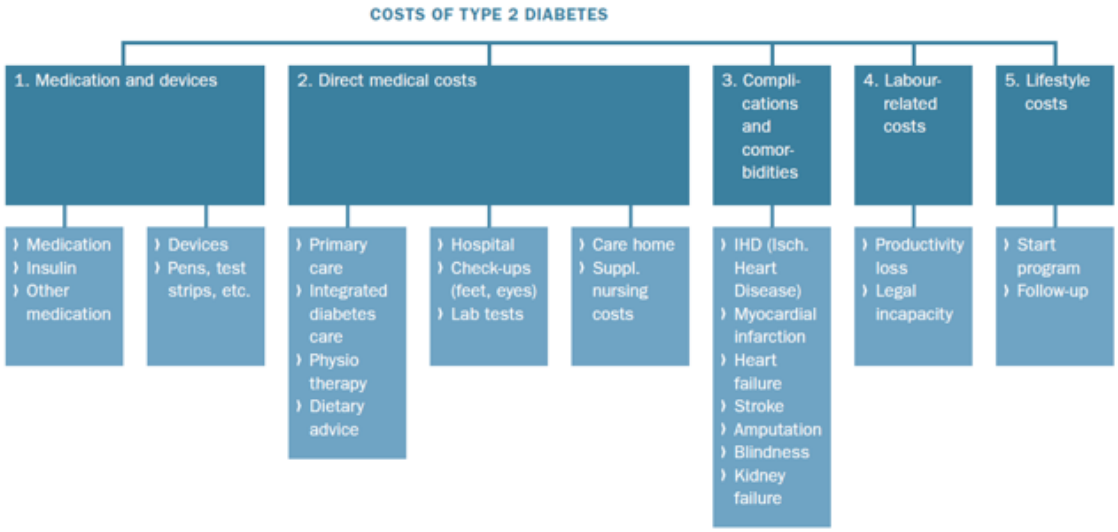


Figure 9 – Costs of T2DM according to The Vintura Business Case (TNO, 2017, p. 9)

According to its calculations, Vintura suggested a substantial cost reduction per participant per age group in which the participant develops T2DM (Figure 10). For example, the average age of T2DM onset was defined as 55 years old (TNO, 2017, p. 17). TNO (2017, p. 17) estimated that the total costs of a 55 years old T2DM patient not participating in the LaM

intervention program are 136.29 euros, as indicated by the red line. However, if the same patient would participate in the LaM intervention program, the total costs are 10.385 euros, as indicated by the green line. It follows that a T2DM patient of 55 years old participating in the LaM program could save 125.944 euros throughout the remainder of his or her lifetime. Hence, assuming that LaM is effective, TNO (2017, p. 17) suggests that participating in LaM is less costly than managing T2DM with traditional treatment methods.

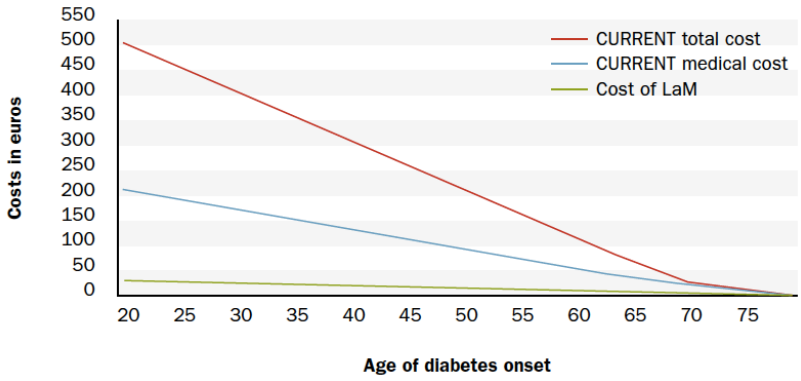


Figure 10 – Cost savings of T2DM versus Age of T2DM onset (TNO, 2017, p. 17)

Even though Vintura disclaims no rights to be reserved on the content, it still paints a very optimistic image of the possible cost reduction as a result of implementing LaM as intervention program. The Vintura business case only considered reimbursable costs associated with T2DM (Keurentjens et al., 2016), resulting in several factors being excluded for the T2DM population using oral medication. For example, hospital costs are only determined by costs resulting from controls and laboratory research, whereas travel expenses are not considered. Likewise, for both populations using insulin injections, costs resulting from needing a dietitian are excluded. Also, costs resulting from productivity loss and absenteeism for T2DM patients using more than 40 units of insulin per day are excluded. Additionally, when determining the costs of T2DM to imitate possible real-life scenarios, Vintura did not consider the development of the T2DM population over the years, nor did Vintura consider the development of the prediabetes population over the years in their calculations. As a result, the effect of an aging population on the T2DM population and both prediabetes populations was not considered. Also, the effect of an increase in screening in general practices since 2009 and the effect of an increasing obesity population.

2.6. The Total Societal Costs of T2DM

2.6.1. Unavoidable Costs and Avoidable Costs

The total societal costs associated with T2DM are costs resulting from individuals suffering from undiagnosed prediabetes, diagnosed prediabetes (IFG), diagnosed prediabetes (IGT), and T2DM. Baan et al. (2009, p. 9) distinguished costs associated with T2DM as unavoidable costs and avoidable costs. Unavoidable costs associated with T2DM arise due to an aging population and an increase in attention for DM within general practices, resulting in an increase of individuals diagnosed with prediabetes, both IFG and IGT, or T2DM (Baan et al., 2009, p. 9). Accordingly, an increase in total societal costs associated with T2DM are expected (Badir, 2014, p. 2). Avoidable costs associated with T2DM arise due to an increasing number of obese individuals and other factors increasing the risks on cardiovascular diseases (Baan et al., 2009, p. 9). It should be noted that these costs are only partially avoidable, as obesity is a consequence of the interaction of heritable and non-heritable risk factors (Loos & Janssens, 2017, p. 540).

The distinction in cost type is important to be able to understand and estimate the growth of total societal costs of the coming decade, as the health care costs have increased significantly from 46.9 billion euros in 2000 to 94.2 billion euros in 2010 in The Netherlands (Badir, 2014, p. 2). Approximately 6% of the total health care costs are determined by costs associated with DM (CBS, 2016b; Van der Wal, 2011, p. 4). As 90% of the DM population consists of T2DM patients ("Suiker in perspectief," 2013), the T2DM population determines a great majority of these costs. Additionally, approximately 33% of the obese population develops T2DM (Voorkomhartaanval.nl, 2016). Baan et al. (2009, p. 36) report an expected increase in obesity population to approximately 1.3 million individuals in 2025 in The Netherlands. Hence, an increase in medical costs is expected (Van der Wal, 2011, p. 4). Consequently, an increase in total societal costs is expected as a result of increasing productivity loss (Van der Wal, 2011, p. 6). However, this contribution in health care costs are abatable and/or preventable, as Baan et al. (2009, p. 9) and Redekop et al. (2002, p. 463) suggested that obesity is relatively easy to prevent or to reduce when assuming that individuals can make long-term behavior changes.

2.6.2. Costs for Stakeholders

The present study argues that the total societal costs of T2DM need to be considered to assess the cost-effectiveness of LaM. That is, costs for all stakeholders involved in the T2DM patient journey. Hence, in contrast with the Vintura business case (Keurentjens et al., 2016), the development of the aging population, the obesity population, and the non-reimbursable costs

are considered in the present study. Furthermore, also in contrast to the cost assessment by Vintura, the present study does not distinguish costs by medication usage, because the data availability is considered to be too limited.

The first stakeholder to be considered are the Dutch authorities. The Netherlands is a welfare state (Sainsbury, 1999, p. 102) and hence, the public authorities provide unemployment benefits to the disabled (UWV, n.d.-a). In case of a T2DM patient becoming disabled, the individual may claim for WIA-benefits. WIA-benefits (Wet Werk en Inkomen in Dutch) consist of two types of benefit: WGA-benefits (Werkhervatting Gedeeltelijk Arbeidsgeschikten in Dutch) and IVA-benefits (Inkomensvoorziening Volledig Arbeidsongeschikten in Dutch) (UWV, n.d.-a). WGA applies to all individuals that are unable to work for a period of 2 years or over and are expected be able to work in the future again. IVA applies to all individuals with limited expectations to be able to work in the future again (UWV, n.d.-a). These costs were excluded in the Vintura business case but are perceived important for the total societal cost assessment and are therefore included in the present study.

The second stakeholder group considered includes both the patient and the health insurer. According to the Vintura business case, costs arise due to the need for primary care, hospitalization, and medical tools (Keurentjens et al., 2016). Vintura excluded some medical costs and costs of tools, as they are non-reimbursable. The present study did include those costs as costs resulting from ambulance care, physiotherapy, and costs of other healthcare providers. Moreover, the present study considered costs for elderly care. It is important to examine the costs for the elderly T2DM population separately, as insulin resistance is likely to increase by aging (Yakaryilmaz & Öztürk, 2017, p. 279) . Additionally, the Dutch population is an aging population which might result in an increasing T2DM population. Finally, costs arising from managing organizations concerned with T2DM by T2DM patients' foundation associations are considered (RIVM, 2013). Again, the present study perceives these costs to be important to access to total societal costs and therefore, they are included in this study based on data reported by RIVM (2013).

Medical costs are covered by both the individual and the health insurer. In The Netherlands, all individuals are obligated to have a health insurance and hence, all individuals must pay an underlying insurance and the monthly premiums (Rijksoverheid, n.d.-b). The underlying insurance is a basic amount the individual is obligated to pay when incurring costs resulting from T2DM. This amount is set by the public authorities (De Basisverzekering in Dutch) (Rijksoverheid, n.d.-b). When the underlying insurance is exhausted, the health insurer

is obligated to cover the individual's health care costs. This is referred to as the coinsurance (Rijksoverheid, n.d.-b). Furthermore, individuals are allowed and able to increase their monthly premiums to insure more health care coverage by the health insurance provider (Rijksoverheid, n.d.-c). However, as this study is concerned with examining the general costs associated with T2DM for all Dutch citizens, it is assumed that all Dutch citizens take out the same underlying insurance. Consequently, the distinction in individuals with different insurance policies such as higher premiums and less coinsurance is not considered. Furthermore, costs resulting from participating in lifestyle intervention programs are considered as costs for the individual (Keurentjens et al., 2016). Finally, travel expenses are considered. That is, costs resulting for the T2DM patient because of making arrangements for their own transportation, other than ambulance care, to visit a doctor (DSW Zorgverzekeraar, n.d.).

The third stakeholder considered is the employer. The employer develops costs arising due to labor productivity loss of the individual suffering from T2DM, which eventually may result in absenteeism of the T2DM patient (Dall et al., 2010, p. 2). Additionally, the costs resulting from an obligatory salary payment for disabled employees is considered. When an employee is declared partially or fully disabled in the Netherlands, the employer is obligated to pay the salary of the employee up to 2 years (UWV, n.d.-b). The Vintura business case did not consider these costs. The present study however considers these costs to be of importance in the societal cost assessment and therefore these costs are included based on data from a Dutch financial services organization (KPMG, 2012).

3. Methods

3.1. System Dynamics

To understand the T2DM patient journey in The Netherlands and the business potential of LaM as an intervention program and a prevention program, system dynamics will be applied. In the 1950's, system dynamics was developed by Forrester. At the time, it was called Industrial Dynamics, as it studied "the information-feedback characteristics of industrial activity to show how organization structure, amplifications (in policies), and time delays (in decisions and actions) interact to influence the success of the enterprise" (Forrester, 1961, p. 13). In other words, to support policy-makers in their understanding of the processes to which their efforts were directed (Radzicki & Taylor, 1997). Later, industrial dynamics evolved to system dynamics as it was applied to model and to simulate social systems. Forrester discovered that the impediment of progress mostly did not lie within the engineering side of the problem, but within the managers' side of the problem (Radzicki & Taylor, 1997). Reasoning that social systems are harder to understand, Forrester applied industrial dynamics to social systems and hence, the method system dynamics emerged (Radzicki & Taylor, 1997).

Nowadays, system dynamics is applied to understand the dynamic behavior of social systems and to identify leverage points to intervene (Guariguata et al., 2016, p. 1) by building causal loop diagrams (CLDs) and/or stock and flow diagrams (SFDs). Symbols used to show the variables and its relationships are called stocks and flows. Stocks represent a certain state of a system, which is represented by a square box and flows represent the action that changes the stock over time by using a double arrow (Ford, 2010, p. 18; Sterman, 2000, p. 193) (Figure 11). The process of stocks changing over time is referred to as accumulation (Ford, 2010, p. 39). The difference between a CLD and SFD is in the lay-out, as both can be used to represent the same system. For example, both Figure 12 and Figure 13 show the process of population increasing because of births; the larger the population, the more possible births and hence, the larger the population. A CLD and SFD are sometimes referred to as a qualitative model and a quantitative model respectively (Wolstenholme, 1998, p. 2). Both qualitative and quantitative models can be used in problem structuring and group decision-making (Scott, Cavana, & Cameron, 2016, p. 1) and to align the mental models of policymakers to eventually determine policy options (Homer, 1996, p. 11). However, in contrast with qualitative models, quantitative modelling allows for simulating complex systems in a controlled and systemic way using software programs, such as Vensim or Stella Architect. Hence, scenario analysis can be conducted to simulate different scenarios under several circumstances at multiple moments in

time to support decision-makers to evaluate policy options (Campbell, 2001, p. 196; Homer et al., 2014, p. 2; Homer, Hirsch, Minniti, & Pierson, 2004, p. 202; Jones et al., 2006, p. 488).

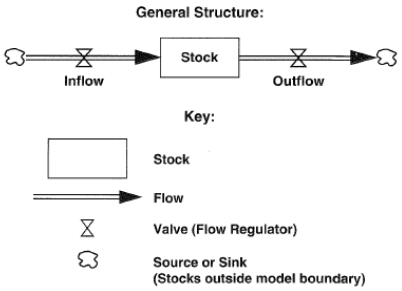


Figure 11 – Stock and Flows (Sterman, 2000, p. 193)

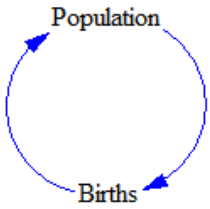


Figure 12 – Causal Loop Diagram

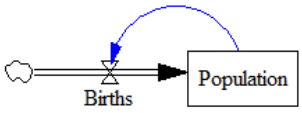


Figure 13 – Stock and Flow Diagram

3.2. The Role of Feedback

Systems dynamics uses the approach of systems thinking which assumes that a system's behavior emerges from its underlying structure (Meadows & Wright, 2008, p. 44). Behavior can change over time due to feedback mechanisms which arise from the mutually interacting components in a system (Sterman, 2000, p. 12). Sterman (2000, p. 12) distinguishes between two types of feedback loops: balancing feedback loops and reinforcing feedback loops. A balancing feedback loop, or negative feedback loop, corrects the behavior of a system as a change in behavior is opposed by the feedback effect (Sterman, 2000, p. 144). For example, the larger the population, the more people can pass away which results in a smaller population (Figure 14). A balancing feedback loop is often denoted with a B or minus (-) sign. This is in contrast with a reinforcing feedback loop, or positive feedback loop, which changes the system behavior by reinforcing the original behavior (Sterman, 2000, p. 144). For example, the larger the population, the more people can be born which results in a larger population (Figure 15). A reinforcing feedback loop is often denoted with an R or plus (+) sign.

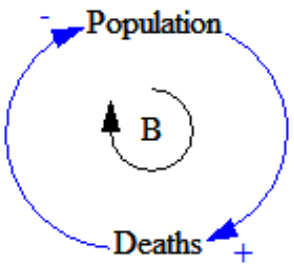


Figure 14 – Balancing Feedback Loop

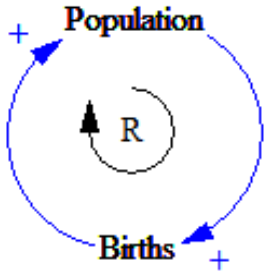


Figure 15 – Reinforcing Feedback Loop

3.3. Data Collection

To develop the system dynamics model representing the T2DM patient journey and the total societal costs associated with T2DM, a literature review and expert interviews are conducted. A literature review is conducted to validate the model structure identified for the T2DM patient journey by Jones et al. (2006) and Gelevert (2012). A literature review is important for gathering knowledge on the system being studied and to quantify the model by adding data to the model. After merging the proposed structure by Jones et al. (2006) and Gelevert (2012), expert interviews are held to elicit their knowledge on T2DM and LaM and to validate the relationships presented in the preliminary model (Figure 16) (Vennix, 1996, p. 114). Expert interviews are useful as it can support the modeler to become familiar with the research topic and to elicit expert knowledge (Vennix, 1996, p. 116). Accordingly, five interviews are held with experts working at TNO. The experts were invited to participate in an expert interview, because of their knowledge on T2DM and/or their involvement with LaM. The invited experts have backgrounds in Health Sciences, Molecular Biology, Molecular Sciences, Economics & Social History, and Medical Sciences with a Female/Male ratio of 2/3. All experts are Dutch native speakers. Therefore, the expert interviews are conducted in Dutch. The expert interviews are conducted according to the interview guide approach, that is interview topics and sequence of the interview topics are specified, as this approach is most appropriate to build a preliminary model (Vennix, 1996, p. 116; 2011, p. 253). A preliminary model will limit the participants' time investment (Vennix, 1996, p. 113), which is important for the willingness to participate in the expert interviews as the participants are busily engaged.

The interview started with an introduction by the interviewer, explaining her role within TNO, and by asking the participant for his or her consent on recording the interview. Audio-recordings are highly valuable as it provides the opportunity to listen to the exact argumentation again in the future (Vennix, 1996, p. 112). The audio-recordings are translated into research reports and analyzed for overall themes (Vennix, 2011, p. 266). The experts were informed that the data will be treated confidentially and anonymously. Furthermore, a brief explanation of the purpose of the study is provided and the preliminary model is presented and explained (Figure 16). Next, the experts were asked about their knowledge on T2DM, the influence of the social environment, the role of stakeholders, and their experience with T2DM intervention programs and T2DM prevention programs. Additionally, the participants were asked about protocols around reversing T2DM patients and the results associated with reversing patients.

For example, the number of check-ups per year and the perceived trend in recovered T2DM patients. Then, the experts were asked about the issue of who bares the responsibility to support T2DM patients making lifestyle changes. At each interview's close, the experts are thanked for their participation.

During the expert interviews, some changes in the preliminary model are suggested. For example, in contrast with Gelevert (2012, p. 10), an outflow from the T2DM population to the normoglycemic population is suggested, as experts argued the possibility of reversing both prediabetics and T2DM patients (Expert A, personal communication, February 13, 2017, p. 138; Expert B, personal communication, February 22, 2017, p. 144; Expert E, personal communication, April 11, 2017, p. 160). After crosschecking with the relevant literature, the preliminary model is modified accordingly (Petersen et al., 2005, p. 607; Tuomilehto et al., 2001, p. 1348). The modified preliminary model is validated by the majority of the experts, as the changes were suggested in the early expert interviews.

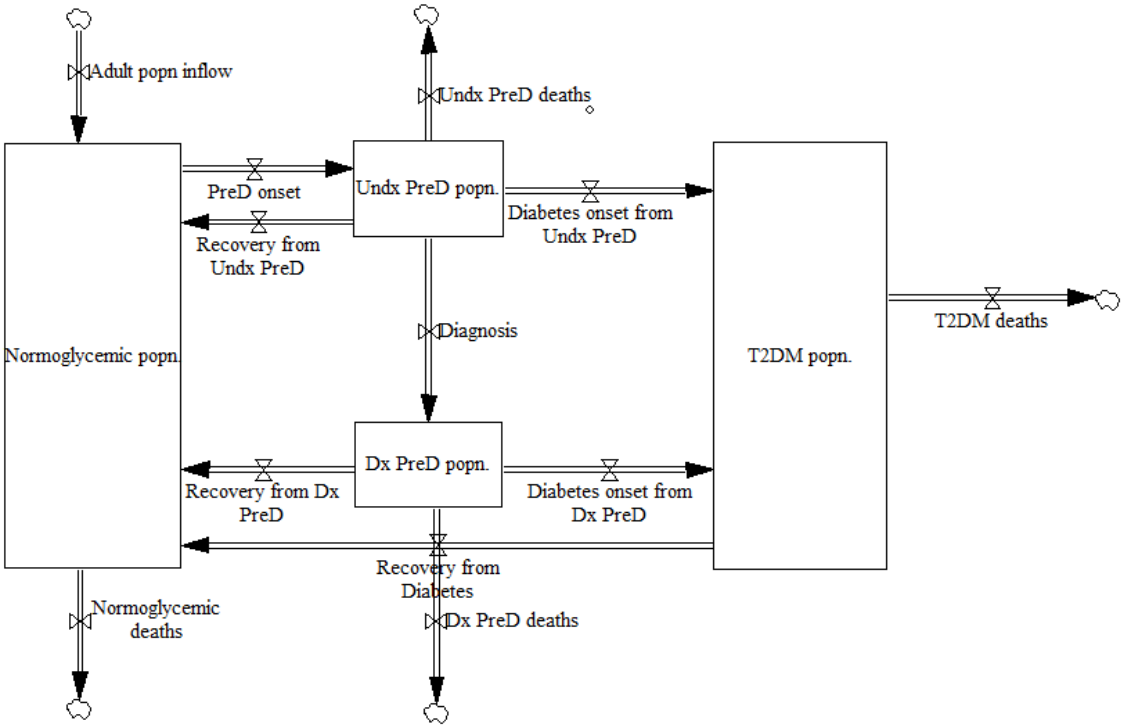


Figure 16 – The Preliminary Model

4. The Model

4.1. The T2DM Patient Journey

The T2DM patient journey model displays the journey of individuals developing T2DM in The Netherlands and the costs associated with T2DM (Figure 17). The T2DM patient journey model is based upon the models developed by Jones et al. (2006) and Gelevert (2012). It consists of the following stocks: the normoglycemic population, the undiagnosed prediabetes population, the diagnosed prediabetes population (IFG), the diagnosed prediabetes population (IGT), and the T2DM population.

4.1.1. The Normoglycemic Population

The *Normoglycemic Popn* consists of all individuals able to develop T2DM. That is, the total Dutch population minus the T2DM population as T1DM patients are able to develop insulin resistance (University of Pittsburgh, 2003). Individuals are recruited to this population because of being born, migration, and passing away (Net Recruitment Rate). Besides passing away, individuals leave the stock when developing prediabetes (PreD Onset Rate).

Furthermore, the present study assumes that a fraction of both prediabetes populations and the T2DM population are able to recover (Fraction Recovery Dx PreD Popn (IFG), Fraction Recovery Dx PreD Popn (IGT) and Normal Recovery Fraction (T2DM)). Hence, individuals that suffered from either prediabetes or T2DM are again recruited to the normoglycemic population (Recovery Rate Dx PreD Popn (IFG), Recovery Rate Dx PreD Popn (IGT), and Recovery Rate T2DM Popn) (Equation 1).

$Normoglycemic\ Popn(t) = Normoglycemic\ Popn(0) + \int_0^t Net\ Recruitment\ Rate - PreD\ onset\ Rate + Recovery\ Rate\ Undx\ PreD\ Popn + Recovery\ Rate\ Dx\ PreD\ Popn\ (IFG) + Recovery\ Rate\ Dx\ PreD\ Popn\ (IGT) + Recovery\ Rate\ T2DM\ Popn * dt;$	Persons

Equation 1 – Normoglycemic Population

Both non-obese individuals (Onset Rate from Non-Obese) and obese individuals (Onset Rate from Obese) can experience symptoms of prediabetes. The onset rates are determined by the *Non-Obese Popn*, *Obesity Popn*, *Fraction Individuals developing Prediabetes*, *Fraction Obese developing PreD (BMI)* and *Fraction Obese developing PreD (WC)*. The *Obesity Popn*

changes because of the product of the *Average Net Fractional Growth Rate Obese Popn* and the *Obesity Popn.* Together they determine the *Net Growth Rate Obese Popn* (Equation 2).

$Obesity\ Popn(t) = Obesity\ Popn(0) + \int_0^t Net\ Growth\ Rate\ Obese\ Popn * dt;$	Persons

Equation 2 – Obesity Population

4.1.1. The Undiagnosed Prediabetes Population

Individuals experiencing symptoms of prediabetes per definition first develop undiagnosed prediabetic and are thus recruited to the undiagnosed prediabetes population (Undx PreD Popn). Undiagnosed prediabetes patients can see a general practitioner and receive the diagnosis Impaired Fasting Glucose (IFG) or Impaired Glucose Tolerance (IGT). The *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are determined by the *Fraction Incidence (IFG)* and the *Fraction Incidence (IGT)*. Also individuals not visiting a general practitioner can experience symptoms of T2DM (Diabetes Onset from Undx PreD), as the disease progresses over time (Time Diabetes onset Undx PreD Patients). Individuals also leave the stock because of reaching the *Average Life Expectancy Undx PreD Patient* and then passing away (Undx PreD Popn Death Rate). Furthermore, a fraction of the undiagnosed prediabetes patients recovers from undiagnosed prediabetes (Fraction Recovery Undx PreD Popn) and is recruited to the *Normoglycemic Popn* again (Recovery Rate Undx PreD Popn).

$Undx\ PreD\ Popn(t) = Undx\ PreD\ Popn(0) + \int_0^t PreD\ onset\ Rate - Diabetes\ onset\ from\ Undx\ PreD - Diagnosis\ Rate\ (IFG) - Diagnosis\ Rate\ (IGT) - Recovery\ Rate\ from\ Undx\ PreD\ Popn - Undx\ PreD\ Death\ Rate * dt;$	Persons

Equation 3 – Undiagnosed Prediabetes Population

4.1.2. The Diagnosed Prediabetes Population (IFG)

Individuals suffering from Impaired Fasting Glucose (IFG) are recruited from the undiagnosed prediabetes population to the diagnosed prediabetes population (Dx PreD Popn (IFG)) when receiving the diagnosis IFG (Diagnosis Rate (IFG)). Diagnosed prediabetes patients (IFG) leave the stock because of developing T2DM (Diabetes Onset from Dx PreD (IFG)), as the disease progresses over time (Time Diabetes Onset Dx PreD Patient (IFG)). Diagnosed

prediabetes patients (IFG) can also pass away (Dx PreD Popn Death Rate (IFG)) because of reaching the *Average Life Expectancy Dx PreD Patient (IFG)*. Furthermore, a fraction of the diagnosed prediabetes patients (IFG) recovers from diagnosed prediabetes (IFG) (Fraction Recovery Dx PreD Popn (IFG)) and is again recruited to the normoglycemic population (Recovery Rate Dx PreD Popn (IFG)).

$$Dx\ PreD\ Popn\ (IFG)(t) = Dx\ PreD\ Popn\ (IFG)(0) + \int_0^t Diagnosis\ Rate\ (IFG) - Diabetes\ onset\ from\ Dx\ PreD\ (IFG) - Recovery\ Rate\ Dx\ PreD\ Popn\ (IFG) - Dx\ PreD\ Death\ Rate\ (IFG)\ * dt;$$	Persons

Equation 4 – Diagnosed Prediabetes Population (IFG)

4.1.3. The Diagnosed Prediabetes Population (IGT)

The behavior for both diagnosed prediabetes populations is governed by the same structure and thus, individuals suffering from Impaired Glucose Tolerance (IGT) are recruited from the undiagnosed prediabetes population to the diagnosed prediabetes population (Dx PreD Popn (IGT)) when receiving the diagnosis IGT (Diagnosis Rate (IGT)). Diagnosed prediabetes patients (IGT) leave the stock because of developing T2DM (Diabetes Onset from Dx PreD (IGT)), as the disease progresses over time (Time Diabetes Onset Dx PreD Patient (IGT)). Diagnosed prediabetes patients (IGT) can also pass away (Dx PreD Popn Death Rate (IGT)) because of reaching the *Average Life Expectancy Dx PreD Patient (*IGT*)*. Furthermore, a fraction of the diagnosed prediabetes patients (IGT) recovers from diagnosed prediabetes (IGT) (Fraction Recovery Dx PreD Popn (IGT)) and is again recruited to the normoglycemic population (Recovery Rate Dx PreD Popn (IGT)).

$$Dx\ PreD\ Popn\ (IGT)(t) = Dx\ PreD\ Popn\ (IGT)(0) + \int_0^t Diagnosis\ Rate\ (IGT) - Diabetes\ onset\ from\ Dx\ PreD\ (IGT) - Recovery\ Rate\ Dx\ PreD\ Popn\ (IGT) - Dx\ PreD\ Death\ Rate\ (IGT)\ * dt;$$	Persons

Equation 5 – Diagnosed Prediabetes Population (IGT)

4.1.4. The T2DM Population

Individuals are recruited to the *T2DM Popn* from the *Undx PreD Popn*, *Dx PreD Popn (IFG)*,

and *Dx PreD Popn (IGT)* (Diabetes onset from Undx PreD, Diabetes onset from Dx PreD (IFG), and Diabetes onset from Dx PreD (IGT), respectively). T2DM patients leave the T2DM stock in two ways. First, passing away due to T2DM (T2DM Popn Death Rate) when reaching the *Average Life Expectancy T2DM Patient*. Second, by recovering from T2DM. The fraction that recovers from T2DM (Normal Recovery Fraction (T2DM)) determines the *Recovery Rate T2DM Popn* and thus, the number of people recruited again to the *Normoglycemic Popn*.

$T2DM\ Popn(t) = T2DM\ Popn(0) + \int_0^t Diabetes\ onset\ from\ Undx\ PreD + Diabetes\ onset\ from\ Dx\ PreD\ (IFG) + Diabetes\ onset\ from\ Dx\ PreD\ (IGT) - T2DM\ Death\ Rate - Recovery\ Rate\ T2DM\ Popn\ * dt$; $T2DM\ Popn\ (0) = Total\ Popn\ 2013\ * Fraction\ T2DM\ over\ Total\ Popn\ 2013$	Persons

Equation 6 – T2DM Population

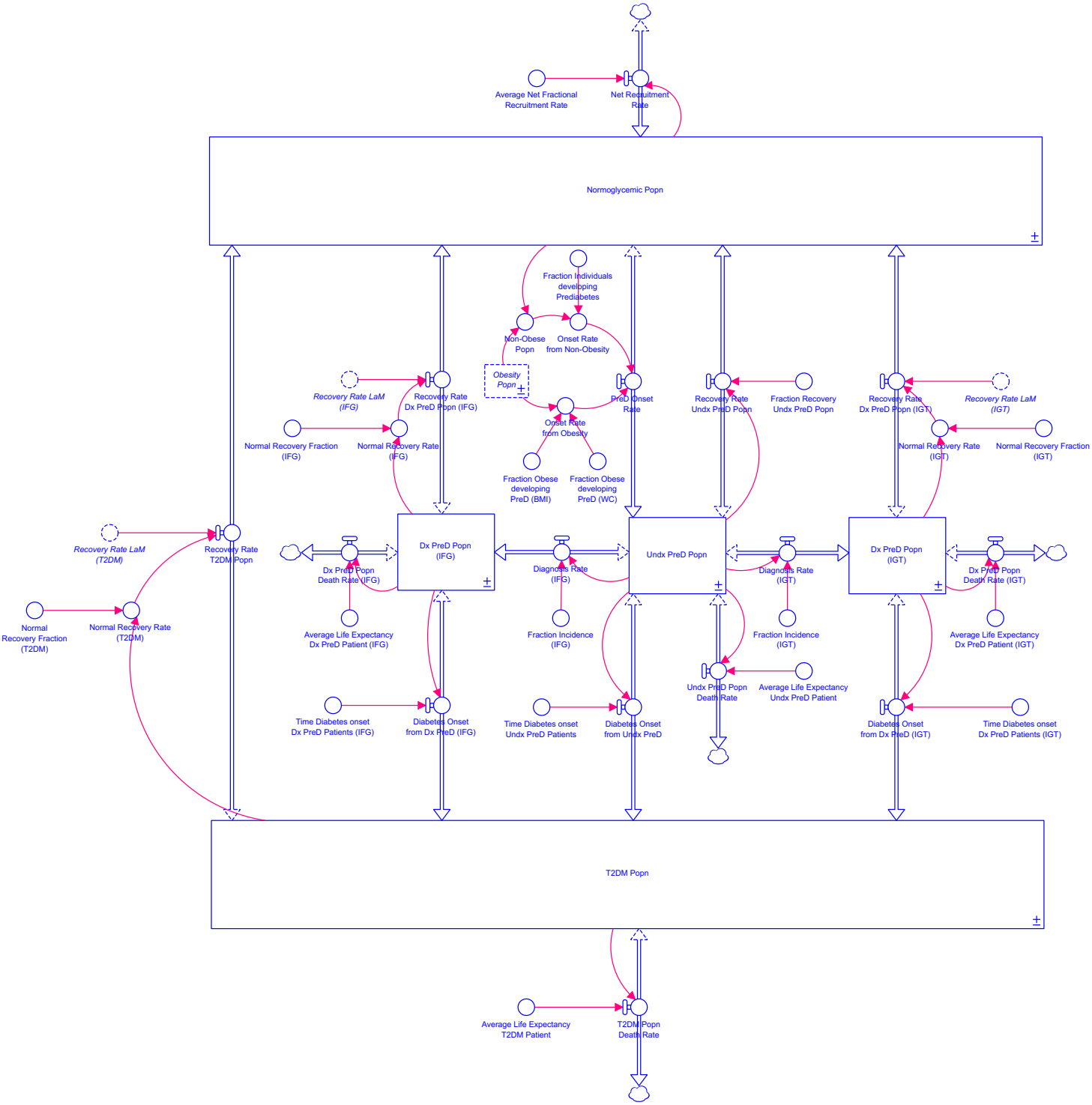


Figure 17 – The T2DM Patient Journey

4.2. The Societal Costs

The total societal costs consist of costs for the Dutch authorities, the patient, the health insurer, and the employer (Figure 19).

4.2.1. Costs for the Dutch Authorities

The costs for the Dutch authorities (Total Costs for Public Authorities T2DM Popn (WIA-Benefits)) are determined by the *Total WGA Benefits per T2DM Patient*, the *Total IVA Benefits per T2DM Patient*, and the *T2DM Popn*. The costs of WGA-benefits arise due to the *Total Costs WGA Execution T2DM*, the *Total Costs WGA T2DM*, and the *Number of T2DM patients with WGA*. The *Number of T2DM patients with WGA* is determined by the *Total Number of Persons with WGA* and the *Fraction T2DM over Total Popn 2013*. The costs of IVA-benefits arise due to the *Total Costs IVA Execution T2DM*, the *Total Costs IVA T2DM*, and the *Number of T2DM patients with IVA*. The *Number of T2DM patients with IVA* is determined by the *Total Number of Persons with IVA* and the *Fraction T2DM over Total Popn 2013*.

4.2.2. Costs for the Health Care Insurer and the Patient

The costs for the health care insurer (Total Costs for Health Care Insurer T2DM) are determined by the *Total Medical Costs T2DM Popn (Coinsurance)* minus the product of the *Costs Health Care Insurance per T2DM Patient* and the *T2DM Popn*. The costs for the health care insurer consist of the *Underlying Insurance per T2DM Patient* and the *Premiums per T2DM Patient*. The total medical costs consist of costs resulting from *Hospitalization DM*, *Ambulance Care DM*, *Tools DM*, *Total Costs Elderly Care DM*, *Primary Care DM*, *Other Health Care Providers DM*, and the *Fraction T2DM over DM Popn*. All costs are determined for the total DM population (RIVM, 2013). Therefore, to determine the costs for the T2DM population, the product is taken of the costs of the DM and the T2DM/DM ratio. The costs of tools consist of costs resulting from *Medication DM* and *Devices DM*. The costs resulting from elderly care (Total Costs Elderly Care DM) are determine by costs resulting from *Elderly Care DM* and the *Fraction 65+ year with T2DM*. The costs of primary care are a result of costs arising from *GP Care DM*, *Physiotherapy DM*, and *Other Costs DM*.

4.2.3. Costs for the Employer

The costs for the employer (Total Costs Employer T2DM Popn) are determined by the *Costs of Absenteeism T2DM Popn*, the *Costs of Labor Productivity Loss T2DM Patient (WIA*

employer), and the *Total Obligatory Continuation of Employee's Salary Payment T2DM Popn*. The *Total Obligatory Continuation of Employee's Salary Payment T2DM Popn* is determined by *Obligatory Continuation of Employee's Salary Payment per T2DM Patient*, which is determined by the average Dutch income in 2013 (Obligatory Continuation of Employee's Salary Payment per T2DM Patient) and the total T2DM population (T2DM for Salary Payment). Figure 18 shows that each T2DM patient will receive the obligatory salary payment for two years.

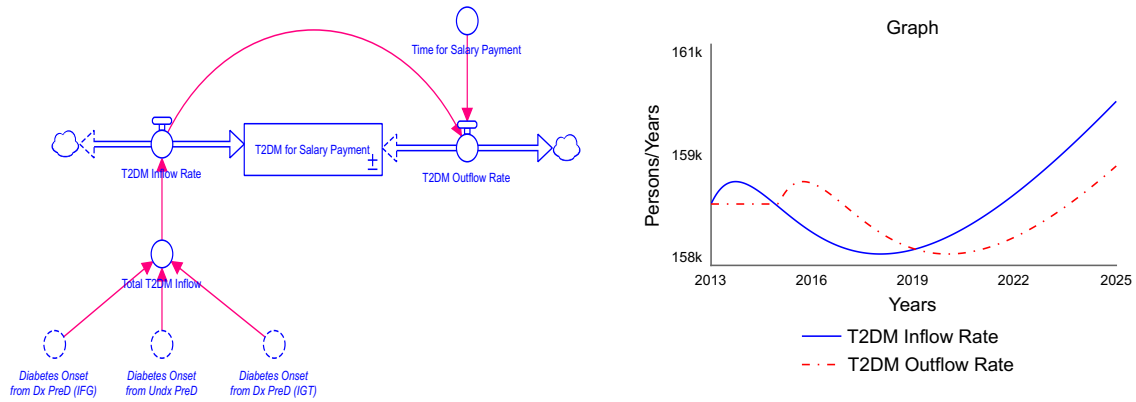


Figure 18 – T2DM for Salary Payment Structure

4.2.4. Total Societal Costs

The *Total Societal Costs T2DM Popn* consist of the *Total Costs for Health Care Insurer T2DM*, the *Total Costs Management Organizations T2DM Popn*, the *Total Costs Employer T2DM Popn*, the *Total Costs for Public Authorities T2DM Popn (WIA-Benefits)*, and the *Total Costs of Other Lifestyle Programs T2DM Popn*. The total costs for managing organizations concerned with T2DM consist of costs resulting from the *Total Costs Management Organizations DM* and the *Fraction T2DM over DM Popn*, as again the costs are determined for the total DM population (RIVM, 2013). The total costs of other lifestyle programs are determined by the *Costs of Other Lifestyle Programs per T2DM Patient* and the *T2DM Popn*.

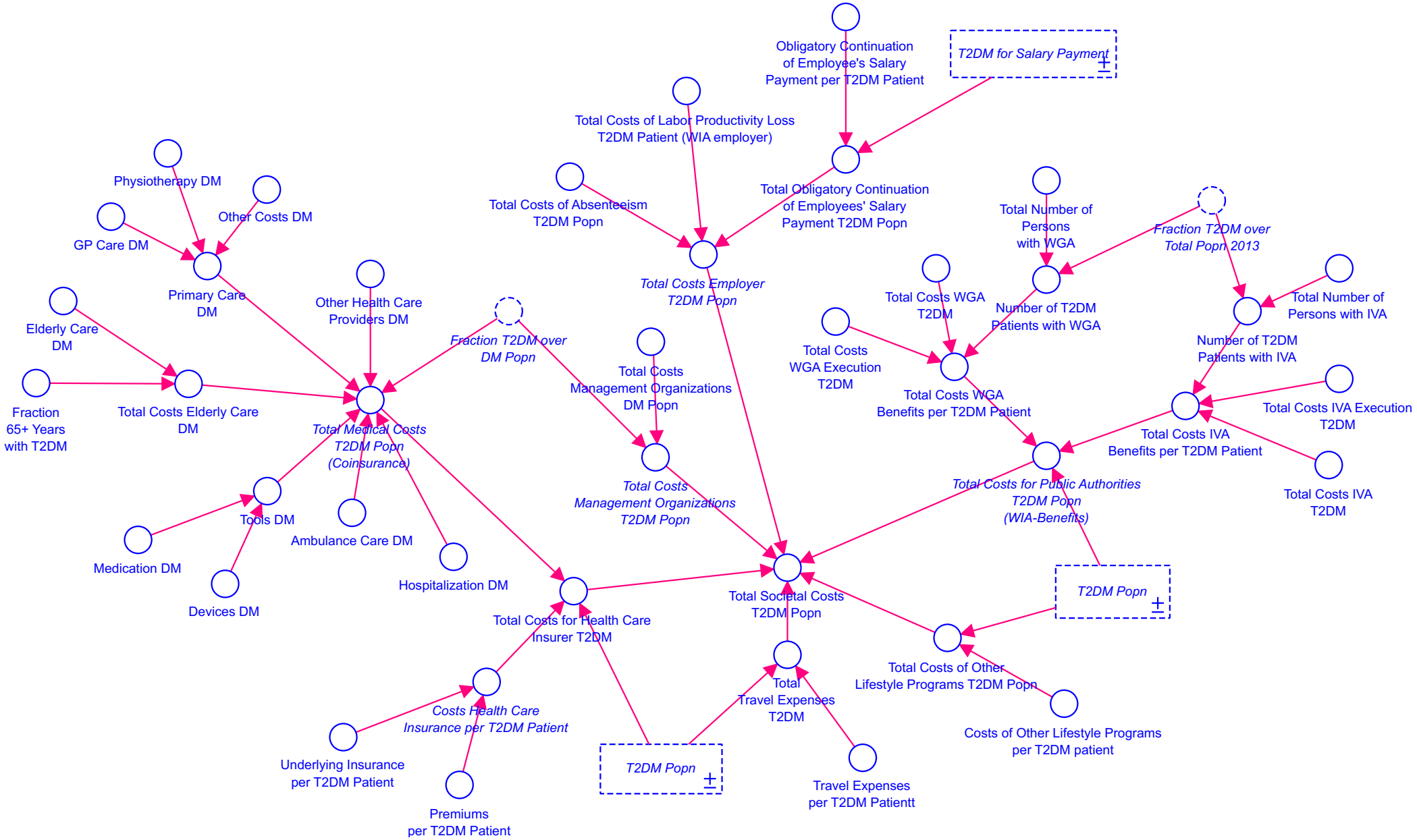


Figure 19 – The Total Societal Costs of T2DM Structure

4.3. Lifestyle as a Medicine

4.3.1. Intervention Program

The structure enabling the implementation of intervention program LaM is presented in Figure 20. Assuming that individuals are able to make sustainable lifestyle changes, the present study argues that T2DM patients can either recover without intervention program LaM (Normal Recovery Rate (T2DM)) and with the support of LaM (Recovery Rate LaM (T2DM)). The *Recovery Rate LaM (T2DM)* is determined by the *LaM Recruitment Rate (T2DM),* the *LaM Success Rate (T2DM)*, and the *Switch LaM (T2DM)*. The number of individuals recruited to participate in intervention program LaM is determined by the *Potential Recruitment Rate (T2DM)* or the *Indicated Recruitment Rate (T2DM)*, as it is initialized with the special-function MIN. The special-function MIN ensures that the lowest value of the two variables is chosen, when simulating the model. The *Potential Recruitment Rate (T2DM)* is determined by the *Maximum Patients able to treat (T2DM)*. The *Maximum Patients able to treat (T2DM)* is determined by the *T2DM Popn* and the *Time to Treat (T2DM)*. The *Indicated Recruitment Rate (T2DM)* represents the actual number of T2DM patients that is recruited to participate in the LaM program. It is determined by the *Time to Recruit (T2DM)*, the *Stakeholders' Investments (T2DM)*, and the *Total Costs LaM per Person (T2DM)*. The *Stakeholders' Investments* are determined by the *Total Societal Costs T2DM Popn* and the *Budget Stakeholders' Investments (T2DM)*. The *Total Costs LaM per Person (T2DM)* are determined by the *T2DM Popn* and the *Total Costs LaM Execution (T2DM)*. The costs of executing intervention program LaM are determined by Keurentjens et al. (2016) and consist of an *Every year Boost LaM Program*, a *Boost First Year LaM Program Costs*, and a *Boost Fifth Year LaM Program Costs*. The *Boost Fifth Year LaM Program Costs* is determined by a special function PULSE of *Costs of Fifth Year Boost.*

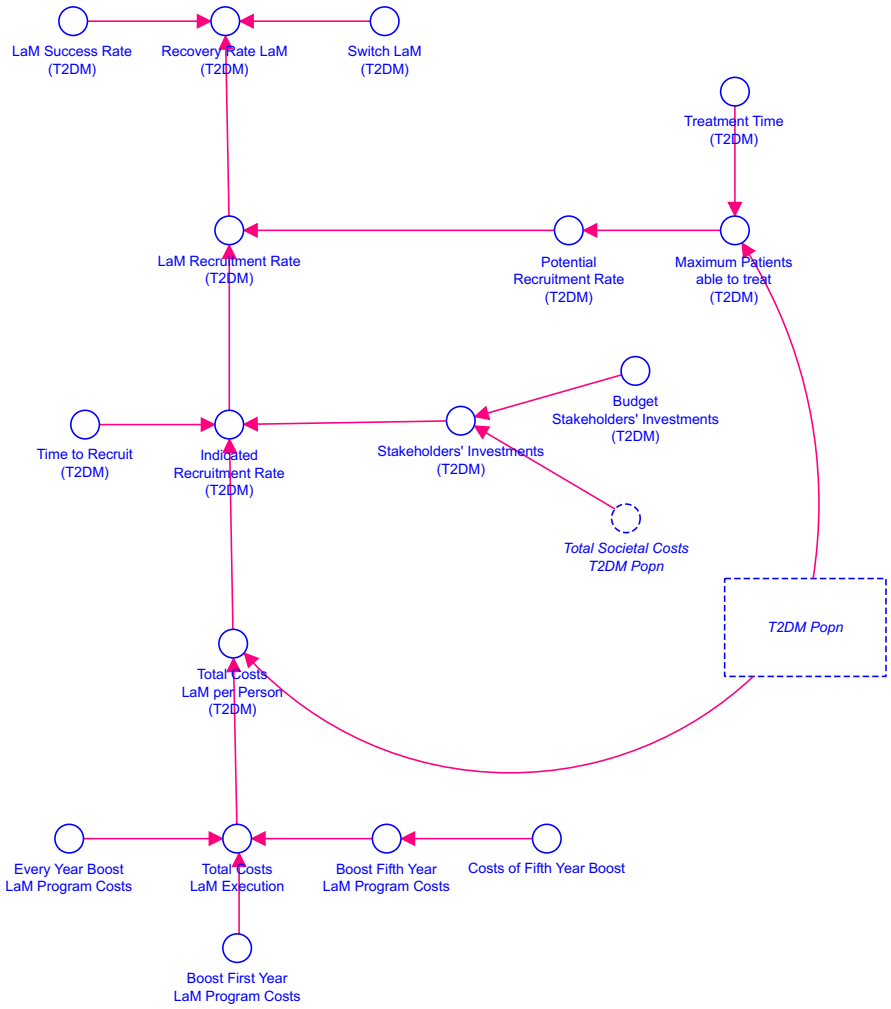


Figure 20 – Structure Intervention Program LaM

4.3.2. Prevention Program (IFG)

The structure enabling the LaM prevention program on the diagnosed prediabetes population suffering from IFG is presented in Figure 21. Assuming that diagnosed prediabetes patients (IFG) are able to make sustainable lifestyle changes, the present study argues that diagnosed prediabetes patients (IFG) can either recover without prevention program LaM (Normal Recovery Fraction (IFG)) and with the support of LaM (Recovery Rate LaM (IFG)). The *Recovery Rate LaM (IFG)* is determined by the *LaM Recruitment Rate (IFG),* the *LaM Success Rate (IFG),* and the *Switch LaM (IFG)*. The number of participants in prevention program (IFG) LaM is determined by the *Potential Recruitment Rate (IFG)* or the *Indicated Recruitment Rate (IFG)*. Similar to the intervention structure, the *LaM Recruitment Rate (IFG)* is initialized with the special-function MIN. The *Potential Recruitment Rate (IFG)* is determined by the *Maximum Patients able to treat (IFG*). The *Maximum Patients able to treat (IFG)* is determined by the *Dx PreD Popn (IFG)* and the *Time to Treat (IFG)*. The *Indicated Recruitment Rate*

(IFG) represents the actual number of diagnosed prediabetes patients (IFG) recruited to participate in prevention program (IFG) LaM. It is determined by the *Time to Recruit (IFG)*, the *Stakeholders' Investments (IFG)*, and the *Total Costs LaM per Person (IFG)*. The *Stakeholders' Investments (IFG)* are determined by the *Total Societal Costs T2DM Popn* and the *Budget Stakeholders' Investments (IFG)*. The total costs of LaM per diagnosed prediabetes patient (IFG) are determined by the *Total Costs LaM Execution (IFG)* and the *Dx PreD Popn (IFG)*. The *Total Costs LaM Execution (IFG)* is determined by the *Fraction Dx PreD Popn (IFG) over T2DM Popn* and the *Total Costs LaM Execution (T2DM)*. The *Fraction Dx PreD Popn (IFG) over T2DM Popn* is determined by the *Dx PreD Popn (IFG)* and the *T2DM Popn*.

4.3.3. Prevention Program (IGT)

The structure enabling the LaM prevention program on the diagnosed prediabetes population suffering from IGT is presented in Figure 22. Assuming that diagnosed prediabetes patients (IGT) are able to make sustainable lifestyle changes, the present study argues that diagnosed prediabetes patients (IGT) can either recover without prevention program LaM (Normal Recovery Fraction (IGT)) and with the support of LaM (Recovery Rate LaM (IGT)). The structure of prevention program (IGT) is similar to that of the prevention program (IFG). Hence, the variables governing this structure are *Normal Recovery Fraction (IGT), Recovery Rate LaM (IGT)*, *LaM Recruitment Rate (IGT)*, *LaM Success Rate (IGT)*, *Switch LaM (IGT)*, *Potential Recruitment Rate (IGT)*, *Indicated Recruitment Rate (IGT)*, *Maximum Patients able to treat (IGT)*, *Dx PreD Popn (IGT)*, *Time to Treat (IGT)*, *Time to Recruit (IGT)*, *Stakeholders' Investments (IGT)*, *Total Costs LaM per Person (IGT)*, *Budget Stakeholders' Investments (IGT)*, *Total Societal Costs T2DM Popn, Total Costs LaM Execution (IGT)*, *Fraction Dx PreD Popn (IGT) over T2DM Popn, Dx PreD Popn (IGT),* and *T2DM Popn*.

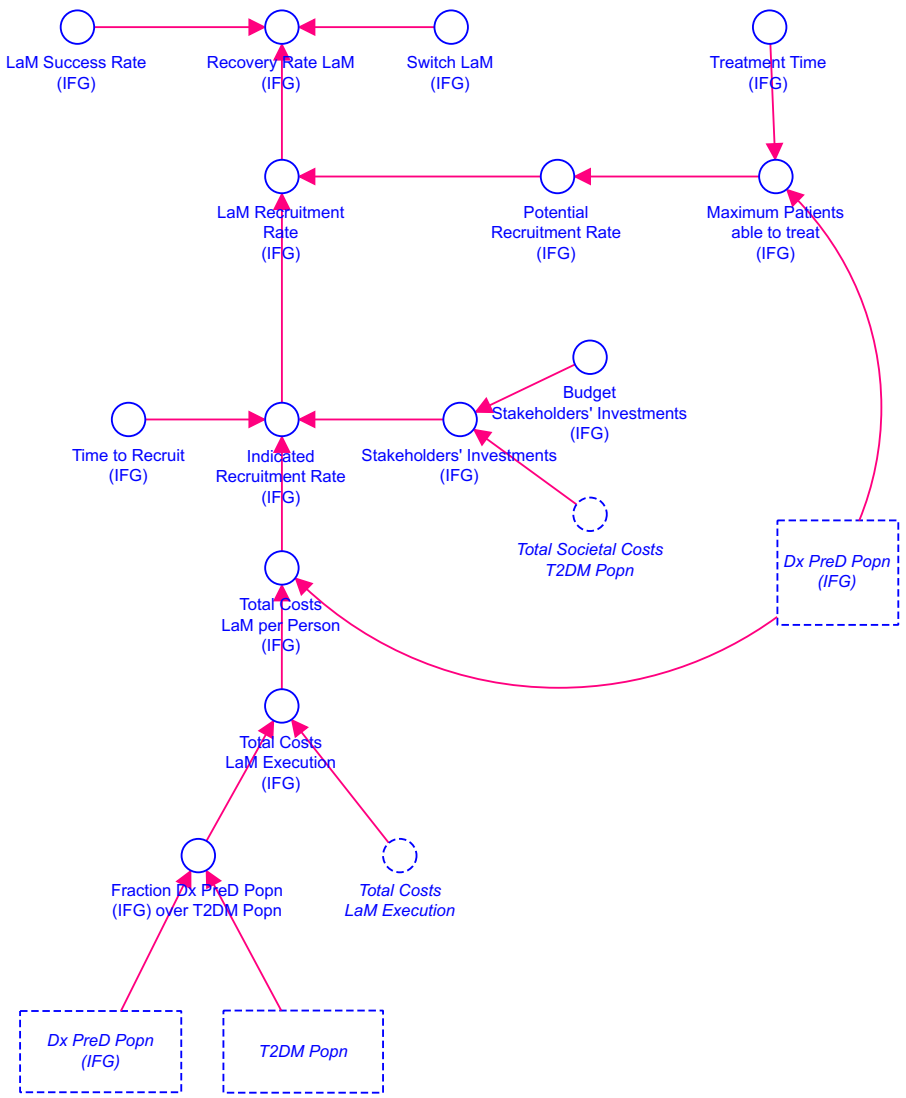


Figure 21 – Structure Prevention Program (IFG)

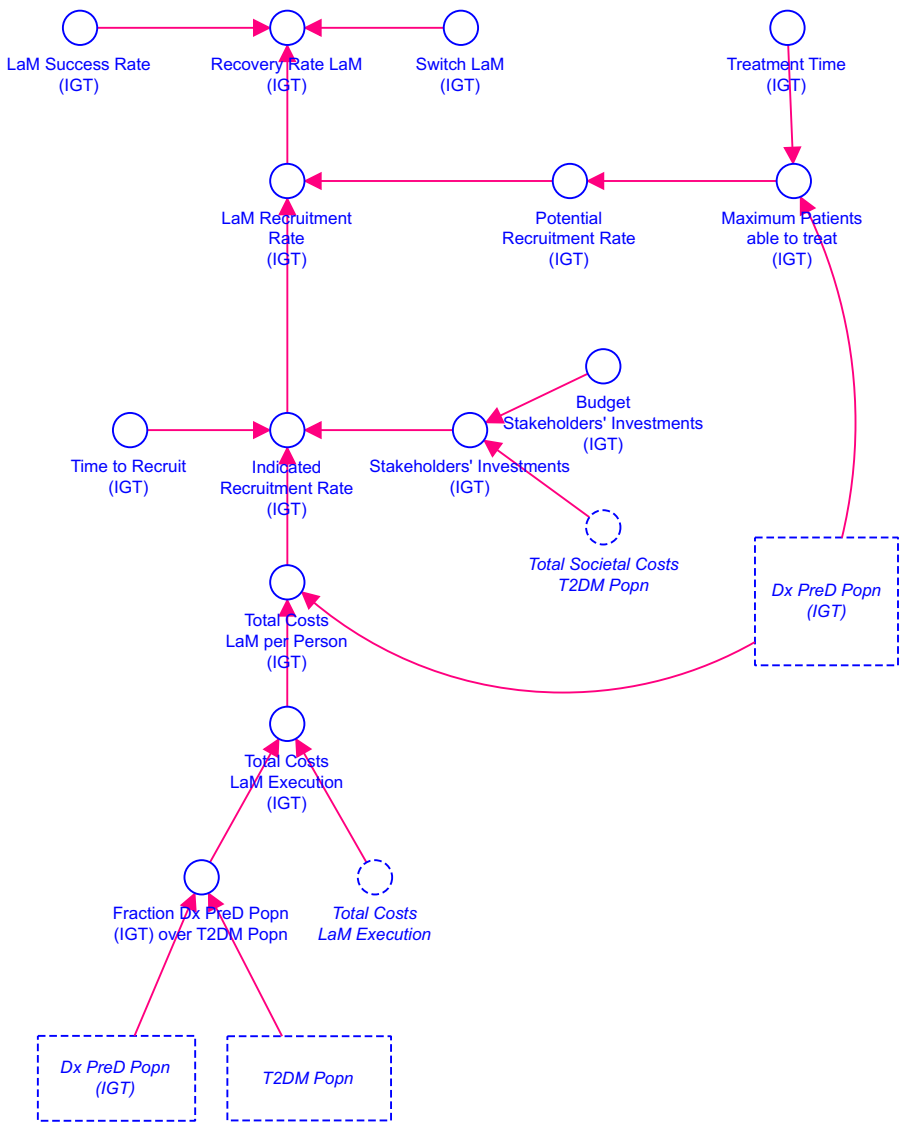


Figure 22 – Structure Prevention Program (IGT)

5. Model Validation

Model validation is an important topic of debate within the system dynamics community. Critics argue that system dynamics is not a truly scientific method, as it cannot employ formal model validation procedures (Barlas & Carpenter, 1990, p. 148). Advocates of system dynamics responded that indeed models cannot be proven valid but models can be judged valid, as system dynamics models are "strongly tied to the nature and the context of the problem" (Barlas & Carpenter, 1990, p. 148). Hence, model validation is a social, qualitative process. Therefore, it is argued that model validity should be judged considering the model's purpose (Barlas & Carpenter, 1990, p. 193). Accordingly, the T2DM patient journey model's validity will be judged considering its purpose by conducting several structure tests and structure-behavior oriented tests (Forrester & Senge, 1980, p. 210; Homer et al., 2014, p. 75).

5.1. Model Calibration

To calibrate the model, databases of, among others, CBS, KPMG, Nederlandse Zorgautoriteit, NIVEL, RIVM, and TNO are used. For some concepts, data estimates had to be made due to limited data availability or conflicting datasets. The T2DM patient journey model does not consider the Dutch population's composition in terms of ethnic backgrounds and migration. Therefore, an average net fractional recruitment rate is used to determine the normoglycemic population. This includes changes in the Dutch population because of births, deaths, and migration. Additionally, in contrast with Gelevert (2012), no distinction in age groups is made, as specific data for all other variables per age group is scarce. It is considered to not have a significant effect, as the fraction of individuals below the age of 20 years old suffering from T2DM is close to zero (CBS, 2017b). Furthermore, it is assumed that the development of prediabetes is influenced by two factors only: obesity and others. Obesity is considered as a separate factor, as researchers argue that obesity contributes most in the development of prediabetes (Feskens, 2011, p. 158). Moreover, considering the average life expectancy of prediabetes patients and T2DM patients, it is assumed to be 8 to 10 years lower than that of a healthy individual. The average life expectancy of a healthy individual is 81.3 years (CBS, 2017a; Stichting Preventie Diabetes, 2017). Assuming that individuals unaware of their condition pass away sooner than individuals aware of their condition, a shortened lifespan of 10 years and 8 years is considered for the undiagnosed prediabetes population and the diagnosed prediabetes population respectively. For the T2DM population, an average life

expectancy of 9 years is assumed. It is assumed that average life expectancy is similar for a diagnosed prediabetes patient (IFG) and a diagnosed prediabetes patient (IGT).

No data on recovery rates are available yet. Therefore, the recovery fractions are determined by looking at the model's behavior. It is assumed that already recovered individuals and normal healthy individuals develop T2DM at the same pace. Additionally, it is assumed that the recovery fraction for T2DM population is the highest, as a T2DM patient is both diagnosed and critically ill. Assuming that individuals want to decrease the risks of cardiovascular diseases, the recovery fraction for T2DM patients is set at 19%. For both diagnosed prediabetes populations, the same reasoning applies. However, as the disease has not yet progressed as much, it is assumed that the motivation to recover of diagnosed prediabetes patient suffering from IFG or IGT is less and thus the recovery fraction for both the diagnosed prediabetes population (IFG) and the diagnosed prediabetes population (IGT) is set at 10%. It is assumed that the recovery fraction is similar for a diagnosed prediabetes patient (IFG) and a diagnosed prediabetes patient (IGT). Furthermore, it is assumed that undiagnosed prediabetes patients are unaware of their condition and thus are the least motivated to recover. Therefore, the recovery for undiagnosed prediabetes population is set at 5%

Regarding the quantification of the total societal costs, it is assumed that the total societal costs in 2011 apply for 2013, because RIVM (2013) has not yet published data on the total societal costs in 2013. Additionally, the total societal costs are determined for the total DM population and therefore, in accordance with the relevant literature, the costs for the T2DM population are determined by taking the product of the total societal costs of the total DM population and the fraction that 9 out of 10 DM patients suffer from T2DM (CBS, 2016a; "Suiker in perspectief," 2013). Moreover, it is assumed that all T2DM patients and all prediabetes patients are employed. Additionally, the obligatory salary payment is determined based on the average Dutch income in 2013 published by CBP (2012). In line with the assumptions for the underlying assurance, it is assumed that all Dutch citizens only take out an underlying insurance. Additionally, it is assumed that all individuals are insured at DSW and thus, receive the same compensation to cover their travel expenses. It assumed not to be an issue for the model's validity, as most Dutch health insurers have the same rates approximately.

Moreover, regarding the LaM intervention and prevention structure, no data on treatment time and time to recruit is available as LaM is yet to be implemented. Therefore, the treatment time is determined by looking at data of a similar intervention program (Keer Diabetes2 Om, 2017). The time needed to recruit a T2DM patient is assumed to be 1 year.

Moreover, the budget availability for stakeholders' investments for the intervention program is considered to be exogenous and thus, assumed to be outside the model's boundary. Therefore, it is set at an initial value higher than the total societal costs. Except for the LaM execution costs for both diagnosed prediabetes populations, the initial values of the variables enabling the prevention structure are assumed to be similar to that of the T2DM population. This is due to limited data availability. Furthermore, the Vintura business case did not consider LaM as prevention program and thus, no execution costs for LaM as prevention program are determined. Therefore, the present study assumes that the execution costs of prevention program LaM per diagnosed prediabetes patient, both IFG and IGT, are similar to the costs of LaM intervention costs per T2DM patient.

5.2. Model Testing

5.2.1. Dimensional Consistency Test

Dimensional consistency test examines if each equation is dimensional consistent in terms of units (Sterman, 2000, p. 859). Stella Architect does not report unit inconsistency and thus, the model is considered dimensionally consistent.

5.2.2. Parameter Confirmation Test

The parameter confirmation test examines whether all parameter values used in the model have real-world counterparts (Sterman, 2000, p. 859). No real-world counterpart values are found for the normal recovery rates of the populations considered in the T2DM patient journey model. This is due to little research being focused on prediabetes and recovery from prediabetes, or because the process of gathering data is still ongoing. All other parameter values are elicited from the relevant literature and expert interviews, and thus are assumed to have real-world counterpart values.

5.2.3. Direct Extreme Conditions Test

The direct extreme conditions test examines if each equation makes sense when the inputs to the equation take on extreme values (Sterman, 2000, p. 860). The findings are reported in Appendix 3.2. The simulations confirm the expected behavior, when the most important stocks take on extreme values.

If the *Normoglycemic Popn* is zero, the obesity population and the net recruitment rate have to be zero as well. Hence, the *Normoglycemic Popn* is only increasing at a diminishing

rate until approximately 2016 and then becomes increasing at an increasing rate until approximately 2025, because of individuals already being in the system reproducing and recovering (Figure 44). None of the populations will reach zero within the period 2013-2025, as the individuals already in the system reproduce and thus, increase the *Normoglycemic Popn* allowing individuals to develop (pre)diabetes and recover from (pre)diabetes. This results in a *Undx PreD Popn* that is decreasing at a diminishing rate until approximately 2016 and increasing at an increasing rate until approximately 2025 (Figure 45). Regarding both prediabetes populations, they are increasing at a diminishing rate until approximately 2025 as well (Figure 46 and Figure 47, respectively) As the number of individuals developing T2DM is so small, the *T2DM Popn* is expected to continue to decrease at an increasing rate until approximately 2025 (Figure 48). Furthermore, there are fewer sick individuals and thus the total societal costs are less as well when compared to the base run (Figure 49).

If the *Undx PreD Popn* is zero (Figure 51), this must result in less diagnosed prediabetes patients, both IFG and IGT, as there are no undiagnosed prediabetes patients to diagnose. Hence, both diagnosed prediabetes populations are decreasing at a diminishing rate until approximately 2016. From 2016, there are again some new undiagnosed prediabetes patients who can be diagnosed with either IFG and IGT resulting in increasing diagnosed prediabetes populations again (Figure 52 and Figure 53, respectively). This also results in a *T2DM Popn* that is decreasing at a diminishing rate until approximately 2016, which is increasing thereafter until approximately 2025 (Figure 54). The fewer individuals are developing prediabetes or T2DM, the fewer individuals are recruited to the *Normoglycemic Popn*. Hence, the steepness of the increasingly increasing *Normoglycemic Popn* is less when compared to the base run (Figure 50). Furthermore, there are fewer sick individuals and thus the total societal costs are less as well when compared to the base run (Figure 55).

If the *Dx PreD Popn (IFG)* is zero (Figure 58), the number of diagnosed prediabetes patients (IFG) developing T2DM must be less when compared to the base run. Hence, the *T2DM Popn* will be first decreasing at a diminishing rate until approximately 2016 and increasing at an increasing rate thereafter until approximately 2025 (Figure 60). This results in a *Normoglycemic Popn* that recruits fewer individuals when compared to the base run (Figure 56). Additionally, fewer individuals develop undiagnosed prediabetes resulting in an *Undx PreD Popn* that increasing at an increasing rate until approximately 2025, but less steep when compared to the base run (Figure 57). Furthermore, a change in the stock *Dx PreD Popn (IFG)* will not have a significant effect on the stock *Dx PreD Popn (IGT)*, as confirmed by the

simulation (Figure 59). Moreover, there are fewer sick individuals and thus the total societal costs are less as well when compared to the base run (Figure 61).

The same behavior as explained above for the *Dx PreD Popn (IFG)* applies when the *Dx PreD Popn (IGT)* is zero (Figure 65). Hence, the *T2DM Popn* will be first decreasing at a diminishing rate until approximately 2016 and increasing at an increasing rate thereafter until approximately 2025 (Figure 66). The *Normoglycemic Popn* recruits fewer individuals when compared to the base run (Figure 62). The *Undx PreD Popn* is increasing at an increasing rate until approximately 2025, but less steep when compared to the base run (Figure 63) and the stock of *Dx PreD Popn (IFG)* is not affected by change in the stock *Dx PreD Popn (IGT)* (Figure 64). Furthermore, there are fewer sick individuals and thus the total societal costs are less as well when compared to the base run (Figure 67).

Then, if the *T2DM Popn* is zero, there are no recovered T2DM patients. Hence, there are no new recruits from the *T2DM Popn* to the *Normoglycemic Popn*, as seen by the decreasing behavior at a diminishing rate until approximately 2025 (Figure 68). Consequently, fewer individuals are able to develop undiagnosed prediabetes and fewer individuals are able to develop diagnosed prediabetes, either IFG or IGT, resulting in all three populations being smaller in terms of total individuals when compared to the base run (Figure 69, Figure 70, and Figure 71, respectively). This results in a smaller *T2DM Popn* (Figure 72). Furthermore, there are fewer sick individuals and thus the total societal costs are fewer as well when compared to the base run (Figure 73).

5.2.4. Behavior Sensitivity Analysis Test

By conducting behavior sensitivity analysis, all exogenous variables are examined on the basis of their impact on the model's behavior (Sterman, 2000, p. 861). The base runs are presented in Appendix 3.1. The simulation runs are reported in Appendix 3.3. When conducting behavior sensitivity analysis on *Average Net Fractional Recruitment Rate*[1], the simulations show no significant changes in the normoglycemic population, the undiagnosed prediabetes population, the diagnosed prediabetes population (IFG), the diagnosed prediabetes population (IGT), and the T2DM population (Figure 74 to Figure 78). For *Fraction Individuals developing Prediabetes*[1], the simulations show that all five populations are very sensitive to changes in the fraction (Figure 79 to Figure 83). Regarding the fractions determining the number of obese individuals developing diabetes, the model is very sensitive for changes in both the *Fraction*

[1] Five runs; Starting value: 0; Ending value: 1; DT: 1/10; Euler's Integration Method

Obese developing PreD (BMI)[1] (Figure 84 to Figure 88) and *Fraction Obese developing PreD (WC)*[1] (Figure 89 to Figure 93). For *Fraction Incidence (IFG)*[1], the normoglycemic population is not sensitive (Figure 94), whereas the undiagnosed prediabetes population, the diagnosed prediabetes population (IFG), the diagnosed prediabetes population (IGT), and the T2DM population are very sensitive to changes in the fraction (Figure 95 to Figure 98). Similar sensitivity is observed when conducting sensitivity analysis on *Fraction Incidence (IGT)*[1] (Figure 99 to Figure 103).

Next, for *Average Life Expectancy Undx PreD Patient*[2], the simulations show that the normoglycemic population and the T2DM population are not very sensitive to changes in this variable (Figure 104 and Figure 108). The undiagnosed prediabetes population, the diagnosed prediabetes population (IFG), and the diagnosed prediabetes population (IGT) are very sensitive to changes in this variable (Figure 105 to Figure 107). For *Average Life Expectancy Dx PreD Patient (IFG)*[2], the simulations show that only the diagnosed prediabetes population (IFG) is very sensitive to changes in this variable (Figure 109 to Figure 113). The same applies for the *Average Life Expectancy Dx PreD Patient (IGT)*[2]. In those simulation runs, only the diagnosed prediabetes population (IGT) is very sensitive to changes in this variable (Figure 114 to Figure 118). For *Average Life Expectancy Dx PreD Patient (T2DM)*[2], only the T2DM population is observed to be very sensitive (Figure 119 to Figure 123). For *Time Diabetes onset Undx PreD Patients*[3], the simulations show that changes in this variable have a significant effect on the undiagnosed prediabetes population, the diagnosed prediabetes population (IFG), the diagnosed prediabetes population (IGT), and the T2DM population (Figure 125 to Figure 128). Only a slight effect is observed regarding the normoglycemic population (Figure 124). For *Time Diabetes onset Dx PreD Patients (IFG)*[3], significant changes are only observed for the diagnosed prediabetes population (IFG) and the T2DM population (Figure 129 to Figure 133). For changes in *Time Diabetes onset Dx PreD Patients (IGT)*[3], the simulations show a very sensitive diagnosed prediabetes population (IGT) and T2DM population (Figure 134 to Figure 138). Furthermore, with regards to the sensitivity of the recovery fractions, it is observed that all populations are very sensitive to changes in the *Normal Recovery Fraction Undx PreD Popn*[1] (Figure 139 to Figure 143), the *Normal Recovery Fraction Dx PreD Popn (IFG)*[1] (Figure 144 to Figure 148), the *Normal Recovery Fraction Dx PreD Popn (IGT)*[1] (Figure 149 to Figure 153), and the *Normal Recovery Fraction T2DM*[1] (Figure 154 to Figure 158).

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[2] Five runs; Starting value: 0; Ending value: 100; DT: 1/10; Euler's Integration Method
[3] Five runs; Starting value: 0; Ending value: 20; DT: 1/10; Euler's Integration Method

Behavior sensitivity analysis is also conducted on the variables governing the implementation of LaM, both as intervention program and prevention program. Regarding the *LaM Success Rate (IFG)*[4], an insensitive diagnosed prediabetes (IFG) and a very sensitive normoglycemic population, undiagnosed prediabetes population, diagnosed prediabetes population (IFG), and T2DM population are observed (Figure 159 to Figure 163). For *LaM Success Rate (IGT)*[5], similar behavior is observed but with an insensitive diagnosed prediabetes (IGT) (Figure 164 to Figure 168). For *LaM Success Rate (T2DM)*[6], the normoglycemic population, the undiagnosed prediabetes population, and the T2DM population are very sensitive to changes in this variable, whereas both diagnosed prediabetes populations appear to be only somewhat sensitive (Figure 169 to Figure 173). Furthermore, the simulations show no sensitivity to changes in *Time to Recruit (IFG)*[7] (Figure 174 to Figure 178), *Time to Recruit (IGT)*[8] (Figure 179 to Figure 183), and *Time to Recruit (T2DM)*[9] (Figure 184 to Figure 188). For *Treatment Time (IFG)*[7], a very sensitive normoglycemic population, diagnosed prediabetes (IFG) and a somewhat sensitive T2DM population are observed (Figure 189 to Figure 193). Similar behavior is observed for *Treatment Time (IGT)*[8] (Figure 194 to Figure 198). For *Treatment Time (T2DM)* [9], a very sensitive normoglycemic population and T2DM population and a somewhat sensitive undiagnosed prediabetes population are observed (Figure 199 to Figure 203). Regarding the sensitivity of the variable indicating the stakeholders' budget none of the populations appear to be sensitive to changes in *Budget Stakeholders' Investments (IFG)*[10] (Figure 204 to Figure 208), *Budget Stakeholders' Investments (IGT)*[11] (Figure 209 to Figure 213), and *Budget Stakeholders' Investments (T2DM)*[12] (Figure 214 to Figure 218).

5.2.5. Behavior Reproduction Test

The behavior reproduction test examines the model's ability to replicate the reference mode of behavior (Sterman, 2000, p. 860). CBS (2017a) published data on the normoglycemic

[4] Five runs; Starting value: 0; Ending value: 1; Switch IFG: 1; DT: 1/10; Euler's Integration Method
[5] Five runs; Starting value: 0; Ending value: 1; Switch IGT: 1; DT: 1/10; Euler's Integration Method
[6] Five runs; Starting value: 0; Ending value: 1; Switch T2DM: 1; DT: 1/10; Euler's Integration Method
[7] Five runs; Starting value: 0; Ending value: 10; Switch IFG: 1; DT: 1/10; Euler's Integration Method
[8] Five runs; Starting value: 0; Ending value: 10; Switch IGT: 1; DT: 1/10; Euler's Integration Method
[9] Five runs; Starting value: 0; Ending value: 10; Switch T2DM: 1; DT: 1/10; Euler's Integration Method
[10] Five runs; Starting value: 0; Ending value: 2,000,000,000,000; Switch IFG: 1; DT: 1/10; Euler's Integration Method
[11] Five runs; Starting value: 0; Ending value: 2,000,000,000,000; Switch IGT: 1; DT: 1/10; Euler's Integration Method
[12] Five runs; Starting value: 0; Ending value: 2,000,000,000,000; Switch T2DM: 1; DT: 1/10; Euler's Integration Method

population and the T2DM population from 2013 to 2016. When comparing the model's behavior and the CBS (2017a) data, the same behavior is observed (Figure 23 and Figure 24, respectively). Hence, the model is able to replicate the reference mode of behavior.

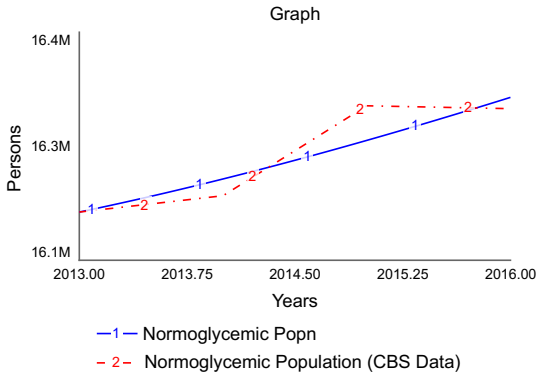

Figure 23 – Behavior Reproduction Test; Norm Popn

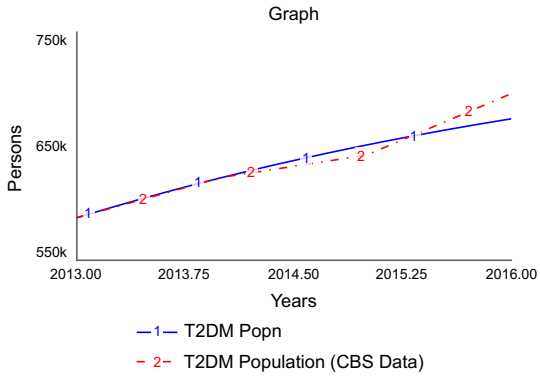

Figure 24 – Behavior Reproduction Test; T2DM Popn

5.2.6. Integration Error Test

Integration error test examines if the model's behavior is determined by the time step, time frame, and numerical integration method chosen by the modeler (Sterman, 2000, p. 860). The simulation runs are reported in Appendix 3.4. The base run is simulated using Euler's integration method from 2013 to 2025 with a delta time (DT) of 1/100. The simulations show no (significant) changes (Figure 219 to Figure 224). Hence, the model is not sensitive to numerical integration method chosen nor to choosing a smaller DT.

6. Results

To answer the research question and the sub-questions proposed in chapter 1, the T2DM patient journey model is simulated from 2013 to 2025. The simulations are run for a 13-year time period to enable comparison with results presented in the relevant literature, such as Baan et al. (2009, p. 36), and to observe the development of T2DM up to 2025. Supporting graphs are presented in Appendix 4.

The outcomes are a result of an interaction of the components in the system. Feedback plays a key role in this system, because of two factors. First, the prevalence of T2DM is increasing as more individuals develop obesity (Koh-Banerjee et al., 2004, p. 1150), which is governed by the relationship between the *Obesity Population* and the *PreD Onset Rate* (Figure 25). Second, the development of T2DM is a vicious cycle, which can only be broken by the recovery process. If an individual becomes insulin resistant, insulin therapy is required. However, the more insulin is used, the more insulin resistant the patient becomes and thus higher doses of insulin are needed for treatment (Simons et al., 2016, p. 340). Per definition, the more insulin resistant the patient becomes, the more the disease progresses. Hence, assuming that an individual does not participate in the recovery process, the individual progresses from being healthy to developing prediabetes to becoming T2DM patient. This process is indicated by the (pre)diabetes onset rates (Figure 25). Consequently, the total societal costs of T2DM increase as well, as shown by the relationship between the *T2DM Population* and the *Total Societal Costs T2DM Population* (Figure 25).

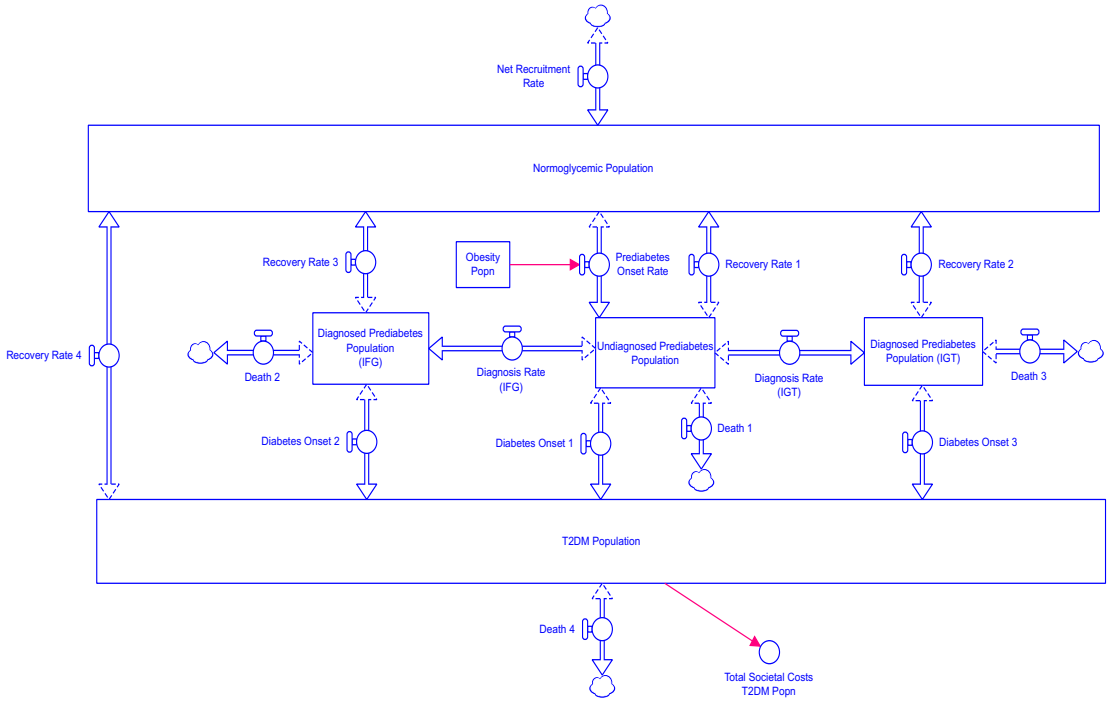

Figure 25 – Simplified SFD of The T2DM Patient Journey

The development of the T2DM population and the total societal costs of T2DM are examined under eight policy options: Current Policy; Intervention Policy; Prevention Policy (IFG); Prevention Policy (IGT); Prevention Policy (IFG + IGT); policy option Intervention + Prevention (IFG); policy option Intervention + Prevention (IGT); and policy option Intervention + Prevention (IFG) + Prevention (IGT). Furthermore, the simulations show inflection points for some graphs. Inflection points are points in time where the behavior of the system changes direction (Sterman, 2000, p. 121). For example, the *Undx PreD* has an inflection point at approximately 2019. This is the result of an increasing net flow of the *Undx PreD*. The net flow is the difference between the inflow *PreD Onset Rate* and the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn*. Because of the delay time, the flows decrease resulting in more undiagnosed prediabetes patients staying in the stock *Undx PreD Popn*.

6.1. Current Policy

A – How do the T2DM population and the total societal costs associated with T2DM develop in case of a continuation of the current situation in the Dutch health care system?

The Current Policy is not concerned with the development of either the diagnosed prediabetes population (IFG) or the diagnosed prediabetes population (IGT). In the current situation, the aging population and the obese population are both increasing at an increasing rate until approximately 2025 (Figure 26). Additionally, the *Net Recruitment Rate* is increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 225). Together with the *PreD Onset Rate* which is increasing at an increasing rate until approximately 2025 as well (Appendix 4 – Figure 226), this results in a *Normoglycemic Popn* that is increasing at an increasing rate until approximately 2025 (Figure 27). The increasingly increasing *PreD Onset Rate* results in an undiagnosed prediabetes population that is increasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231, and Figure 232 & Figure 33, respectively).

The more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a

diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 227). Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 32). Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 as well (Appendix 4 – Figure 230 and Figure 231, respectively). In turn, the diagnosed prediabetes population (IFG) is decreasing at a diminishing rate until approximately 2019 (Figure 29), as a result of the outflows *Diabetes Onset Rate (IFG)*, *Dx PreD Popn (IFG) Death Rate*, and *Recovery Rate Dx PreD Popn (IFG)* exceeding the inflow *Diagnosis Rate (IFG)* (Appendix 4 – Figure 228, Figure 230, and Figure 233 & Figure 33, respectively). From 2019 until approximately 2025, the diagnosed prediabetes population (IFG) is increasing at an increasing rate as a result of the inflow exceeding the outflows. The same behavior is observed for the diagnosed prediabetes population (IGT). That is, decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 30), because of the interaction of the inflow *Diagnosis Rate (IGT)* and the outflows *Diabetes Onset Rate (IGT)*, *Dx PreD Popn (IGT) Death Rate*, and *Recovery Rate Dx PreD Popn (IGT)* (Appendix 4 – Figure 229, Figure 231, and Figure 234 & Figure 34, respectively).

Furthermore, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that develop T2DM. Hence, the more diagnosed prediabetes patients, the more individuals can develop T2DM. This results in a *Diabetes Onset Rate from Dx PreD (IFG)* and a *Diabetes Onset Rate from Dx PreD (IGT)* that are decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 228 and Figure 229, respectively). Then, because of the inflows *Diabetes Onset Rate from Undx PreD*, *Diabetes Onset Rate from Dx PreD (IFG)*, and *Diabetes Onset Rate from Dx PreD (IGT)* exceeding the outflows *T2DM Popn Death Rate* and *Recovery Rate T2DM Popn* (Appendix 4 – Figure 227, Figure 228, Figure 229, and Figure 235 & Figure 35, respectively), the *T2DM Popn* is increasing at a diminishing rate until approximately 2025 (Figure 31). Moreover, the total societal costs associated with T2DM follow the trend of the T2DM population. Hence, the *Total Societal Costs T2DM Popn* are increasing at a diminishing rate until approximately 2025 (Figure 36).

6.2. Intervention Policy

B – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM intervention program in the Dutch health care system?

When LaM is implemented as an intervention program, it is concerned with the recovery of T2DM patients. Consequently, T2DM patients recover with the support of LaM. Additionally, T2DM patients can recover without the support of LaM. Together, these two groups determine the *T2DM Recovery Rate*. The *T2DM Recovery Rate* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, the *T2DM Recovery Rate* is almost stable (Figure 35).

This behavior of the *T2DM Recovery Rate* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27), because of the interaction of the inflows and the outflows of the *Normoglycemic Popn* (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively), as explained under the Current Policy. This increasing behavior is steeper than under the Current Policy. The *PreD Onset Rate* is, among others, determined by, the *Normoglycemic Popn* and therefore also shows the behavior of increasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As similar to under the Current Policy, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 227). This increasing behavior is steeper than under the Current Policy. Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is steeper when compared to the Current Policy. Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well, which is steeper than under the Current

Policy once again (Appendix 4 – Figure 230 and Figure 231, respectively). In turn, this results in both prediabetes populations being decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 29 and Figure 30, respectively), because of the same interaction of inflow and outflows of both diagnosed prediabetes populations as explained under the Current Policy (Appendix 4 – Figure 228, Figure 229, Figure 230, Figure 231, Figure 233, and Figure 234 & Figure 33 and Figure 34, respectively). It should be noted that the decreasingly decreasing behavior is less steep than under the Current Policy, whereas the increasingly increasing behavior is steeper than under the Current Policy. The diagnosed prediabetes recovery rates depend on the new recruits to both diagnosed prediabetes populations and thus, the *Recovery Rate Dx PreD (IFG)* and the *Recovery Rate Dx PreD (IGT)* are decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 as well (Appendix 4 – Figure 33 and Figure 34, respectively). Both resulting in more recovered diagnosed prediabetes patients, when compared to the Current Policy.

Furthermore, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that develop T2DM. Hence, the more diagnosed prediabetes patients, either IFG or IGT, the more individuals can develop T2DM. This results in a *Diabetes Onset Rate from Dx PreD (IFG)* and a *Diabetes Onset Rate from Dx PreD (IGT)* that are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Appendix 4 – Figure 228 and Figure 229, respectively). This results in a *T2DM Popn* that is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, Figure 229, and Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 36).

6.3. Prevention Policy (IFG)

C – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as a prevention program (IFG) in the Dutch health care system?

When LaM is implemented as a prevention program (IFG), it is concerned with the recovery of diagnosed prediabetes patients suffering from IFG. Consequently, diagnosed prediabetes patients (IFG) recover with the support of LaM. Additionally, diagnosed prediabetes patients (IFG) can recover without the support of LaM. Together, these two groups determine the *Recovery Rate Dx PreD Popn (IFG)*. The *Recovery Rate Dx PreD Popn (IFG)* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, it is almost stable (Figure 33).

This behavior of the *Recovery Rate Dx PreD Popn (IFG)* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27), because of the interaction of the inflows and the outflows of the *Normoglycemic Popn* (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively), as explained under the Current Policy. This increasing behavior is steeper than under the Current Policy, but less steep when compared to the Intervention Policy. Furthermore as explained for the policy options above, the *PreD Onset Rate* shows similar behavior as the *Normoglycemic Popn* and thus is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As explained under the policy options above, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 227). This increasing behavior is steeper than under the Current Policy, but less steep when compared to the Intervention Policy. Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is steeper than under the Current Policy, but less steep when compared to the Intervention Policy. Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well, which is steeper than under the Current Policy but less steep when compared to the Intervention Policy again (Appendix 4 – Figure 230 and Figure 231, respectively). Because of the Prevention

Policy (IFG), the outflows *Diabetes Onset Rate (IFG)*, *Dx PreD Popn Death Rate (IFG)*, *Recovery Rate Dx PreD Popn (IFG)* exceed the inflow *Diagnosis Rate (IFG)* (Appendix 4 – Figure 228, Figure 230, Figure 233 & Figure 33, respectively). Consequently, the diagnosed prediabetes population (IFG) stock is depleted. This results in a *Dx PreD Popn (IFG)* that is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 29). This decrease is significantly more than under both the Current Policy and the Intervention Policy. Furthermore, the *Recovery Rate Dx PreD (IFG)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 33). The simulations suggest a higher total of recovered diagnosed prediabetes patients (IFG), than under the Current Policy and the Intervention Policy.

The Prevention Policy (IFG) is not concerned with recovering diagnosed prediabetes patients (IGT). Hence, the behavior of diagnosed prediabetes population (IGT) is fairly similar to that under the Current Policy and the Intervention Policy. That is, decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 30). Again, because of the interaction of the inflows and outflows of the diagnosed prediabetes population (IGT), as explained under the Current Policy (Appendix 4 – Figure 229, Figure 231, and Figure 234 & Figure 34, respectively). Regarding the behavior of the diagnosed prediabetes population (IGT), it should be noted that the decreasingly decrease is less steep than under the Current Policy, but steeper when compared to the Intervention Policy. Furthermore, the *Recovery Rate Dx PreD (IGT)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 34). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IGT) as under both the Current Policy and the Intervention Policy.

Again, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that can develop T2DM. Consequently, the *Diabetes Onset Rate from Dx PreD (IFG)* is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable till around 2025 (Appendix 4 – Figure 228). The simulations suggest a significant smaller number of diagnosed prediabetes patients (IFG) that develop T2DM than under the Current Policy and the Intervention Policy. The *Diabetes Onset Rate from Dx PreD (IGT)* is decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 229). The

simulations suggest an approximate same number of diagnosed prediabetes patients (IGT) that develop T2DM when compared to the Current Policy and the Intervention Policy. This results in a *T2DM Popn* that is increasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, it becomes almost stable until (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, Figure 229, and Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* are increasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 36). It should be noted that the decreasingly increasing behavior of the *T2DM Popn* and the *Total Societal Costs T2DM Popn* is less steep than under the Current Policy.

6.4. Prevention Policy (IGT)

D – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as a prevention program (IGT) in the Dutch health care system?

When LaM is implemented as prevention program (IGT), it is concerned with the recovery of diagnosed prediabetes patients suffering from IGT. The development of the T2DM population under the Prevention Policy (IGT) is similar to that under the Prevention Policy (IFG). However, under the Prevention Policy (IGT), the diagnosed prediabetes population (IGT) is involved. The outcomes are similar. Hence, diagnosed prediabetes patients (IGT) recover with the support of LaM. Additionally, diagnosed prediabetes patients (IGT) can recover without the support of LaM. Together, these two groups determine the *Recovery Rate Dx PreD Popn (IGT)*. The *Recovery Rate Dx PreD Popn (IGT)* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, it becomes almost stable (Figure 34).

This behavior of the *Recovery Rate Dx PreD Popn (IGT)* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27), because of the interaction of the inflows and the outflows of the *Normoglycemic Popn* (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively), as explained under the Current Policy. This increasing behavior is steeper than under the Current Policy, but less steep when compared to the Intervention Policy. Furthermore as explained for

the policy options above, the *PreD Onset Rate* shows similar behavior as the *Normoglycemic Popn* and thus is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As explained under the policy options above, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 227). This increasing behavior is steeper than under the Current Policy, but less steep when compared to the Intervention Policy. Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is steeper than under the Current Policy, but less steep when compared to the Intervention Policy. Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well, which is steeper than under the Current Policy but less steep when compared to the Intervention Policy again (Appendix 4 – Figure 230 and Figure 231, respectively).

The Prevention Policy (IGT) is not concerned with recovering diagnosed prediabetes patients (IFG). Hence, the behavior of the diagnosed prediabetes population (IFG) is fairly similar to that under the Current Policy and the Intervention Policy. That is, decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 29). Again, because of the interaction of the inflows and outflows of the diagnosed prediabetes population (IFG), as explained under the Current Policy (Appendix 4 – Figure 228, Figure 230, and Figure 233 & Figure 33, respectively). Regarding the behavior of the diagnosed prediabetes population (IFG), it should be noted that the decreasingly decreasing behavior is less steep than under the Current Policy, but steeper when compared to the Intervention Policy. Furthermore, the *Recovery Rate Dx PreD (IFG)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 33). The simulations suggest

an approximate similar number of recovered diagnosed prediabetes patients (IFG) as under both the Current Policy and the Intervention Policy.

Because of the Prevention Policy (IGT), the outflows *Diabetes Onset Rate (IGT)*, *Dx PreD Popn Death Rate (IGT)*, *Recovery Rate Dx PreD Popn (IGT)* exceed the inflow *Diagnosis Rate (IGT)* (Appendix 4 – Figure 229, Figure 231, and Figure 234 & Figure 34, respectively). Consequently, the diagnosed prediabetes population (IGT) stock is depleted. This results in a *Dx PreD Popn (IGT)* that is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 30). This decrease is significantly more than under both the Current Policy and the Intervention Policy. Furthermore, the *Recovery Rate Dx PreD (IGT)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 34). The simulations suggest a higher total of recovered diagnosed prediabetes patients (IGT), than under the Current Policy and the Intervention Policy.

Again, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that can develop T2DM. Consequently, the *Diabetes Onset Rate from Dx PreD (IFG)* is decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 228). Hence, the behavior of the diagnosed prediabetes population (IFG) is fairly similar to that under the Current Policy and the Intervention Policy. The simulations suggest that the number of diagnosed prediabetes patients (IFG) that develop T2DM under the Prevention Policy (IGT) is significant larger than under the Prevention Policy (IFG). The *Diabetes Onset Rate from Dx PreD (IGT)* is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Appendix 4 – Figure 229). That is, a significant smaller number of diagnosed prediabetes patients (IGT) develop T2DM than under the Current Policy, the Intervention Policy or the Prevention Policy (IFG). This results in a *T2DM Popn* that is increasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, and Figure 229, Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* are increasing at a diminishing rate until approximately 2019 until which then becomes almost stable until approximately 2025

(Figure 36). It should be noted that the decreasingly increasing behavior of the *T2DM Popn* and the *Total Societal Costs T2DM Popn* is less steep than under the Current Policy.

6.5. Prevention Policy (IFG + IGT)

E – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as a prevention program LaM (IFG + IGT) in the Dutch health care system?

When LaM is implemented as a prevention program (IFG + IGT), it is concerned with the recovery of both diagnosed prediabetes patients suffering from IFG and diagnosed prediabetes patients suffering from IGT. Consequently, the diagnosed prediabetes patients (IFG) and the diagnosed prediabetes patients (IGT) recover with the support of LaM. Additionally, diagnosed prediabetes patients (IFG) and diagnosed prediabetes patients (IGT) can recover without the support of LaM. Together, these four groups determine the *Recovery Rate Dx PreD Popn (IFG)* and the *Recovery Rate Dx PreD Popn (IGT)*, which are decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, they become almost stable (Figure 33 and Figure 34, respectively).

This behavior of the *Recovery Rate Dx PreD Popn (IFG)* and the *Recovery Rate Dx PreD Popn (IGT)* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27). Again, because of the interaction of the inflows and outflows of the *Normoglycemic Popn,* as explained under the Current Policy (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively). This increasing behavior is steeper than under the Current Policy, Prevention Policy (IFG) or Prevention Policy (IGT) and is similar to that under the Intervention Policy. Furthermore as explained for the policy options above, the *PreD Onset Rate* shows similar behavior as the *Normoglycemic Popn* and thus is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As explained under the policy options above, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025

(Appendix 4 – Figure 227). This increasing behavior is similar to the behavior of the *Diabetes Onset Rate from Undx PreD* under the Intervention Policy, but steeper than under the Current Policy, the Prevention Policy (IFG), and the Prevention Policy (IGT). Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is similar to under the Intervention Policy, but steeper than under the Current Policy, the Prevention Policy (IFG), and the Prevention Policy (IGT). Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well (Appendix 4 – Figure 230 and Figure 231, respectively). These are also observed to be similar to the behavior of both diagnosis rates under the Intervention Policy, but steeper than under the Current Policy, the Prevention Policy (IFG), and the Prevention Policy (IGT). Because of the Prevention Policy (IFG + IGT), the outflows exceed the inflows for both diagnosed prediabetes populations (Appendix 4 – Figure 228, Figure 229, Figure 230, Figure 231, Figure 233, and Figure 234 & Figure 33 and Figure 34, respectively). Consequently, both the diagnosed prediabetes population (IFG) stock and the diagnosed prediabetes population (IGT) is depleted. This results in both stocks being decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 29 and Figure 30, respectively). The decreasing behavior of the diagnosed prediabetes population (IFG) is significantly more than under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT), but similar to that under the Prevention Policy (IFG). The decreasing behavior of the diagnosed prediabetes population (IGT) is significantly more than under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG), but similar to that under the Prevention Policy (IGT). Furthermore, the diagnosed prediabetes population recovery rates depend on the new recruits and thus are both decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 33 and Figure 34, respectively). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IFG) under the Prevention Policy (IFG), but a significant larger number of recovered diagnosed prediabetes patients (IFG) when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IGT) under the Prevention Policy (IGT), but a

significant larger number of recovered diagnosed prediabetes patients (IGT) when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IFG).

Again, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that can develop T2DM. Consequently, both the *Diabetes Onset Rate from Dx PreD (IFG)* and the *Diabetes Onset Rate from Dx PreD (IGT)* are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Appendix 4 – Figure 228 and Figure 229, respectively). Regarding the number of diagnosed prediabetes patients (IFG) that develop T2DM, the simulations suggest an approximate similar number as under the Prevention Policy (IFG), but a significantly smaller number than under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). Regarding the number of diagnosed prediabetes patients (IGT) that develop T2DM, the simulations suggest an approximate similar number as under the Prevention Policy (IGT), but a significantly smaller number than under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG). This results in a *T2DM Popn* that is increasing at a diminishing rate until approximately 2016. From 2016 until approximately 2019, it is increasing at a diminishing rate and from 2019 until approximately 2025, it is increasing at an increasing rate (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, and Figure 229, Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* is increasing at a diminishing rate until approximately 2016. From 2016 until approximately 2019, it is increasing at a diminishing rate and from 2019 until approximately 2025, it is increasing at an increasing rate (Figure 36). It should be noted that the decreasingly increasing behavior of the *T2DM Popn* and the *Total Societal Costs T2DM Popn* is less steep than under the Current Policy, the Prevention Policy (IFG), and the Prevention Policy (IGT).

6.6. Policy Option Intervention + Prevention (IFG)

F – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as both an intervention program and a prevention program (IFG) in the Dutch health care system?

When LaM is implemented as an intervention and a prevention program (IFG), it is concerned with the recovery of T2DM patients and diagnosed prediabetes patients suffering from IFG.

Consequently, T2DM patients and diagnosed prediabetes patients (IFG) recover with the support of LaM. Additionally, T2DM patients and diagnosed prediabetes patients (IFG) can recover without the support of LaM. Together, these four groups determine the *T2DM Recovery Rate* and the *Recovery Rate Dx PreD Popn (IFG)*. The *T2DM Recovery Rate* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, the *T2DM Recovery Rate* is almost stable (Figure 35). The *Recovery Rate Dx PreD Popn (IFG)* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, it becomes almost stable (Figure 33).

This behavior of the *T2DM Recovery Rate* and the *Recovery Rate Dx PreD Popn (IFG)* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27). Again, this is because of the interaction of the inflows and outflows of the *Normoglycemic Popn,* as explained under the Current Policy (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively). This increasing behavior is steeper than under the Current Policy, the Intervention Policy, the Prevention Policy (IFG), the Prevention Policy (IGT), and the Prevention Policy (IFG + IGT). Furthermore as explained for the policy options above, the *PreD Onset Rate* shows similar behavior as the *Normoglycemic Popn* and thus is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As explained under the policy options above, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 227). This increasing behavior is steeper than all above policy options. Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is steeper than all above policy options. Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well, which is also observed

to be steeper than under all above policy options (Appendix 4 – Figure 230 and Figure 231, respectively).

Furthermore, because of the policy option Intervention + Prevention Policy (IFG), the outflows *Diabetes Onset Rate (IFG)*, *Dx PreD Popn Death Rate (IFG)*, *Recovery Rate Dx PreD Popn (IFG)* exceed the inflow *Diagnosis Rate (IFG)* (Appendix 4 – Figure 228, Figure 230, Figure 233 & Figure 33, respectively). Consequently, the diagnosed prediabetes population (IFG) stock is depleted. This results in a *Dx PreD Popn (IFG)* that is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 29). This decrease is significantly more than under the Current Policy, the Intervention Policy or the Prevention Policy (IFG), but similar to Prevention Policy (IFG + IGT). Furthermore, the *Recovery Rate Dx PreD (IFG)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 33). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IFG) as under the Prevention Policy (IFG) and the Prevention Policy (IFG + IGT), but a significant higher total of recovered diagnosed prediabetes patients (IFG) than under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG).

The policy option Intervention + Prevention Policy (IFG) is not concerned with recovering diagnosed prediabetes patients (IGT). Hence, the behavior of diagnosed prediabetes population (IGT) is fairly similar to that under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG). That is, decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 30). Again, because of the interaction of the inflows and outflows of the diagnosed prediabetes population (IGT), as explained under the Current Policy (Appendix 4 – Figure 229, Figure 231, and Figure 234 & Figure 34, respectively). Regarding the behavior of the diagnosed prediabetes population (IGT), it should be noted that the decreasingly decrease is steeper when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IFG). Intervention Policy. Furthermore, the *Recovery Rate Dx PreD (IGT)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 34). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IGT) as under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG).

Again, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that can develop T2DM. Consequently, the *Diabetes Onset Rate from Dx PreD (IFG)* is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable till around 2025 (Appendix 4 – Figure 228). The simulations suggest a significant an approximate similar number as under the Prevention Policy (IFG) and the Prevention Policy (IFG + IGT), but a significant smaller number of diagnosed prediabetes patients (IFG) that develop T2DM when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). The *Diabetes Onset Rate from Dx PreD (IGT)* is decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 229). The simulations suggest an approximate similar number as under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). This results in a *T2DM Popn* that is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, it becomes almost stable until (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, Figure 229, and Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 36). It should be noted that the decreasingly increasing behavior of the *T2DM Popn* and the *Total Societal Costs T2DM Popn* is steeper than under the Intervention Policy.

6.7. Policy Option Intervention + Prevention (IGT)

G – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as both an intervention program and a prevention program (IGT) in the Dutch health care system?

When LaM is implemented as an intervention and a prevention program (IGT), it is concerned with the recovery of T2DM patients and diagnosed prediabetes patients suffering from IGT. The development of the T2DM population under the policy option Intervention + Prevention Policy (IGT) is similar to that under the policy option Intervention + Prevention Policy (IFG). However, under the policy option Intervention + Prevention Policy (IGT), the diagnosed prediabetes population (IGT) is involved. The outcomes are similar. Hence, T2DM patients and diagnosed prediabetes patients (IGT) recover with the support of LaM. Additionally,

T2DM patients and diagnosed prediabetes patients (IGT) can recover without the support of LaM. Together, these four groups determine the *T2DM Recovery Rate* and the *Recovery Rate Dx PreD Popn (IGT)*. The *T2DM Recovery Rate* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, the *T2DM Recovery Rate* is almost stable (Figure 35). The *Recovery Rate Dx PreD Popn (IGT)* is decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, it becomes almost stable (Figure 34).

This behavior of the *T2DM Recovery Rate* and the *Recovery Rate Dx PreD Popn (IGT)* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27). Again, because of the interaction of the inflows and outflows of the *Normoglycemic Popn,* as explained under the Current Policy (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively). This increasing behavior is steeper than under the Current Policy, the Intervention Policy, the Prevention Policy (IFG), the Prevention Policy (IGT), and the Prevention Policy (IFG + IGT). Furthermore as explained for the policy options above, the *PreD Onset Rate* shows similar behavior as the *Normoglycemic Popn* and is thus increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As explained under the policy options above, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 227). This increasing behavior is steeper than all above policy options. Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is steeper than all above policy options. Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well, which is also observed to be steeper than under all above policy options (Appendix 4 – Figure 230 and Figure 231, respectively).

The policy option Intervention + Prevention Policy (IGT) is not concerned with recovering diagnosed prediabetes patients (IFG). Hence, the behavior of the diagnosed prediabetes population (IFG) is fairly similar to that under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). That is, decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 29). Again, because of the interaction of the inflows and outflows of the diagnosed prediabetes population (IFG), as explained under the Current Policy (Appendix 4 – Figure 228, Figure 230, and Figure 233 & Figure 33, respectively). The decreasing behavior of the diagnosed prediabetes population (IFG) is steeper than under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). Furthermore, the *Recovery Rate Dx PreD (IFG)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Figure 33). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IFG) as under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT).

Because of the policy option Prevention Policy (IGT), the outflows *Diabetes Onset Rate (IGT)*, *Dx PreD Popn Death Rate (IGT)*, *Recovery Rate Dx PreD Popn (IGT)* exceed the inflow *Diagnosis Rate (IGT)* (Appendix 4 – Figure 229, Figure 231, and Figure 234 & Figure 34, respectively). Consequently, the diagnosed prediabetes population (IGT) stock is depleted. This results in a *Dx PreD Popn (IGT)* that is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 30). This decrease is significantly more than under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG). Furthermore, the *Recovery Rate Dx PreD (IGT)* depends on the new recruits and is thus decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 34). The simulations suggest a similar approximate total number of recovered diagnosed prediabetes patients (IGT) as under the Prevention Policy (IGT), and the Prevention Policy (IFG + IGT), but a significant higher total when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IFG).

Again, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that can develop T2DM. Consequently, the *Diabetes Onset Rate from Dx PreD (IFG)* is decreasing at a diminishing rate until approximately 2019 and increasing at an increasing rate until approximately 2025 (Appendix 4 – Figure 228). Hence, the behavior of the diagnosed prediabetes population (IFG) is fairly similar to that under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). The simulations

suggest that the number of diagnosed prediabetes patients (IFG) that develop T2DM under the Prevention Policy (IGT) is significant larger than under the Prevention Policy (IFG). The *Diabetes Onset Rate from Dx PreD (IGT)* is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Appendix 4 – Figure 229). That is, a significant smaller number of diagnosed prediabetes patients (IGT) that develop T2DM than under the Current Policy, the Intervention Policy or the Prevention Policy (IFG).

This results in a *T2DM Popn* that is decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, and Figure 229, Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 36). It should be noted that the decreasingly decreasing behavior of the *T2DM Popn* and the *Total Societal Costs T2DM Popn* is similar to that under the policy Option Intervention + Prevention (IFG) but steeper than under the Current Policy.

6.8. Policy Option Intervention + Prevention (IFG) + Prevention (IGT)

H – How do the T2DM population and the total societal costs associated with T2DM develop in case of an implementation of LaM as an intervention program LaM, a prevention program LaM (IFG), and a prevention program (IGT) in the Dutch health care system?

When LaM is implemented as an intervention program and a prevention program (IFG + IGT), it is concerned with the recovery of T2DM patients, diagnosed prediabetes patients suffering from IFG, and diagnosed prediabetes patients suffering from IGT. Consequently, T2DM patients, diagnosed prediabetes patients (IFG), and diagnosed prediabetes patients (IGT) recover with the support of LaM. Additionally, T2DM patients, diagnosed prediabetes patients (IFG), and diagnosed prediabetes patients (IGT) can recover without the support of LaM. Together, these groups determine the *T2DM Recovery Rate*, the *Recovery Rate Dx PreD Popn (IFG)*, and the *Recovery Rate Dx PreD Popn (IGT)*. The *T2DM Recovery Rate* is decreasing at a diminishing rate until approximately 2019. From 2022 until approximately 2025, the *T2DM Recovery Rate* is almost stable (Figure 35). Both the *Recovery Rate Dx PreD Popn (IFG)* and

the *Recovery Rate Dx PreD Popn (IGT)* are decreasing at a diminishing rate until approximately 2019. From 2019 until approximately 2025, both are increasing at a diminishing rate (Figure 33).

This behavior of the *T2DM Recovery Rate*, the *Recovery Rate Dx PreD Popn (IFG),* and the *Recovery Rate Dx PreD Popn (IGT)* results in a *Normoglycemic Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 27). Again, because of the interaction of the inflows and outflows of the *Normoglycemic Popn,* as explained under the Current Policy (Appendix 4 – Figure 225 and Figure 226 & Figure 32, Figure 33, Figure 34, Figure 35, respectively). This increasing behavior is steeper than all policy options above. Furthermore as explained for the policy options above, the *PreD Onset Rate* shows similar behavior as the *Normoglycemic Popn* and thus is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 226). This results in an *Undx PreD Popn* that is increasing at a diminishing rate until approximately 2025 (Figure 28), as the inflow *PreD Onset Rate* is exceeding the outflows *Diabetes Onset Rate from Undx PreD*, *Diagnosis Rate (IFG)*, *Diagnosis Rate (IGT)*, *Undx PreD Popn Death Rate*, and *Recovery Rate Undx PreD Popn* (Appendix 4 – Figure 226, Figure 227, Figure 230, Figure 231 & Figure 33, respectively).

As explained under the policy options above, the more undiagnosed prediabetes patients, the more undiagnosed prediabetes patients can develop T2DM. Hence, the *Diabetes Onset Rate from Undx PreD* is increasing at a diminishing rate until approximately 2025 (Appendix 4 – Figure 227). This increasing behavior is steeper than all above policy options. Additionally, the more undiagnosed prediabetes patients can recover from undiagnosed prediabetes. Hence, the *Recovery Rate Undx PreD Popn* is increasing at a diminishing rate until approximately 2025 (Figure 32). Again, the increasing behavior is steeper than all above policy options. Furthermore, it allows for more undiagnosed prediabetes patients to be diagnosed with prediabetes and thus, the *Diagnosis Rate (IFG)* and the *Diagnosis Rate (IGT)* are increasing at a diminishing rate until approximately 2025 as well, which is also observed to be steeper than under all above policy options (Appendix 4 – Figure 230 and Figure 231, respectively).

Furthermore, because of the policy option Intervention + Prevention Policy (IFG) + Prevention Policy (IGT), both diagnosed prediabetes stocks are depleted as a result of the interaction of the outflows and inflows, as explained under the policy option Prevention (IFG) + Prevention (IGT) respectively Appendix 4 – Figure 228, Figure 229, Figure 230, Figure 231, Figure 233, and Figure 234 & Figure 33 and Figure 34, respectively). This results in both stocks

being decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 29 and Figure 30, respectively). Regarding the decrease of the diagnosed prediabetes population (IFG), this decrease is significantly more than under the Current Policy, the Intervention Policy, the Prevention Policy (IGT), and the policy option Intervention + Prevention Policy (IGT), but similar to that under the Prevention Policy (IFG). Regarding the decrease of the diagnosed prediabetes population (IGT), this decrease is significantly more than under the Current Policy, the Intervention Policy, the Prevention Policy (IFG), and the policy option Intervention + Prevention Policy (IGT), but similar to that under the Prevention Policy (IGT). Furthermore, the diagnosed prediabetes population recovery rates depend on the new recruits and thus are both decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 33 and Figure 34, respectively). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IFG) under the Prevention Policy (IFG) and the Prevention Policy (IFG + IGT), but a significant larger number of recovered diagnosed prediabetes patients (IFG) when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). The simulations suggest an approximate similar number of recovered diagnosed prediabetes patients (IGT) under the Prevention Policy (IGT) and the Prevention Policy (IFG + IGT), but a significant larger number of recovered diagnosed prediabetes patients (IGT) when compared to the Current Policy, the Intervention Policy, and the Prevention Policy (IFG).

Again, the number of diagnosed prediabetes patients, both IFG and IGT, determine the number of diagnosed prediabetes patients that can develop T2DM. Consequently, both the *Diabetes Onset Rate from Dx PreD (IFG)* and the *Diabetes Onset Rate from Dx PreD (IGT)* are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Appendix 4 – Figure 228 and Figure 229, respectively). Regarding the number of diagnosed prediabetes patients (IFG) that develop T2DM, the simulations suggest an approximate similar number as under the Prevention Policy (IFG) and the Prevention Policy (IFG + IGT), but a significantly smaller number than under the Current Policy, the Intervention Policy, and the Prevention Policy (IGT). Regarding the number of diagnosed prediabetes patients (IGT) that develop T2DM, the simulations suggest an approximate similar number as under the Prevention Policy (IGT) and the Prevention Policy (IFG + IGT), but a significantly smaller number than under the Current Policy, the Intervention Policy, and the Prevention Policy (IFG). This results in a *T2DM Popn* that is decreasing at a

diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 31). As explained under the Current Policy, this is the result of an interaction of the inflows and outflows of the *T2DM Popn* (Appendix 4 – Figure 227, Figure 228, and Figure 229, Figure 235 & Figure 35, respectively). Moreover, as explained under the Current Policy, the total societal costs associated with T2DM follow the trend of the *T2DM Popn*. Hence, the *Total Societal Costs T2DM Popn* are decreasing at a diminishing rate until approximately 2019 which then becomes almost stable until approximately 2025 (Figure 36). It should be noted that the decreasingly decreasing behavior of the *T2DM Popn* and the *Total Societal Costs T2DM Popn* is steeper than all above policy options.

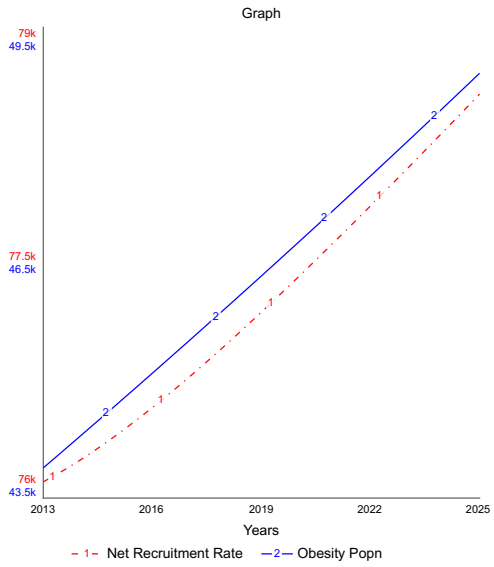

Figure 26 – Current Policy: Aging Population and Development of Obesity Population

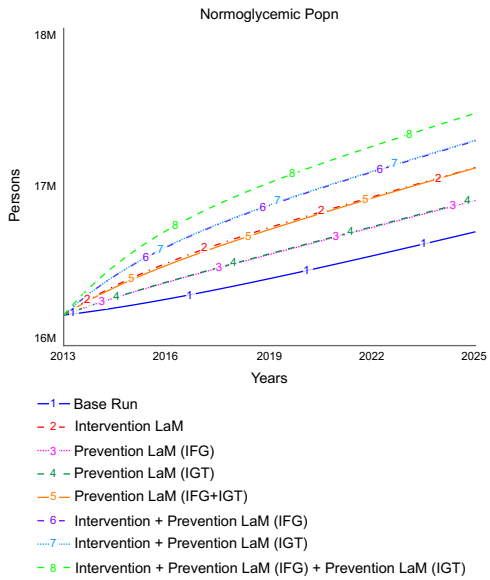

Figure 27 – Development of Normoglycemic Population

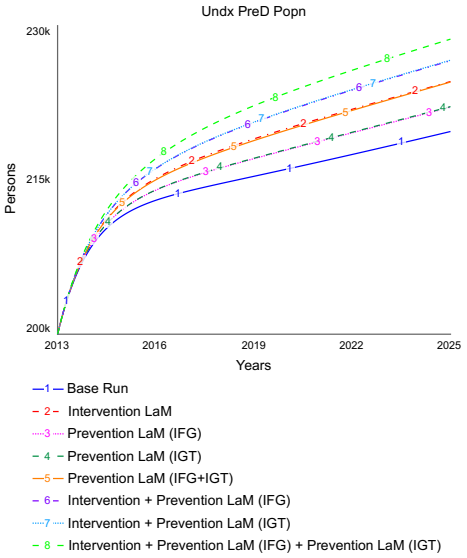

Figure 28 – Development of Undiagnosed Prediabetes Population

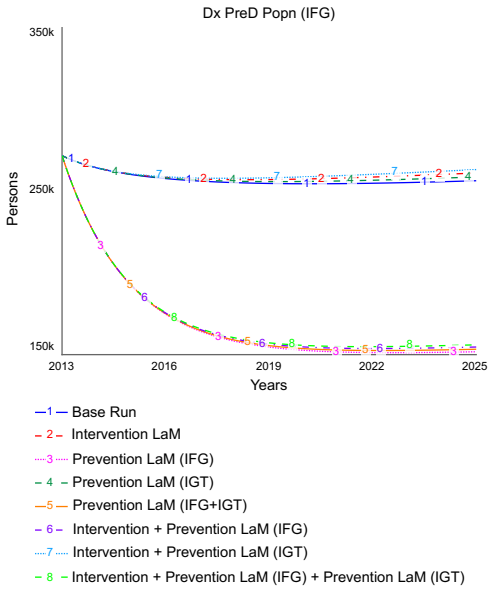

Figure 29 – Development of Diagnosed Prediabetes Population (IFG)

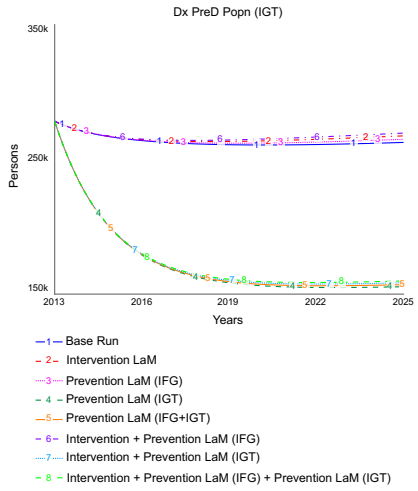

Figure 30 – Development of Diagnosed Prediabetes Population (IGT)

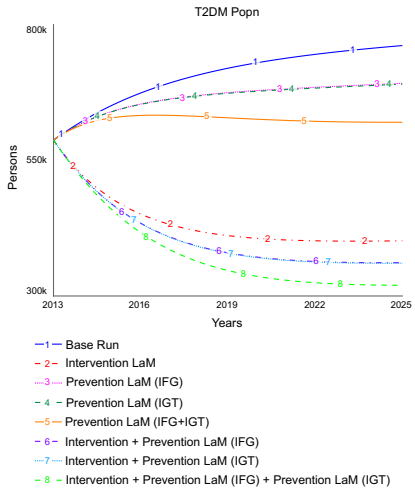

Figure 31 – Development of T2DM Population

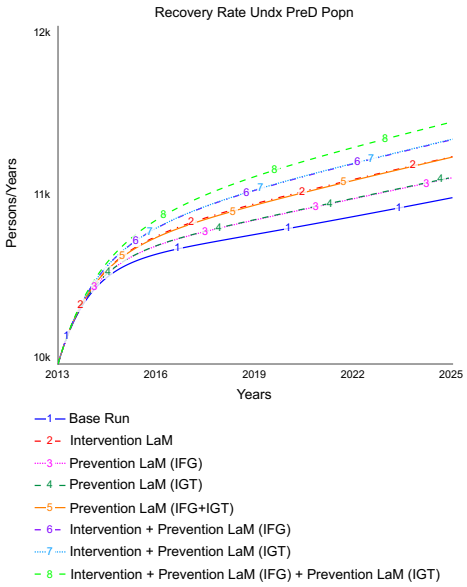

Figure 32 – Recovery Rate Undiagnosed Prediabetes Population

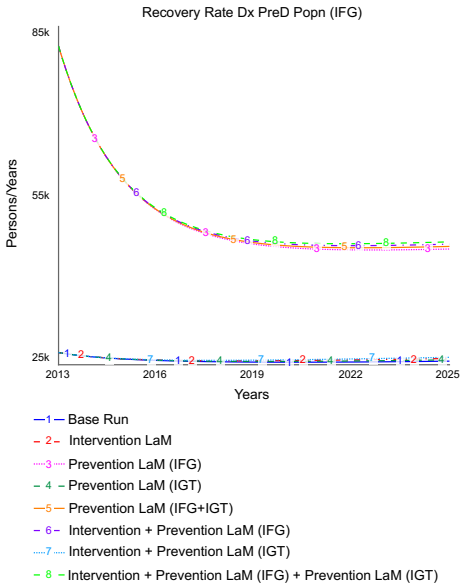

Figure 33 – Recovery Rate Diagnosed Prediabetes Population (IFG)

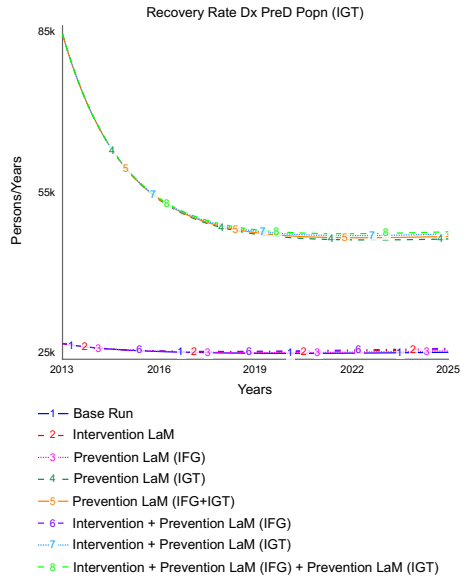

Figure 34 – Recovery Rate Diagnosed Prediabetes Population (IGT)

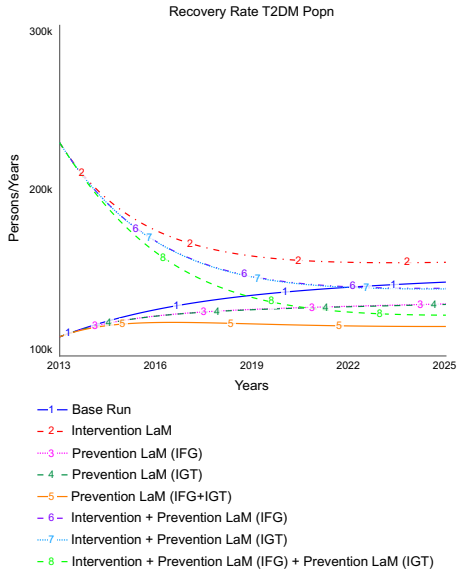

Figure 35 – Recovery Rate T2DM Population

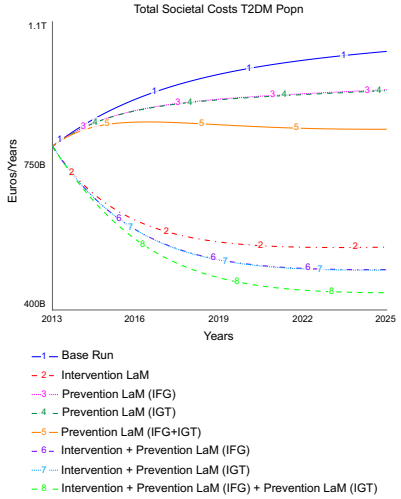

Figure 36 – Development of Total Societal Costs

7. Conclusion

Besides it being physiologically impossible, the goal is not to reach a 100% recovery rate of (pre)diabetes patients, but to reach a state where more individuals are recovering from T2DM than developing T2DM and consequently decreasing the total societal costs associated with T2DM. The policy options can therefore be judged effective in terms of normoglycemic population growth as a result of recovered T2DM patients and in terms of total societal costs reduction. All policy options contribute in normoglycemic population growth, but only four policies contribute to a decreasing T2DM population. Hence, when assessing the policy options' effectiveness in terms of decreasing the T2DM population and increasing the normoglycemic population, the results suggest policy option Intervention + Prevention (IFG) + Prevention (IGT) to be the most effective and Current Policy to be the least effective. The second most effective is policy option Intervention + Prevention (IFG) and the policy option Intervention + Prevention (IGT). The third most effective is Intervention Policy. Policy options Prevention (IFG) and Prevention (IGT) are effective in terms of normoglycemic population growth, but do not contribute in decreasing the T2DM population or decreasing the total societal costs.

When assessing the policy options' effectiveness in terms of their total societal cost reductions, policy option Intervention + Prevention (IFG) + Prevention (IGT) is the most effective and Current Policy is the least effective. The least effective policy is again the Current Policy. The policy option Intervention + Prevention (IFG) and the policy option Intervention + Prevention (IGT) are second most effective. The third most effective is Intervention Policy. Again, policy options Prevention (IFG) and Prevention (IGT) are effective in terms of normoglycemic population growth, but do not contribute in reduction of total societal costs. Hence, all policy options contribute in normoglycemic population growth, but again only four policies contribute to reducing total societal costs.

The best policy option in terms of increasing normoglycemic population, decreasing T2DM population, and reducing total societal costs is the policy option Intervention + Prevention (IFG) and the policy option Intervention + Prevention (IGT). Second most effective is either policy option Intervention + Prevention (IFG) or policy option Intervention + Prevention (IGT). Hence, this shows that a combination of intervention and prevention results in the most desired outcomes. Therefore, the present study argues that prevention policies should be considered in the T2DM decision-making process.

Furthermore, the present study supports the T2DM decision-making process and contributes to society and the Dutch public authorities by providing insights to change their attitudes by presenting results of potential policy options and by creating awareness of the rising number of T2DM patients and the increasing total societal costs associated with T2DM.

8. Discussion

When compared with the current situation, the policy option Intervention + Prevention (IFG) + Prevention (IGT) is observed to be the most effective in terms of normoglycemic population growth, decrease in T2DM population, and reduction of total societal costs. This is due to this policy option having the highest total success rate. Therefore, future research should focus on identifying the most optimal policy option under a similar total LaM success rate. That is, conducting scenario analysis with a total policy success rate instead of a success rate per population. Additionally, the policy option Intervention + Prevention (IFG) + Prevention (IGT) might be hard to implement, as it is focused on recovering all T2DM patients and all diagnosed prediabetes patients. Therefore, future studies should be concerned with examining the resources needed to reach long term implementation success of the policy option Intervention + Prevention (IFG) + Prevention (IGT).

Furthermore, the results suggest a combination of an intervention policy and a prevention policy to be the second most effective both in terms of recovering T2DM patients, decreasing T2DM population, and reducing total societal costs. Therefore, the present study argues that, in addition to focusing on the T2DM population, a shift needs to be made to focusing on recovering both diagnosed prediabetes populations to reach long term success. This shift might support creating awareness among diagnosed prediabetes patients, both IFG and IGT, which might lead to higher normal recovery fractions than under the Current Policy or under the Intervention Policy. Consequently, this will result in an increase in healthy individuals, a decrease in T2DM population, and a reduction in total societal costs. Therefore, future studies should be focused on measuring the effect of awareness creation on the long-term success of shifting from intervention programs to prevention programs. The present study argues that awareness creation is important, as besides the current expenditure of billions of euros which are largely avoidable, it could contribute to positive societal change and reverse obesogenic tendencies in Dutch society. An obesogenic society is a society that stimulates unhealthy lifestyles. Currently, individuals deliberately need to make lifestyle changes to manage their blood glucose levels (Expert A, personal communication, February 13, 2017), whereas a more supportive role from society and public authorities would be beneficial. Over the years, some changes have been made, such as promoting daily exercise and installing bike lanes. At the same time however, grocery stores sell unhealthy products at eye level and stairs are installed behind doors while elevators are prominently placed at the main entrance of office buildings (Expert A, personal communication, February 13, 2017). Dutch citizens are therefore

receiving contradictory prompts from their social environment and a tension appears to exist between incentives that promote healthy and unhealthy lifestyles.

Moreover, the present study is focused on total societal costs reduction. Consequently, the policy option Prevention (IFG + IGT) is not considered to be effective as it does not contribute to a decreasing T2DM population or a reduction of total societal costs. However, the results suggest that this policy option is effective in terms of increasing the number of healthy individuals. Therefore, future studies should include the discussion on reduction of costs versus increasing quality of life in the T2DM decision-making process.

Furthermore, as Sterman once quoted (Box & Draper, 1987, p. 424): "All models are wrong, but some models are useful". That is, all models are a simplification of reality. To fit the model to reality, assumptions had to be made. In accordance with (Meadows, Meadows, Randers, & Behrens, 1972, p. 72), each assumption is explicitly stated and open for criticism. Therefore, future studies should be focused on discussion these assumptions by gaining knowledge on the development of (un)diagnosed prediabetes and the recovery process of (un)diagnosed prediabetes patients. This will also result in less parameter sensitivity in the behavior sensitivity analysis. Additionally, when assessing the effectiveness of the policy options, the underlying assumption is that that all individuals are able to make sustainable lifestyle changes. However, future studies should focus on including the effect of this assumption for two reasons. First, the majority of T2DM patients are elderly (Yakaryilmaz & Öztürk, 2017, p. 279). Consequently, those individuals have practiced unhealthy lifestyles for a long period of time. Hence, it could be argued that this limits the success of adopting a new lifestyle. Second, as T2DM is more progressed than (un)diagnosed prediabetes (Tabák et al., 2009, p. 2217), it is arguable that it is harder to make behavioral lifestyle changes for T2DM patients than for (un)diagnosed prediabetes patients. Another assumption that should be challenged in future research is to measure the effect of stakeholders' budget to investment in lifestyle programs such as LaM.

Moreover, future studies should include the effect of gender, social status, and migration background, as research suggest the factors to be of significance influence in the development of T2DM (Kautzky-Willer, Harreiter, & Pacini, 2016, p. 279; Kivimäki et al., 2015, p. 32; Ujcic-Voortman, Schram, Jacobs-van der Bruggen, Verhoeff, & Baan, 2009, p. 511). Additionally, future research could include the effect of the Dutch culture of excess treatment (Expert A, personal communication, February 13, 2017) on the total societal costs.

Additionally, future studies should examine the effect of different types of obesity on the development of T2DM.

A final note on the study's validity is that the research is conducted in commission of TNO and involved only experts working at TNO. This should be borne in mind when interpreting the results, as the range of potential perspectives could be limited. Therefore, future studies should be concerned with replicating the T2DM patient journey model while obtaining data from more heterogenous data sources.

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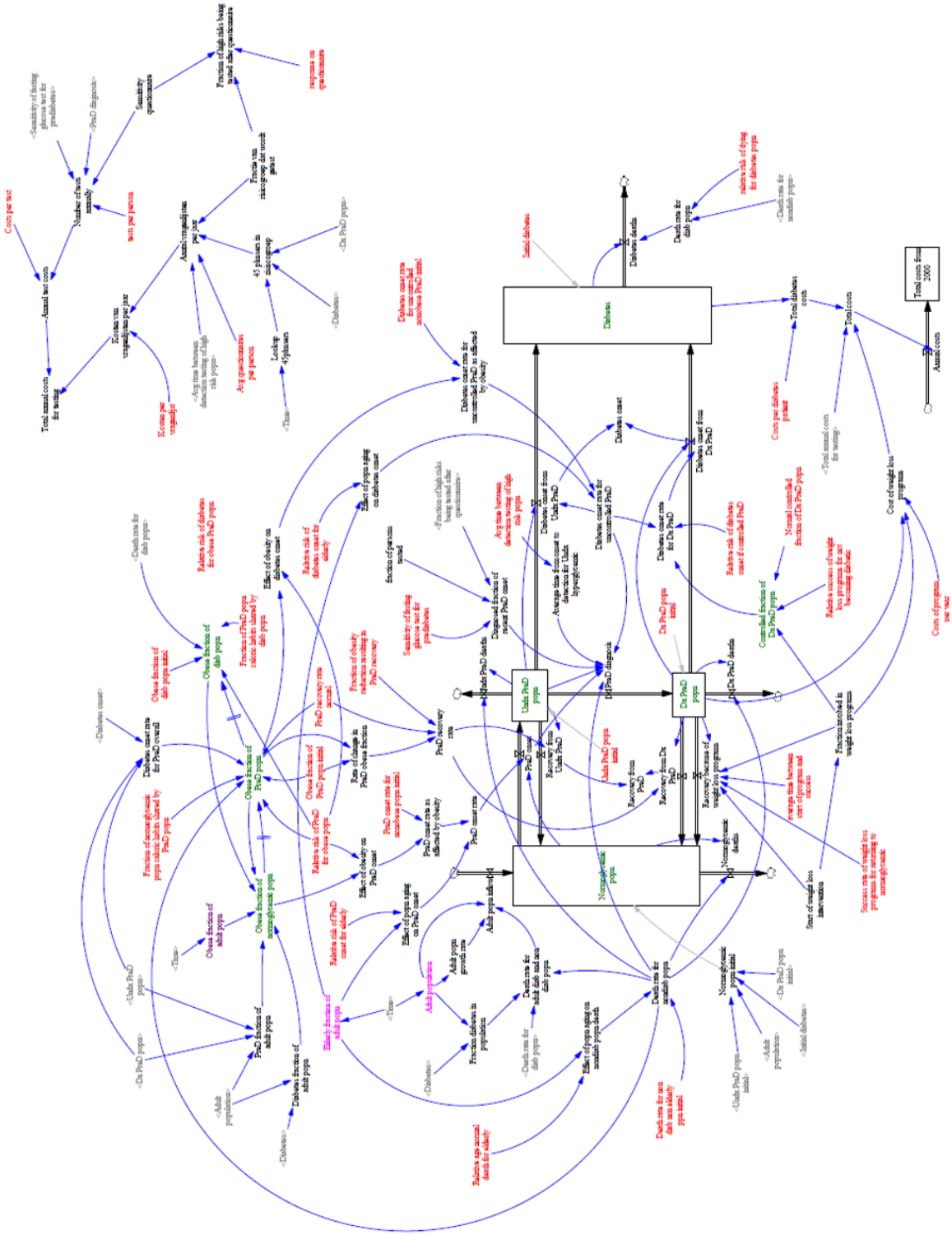
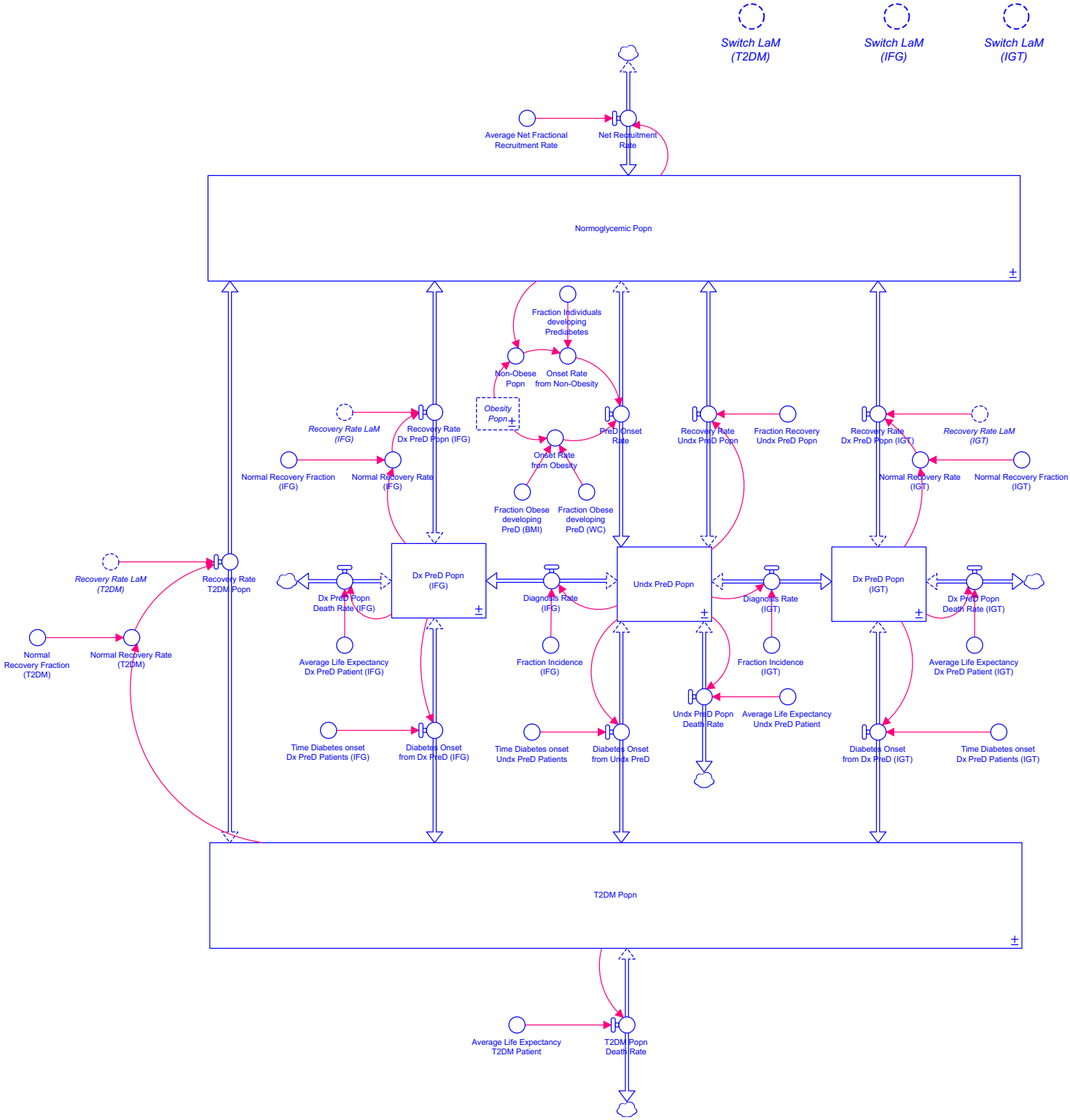
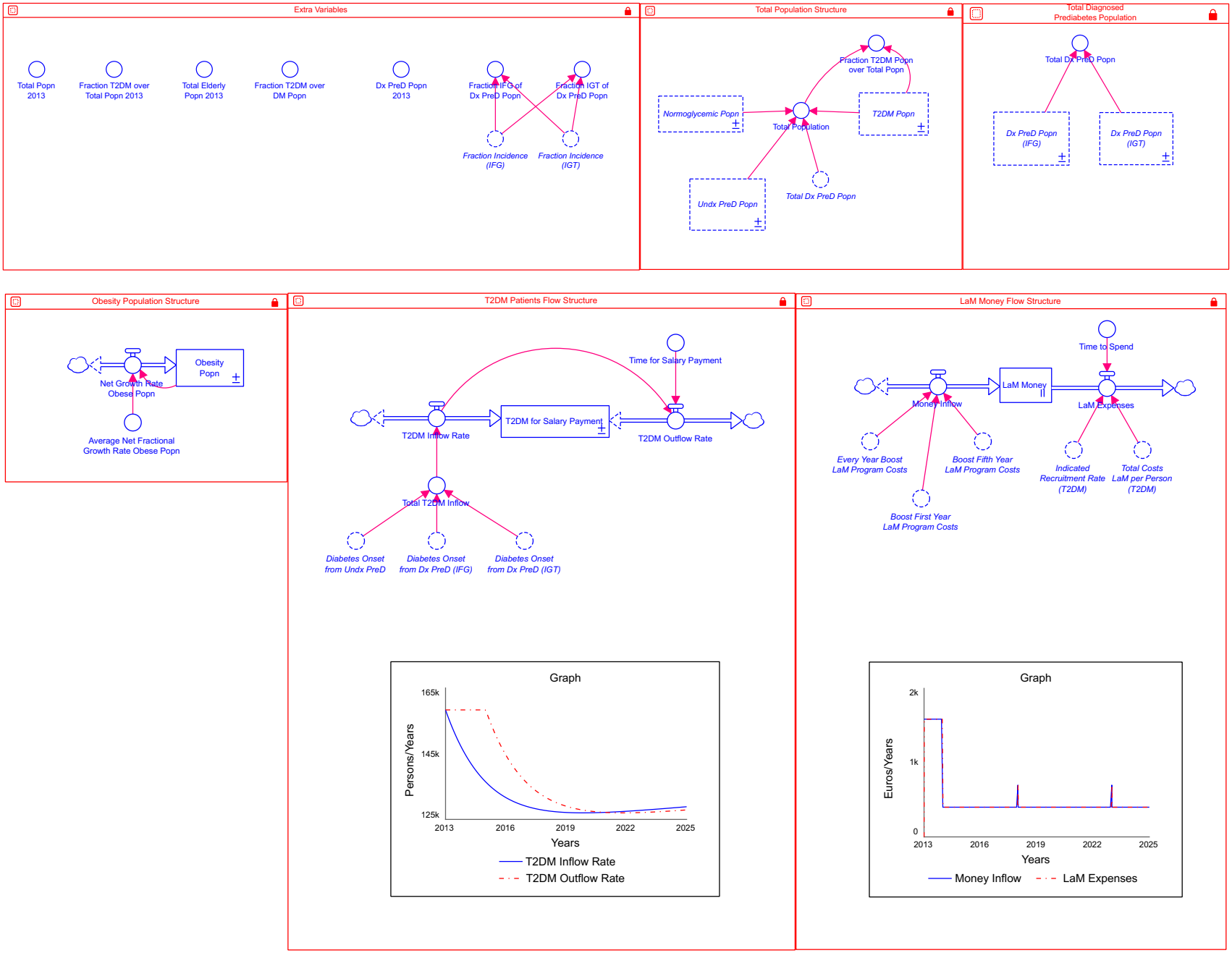
Appendices

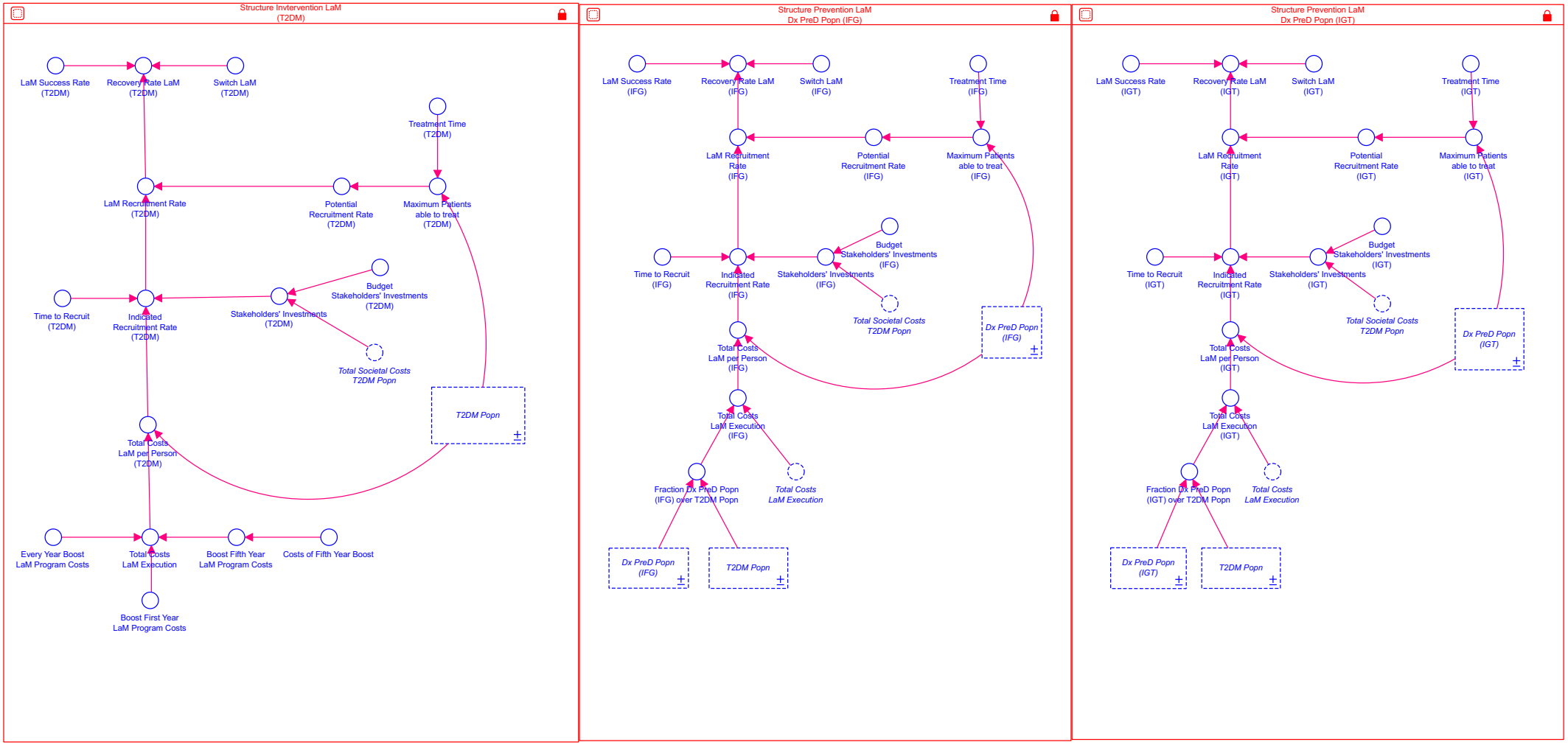
Appendix 1 – The Gelevert Model (2012)

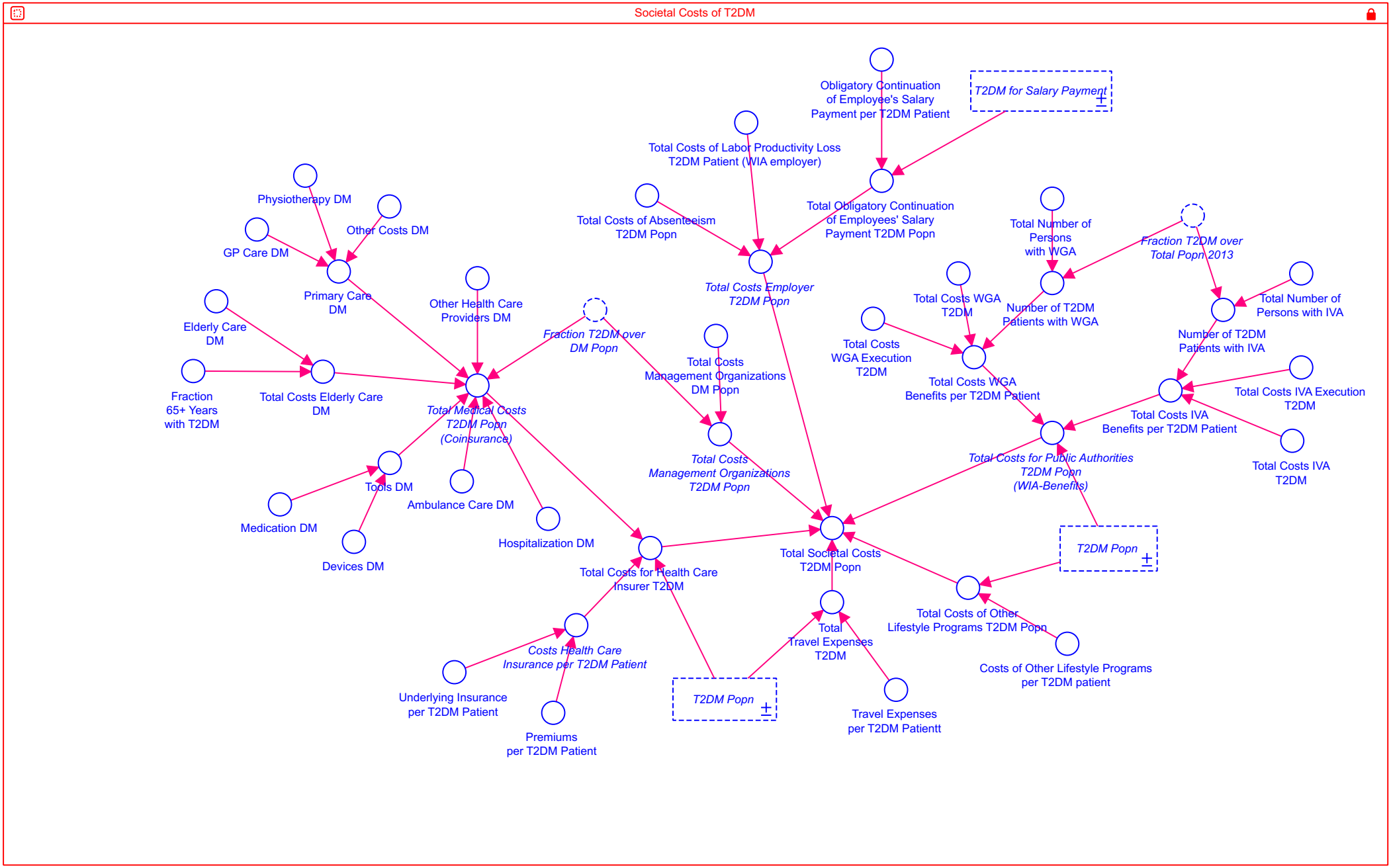


Appendix 2 – The T2DM Patient Journey




Extra Variables
Total Popn 2013
Fraction T2DM over Total Popn 2013
Total Elderly Popn 2013
Fraction T2DM over DM Popn
Dx PreD Popn 2013
Fraction IFG of Dx PreD Popn
Fraction IGT of Dx PreD Popn
Fraction Incidence (IFG)
Fraction Incidence (IGT)
Total Population Structure
Fraction T2DM Popn over Total Popn
Normoglycemic Popn
Total Population
T2DM Popn
Undx PreD Popn
Total Dx PreD Popn
Total Diagnosed Prediabetes Population
Total Dx PreD Popn
Dx PreD Popn (IFG)
Dx PreD Popn (IGT)
Obesity Population Structure
Obesity Popn
Net Growth Rate Obese Popn
Average Net Fractional Growth Rate Obese Popn
T2DM Patients Flow Structure
Time for Salary Payment
T2DM for Salary Payment
T2DM Inflow Rate
T2DM Outflow Rate
Total T2DM Inflow
Diabetes Onset from Undx PreD
Diabetes Onset from Dx PreD (IFG)
Diabetes Onset from Dx PreD (IGT)
Graph
165k
145k
125k
Persons/Years
2013
2016
2019
2022
2025
Years
T2DM Inflow Rate
T2DM Outflow Rate
LaM Money Flow Structure
Time to Spend
LaM Money
Money Inflow
LaM Expenses
Every Year Boost LaM Program Costs
Boost Fifth Year LaM Program Costs
Indicated Recruitment Rate (T2DM)
Total Costs LaM per Person (T2DM)
Boost First Year LaM Program Costs
Graph
2k
1k
0
Euros/Years
2013
2016
2019
2022
2025
Years
Money Inflow
LaM Expenses


Structure Invtervention LaM (T2DM)
LaM Success Rate (T2DM)
Recovery Rate LaM (T2DM)
Switch LaM (T2DM)
Treatment Time (T2DM)
LaM Recruitment Rate (T2DM)
Potential Recruitment Rate (T2DM)
Maximum Patients able to treat (T2DM)
Budget Stakeholders' Investments (T2DM)
Time to Recruit (T2DM)
Indicated Recruitment Rate (T2DM)
Stakeholders' Investments (T2DM)
Total Societal Costs T2DM Popn
T2DM Popn
Total Costs LaM per Person (T2DM)
Every Year Boost LaM Program Costs
Total Costs LaM Execution
Boost Fifth Year LaM Program Costs
Costs of Fifth Year Boost
Boost First Year LaM Program Costs
Structure Prevention LaM Dx PreD Popn (IFG)
LaM Success Rate (IFG)
Recovery Rate LaM (IFG)
Switch LaM (IFG)
Treatment Time (IFG)
LaM Recruitment Rate (IFG)
Potential Recruitment Rate (IFG)
Maximum Patients able to treat (IFG)
Budget Stakeholders' Investments (IFG)
Time to Recruit (IFG)
Indicated Recruitment Rate (IFG)
Stakeholders' Investments (IFG)
Total Societal Costs T2DM Popn
Dx PreD Popn (IFG)
Total Costs LaM per Person (IFG)
Total Costs LaM Execution (IFG)
Fraction Dx PreD Popn (IFG) over T2DM Popn
Total Costs LaM Execution
Dx PreD Popn (IFG)
T2DM Popn
Structure Prevention LaM Dx PreD Popn (IGT)
LaM Success Rate (IGT)
Recovery Rate LaM (IGT)
Switch LaM (IGT)
Treatment Time (IGT)
LaM Recruitment Rate (IGT)
Potential Recruitment Rate (IGT)
Maximum Patients able to treat (IGT)
Budget Stakeholders' Investments (IGT)
Time to Recruit (IGT)
Indicated Recruitment Rate (IGT)
Stakeholders' Investments (IGT)
Total Societal Costs T2DM Popn
Dx PreD Popn (IGT)
Total Costs LaM per Person (IGT)
Total Costs LaM Execution (IGT)
Fraction Dx PreD Popn (IGT) over T2DM Popn
Total Costs LaM Execution
Dx PreD Popn (IGT)
T2DM Popn


Societal Costs of T2DM
Obligatory Continuation of Employee's Salary Payment per T2DM Patient
T2DM for Salary Payment
Total Costs of Labor Productivity Loss T2DM Patient (WIA employer)
Total Costs of Absenteeism T2DM Popn
Total Obligatory Continuation of Employees' Salary Payment T2DM Popn
Total Costs Employer T2DM Popn
Physiotherapy DM
GP Care DM
Other Costs DM
Primary Care DM
Other Health Care Providers DM
Elderly Care DM
Fraction 65+ Years with T2DM
Total Costs Elderly Care DM
Fraction T2DM over DM Popn
Total Medical Costs T2DM Popn (Coinsurance)
Tools DM
Medication DM
Devices DM
Ambulance Care DM
Hospitalization DM
Total Costs Management Organizations DM Popn
Total Costs Management Organizations T2DM Popn
Total Costs for Health Care Insurer T2DM
Costs Health Care Insurance per T2DM Patient
Underlying Insurance per T2DM Patient
Premiums per T2DM Patient
T2DM Popn
Total Societal Costs T2DM Popn
Total Travel Expenses T2DM
Travel Expenses per T2DM Patientt
Total Number of Persons with WGA
Fraction T2DM over Total Popn 2013
Total Costs WGA T2DM
Number of T2DM Patients with WGA
Total Costs WGA Execution T2DM
Total Costs WGA Benefits per T2DM Patient
Total Number of Persons with IVA
Number of T2DM Patients with IVA
Total Costs IVA Execution T2DM
Total Costs IVA Benefits per T2DM Patient
Total Costs IVA T2DM
Total Costs for Public Authorities T2DM Popn (WIA-Benefits)
T2DM Popn
Total Costs of Other Lifestyle Programs T2DM Popn
Costs of Other Lifestyle Programs per T2DM patient

Appendix 3 – Model Validation

Appendix 3.1 – Base Run

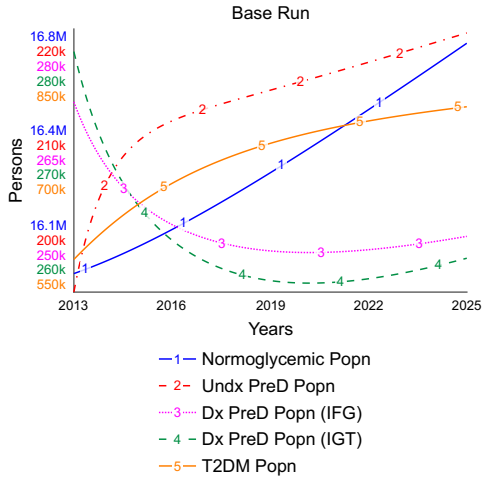


Figure 37 – Behavior of Stocks

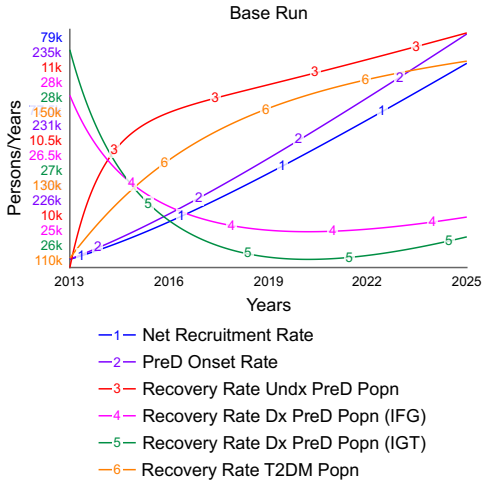


Figure 38 – Behavior of Norm Popn Flows

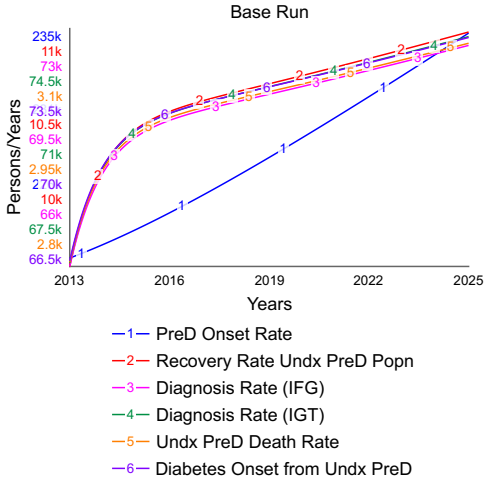


Figure 39 – Behavior of Undx PreD Popn Flows

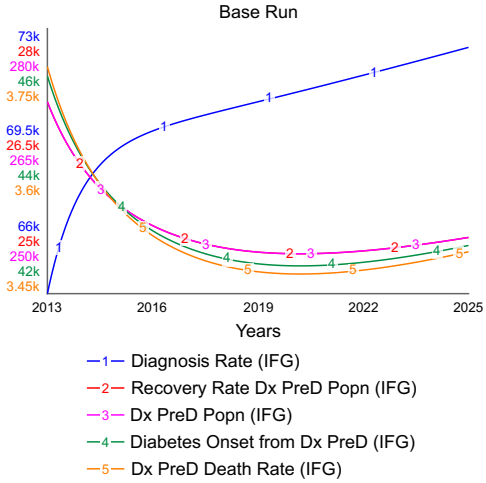


Figure 40 – Behavior of Dx PreD Popn (IFG) Flows

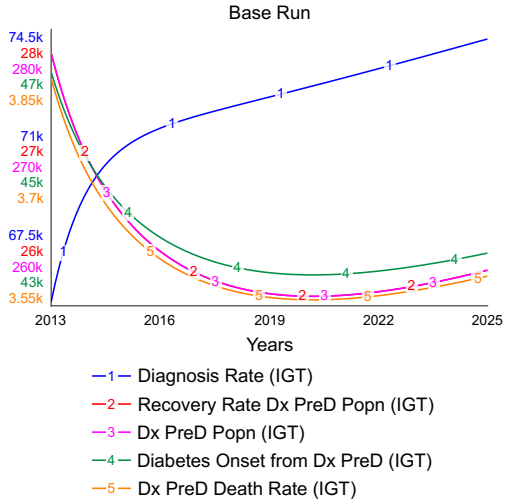


Figure 41 – Behavior of Dx PreD Popn (IGT) Flows

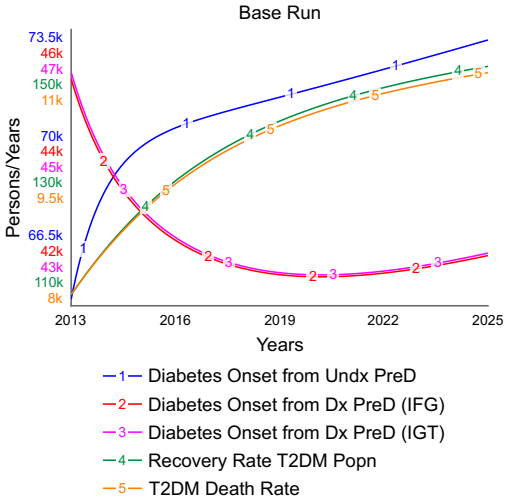


Figure 42 – Behavior of T2DM Popn Flows

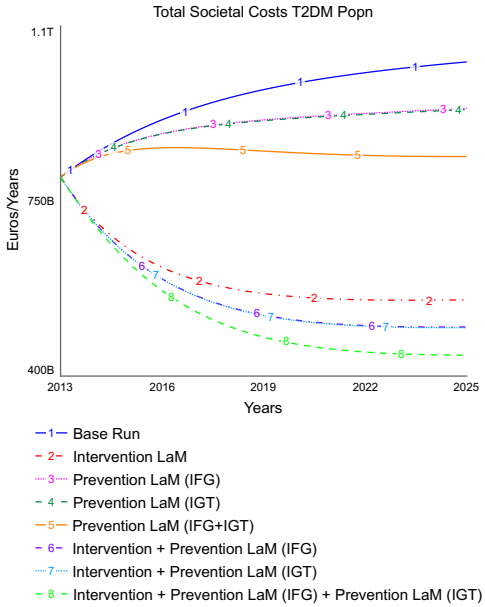


Figure 43 – Behavior of Total Societal Cost T2DMs

Appendix 3.2 – Direct Extreme Conditions Test

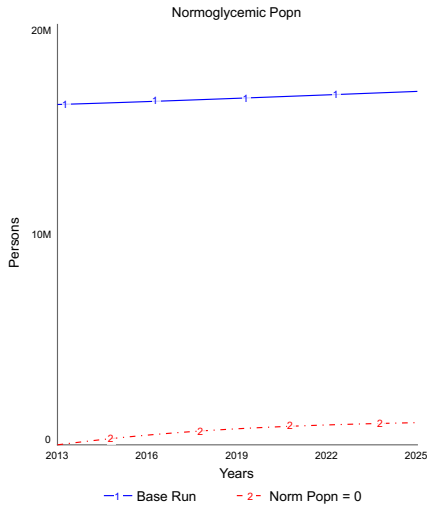


Figure 44 – Behavior of Normoglycemic Popn when Normoglycemic Popn is zero

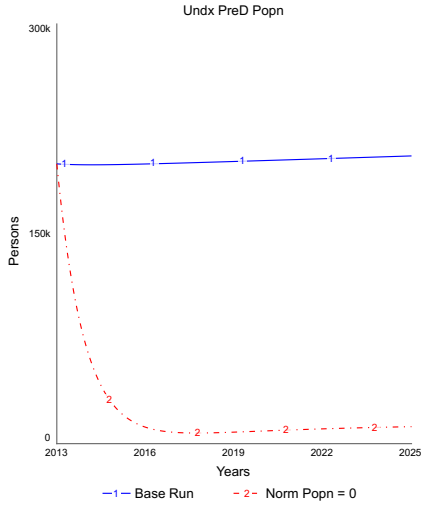


Figure 45 – Behavior of Undx PreD Popn when Normoglycemic Popn is zero

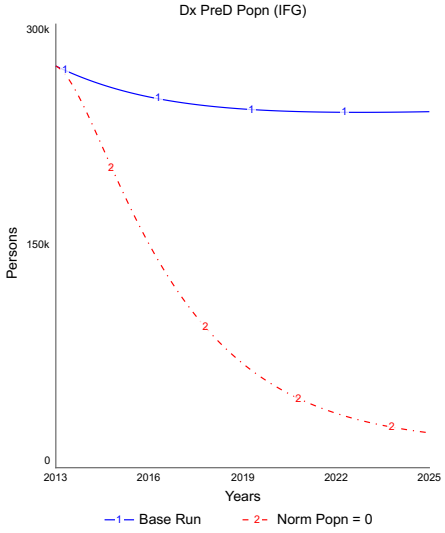


Figure 46 – Behavior of Dx PreD (IFG) Popn when Normoglycemic Popn is zero

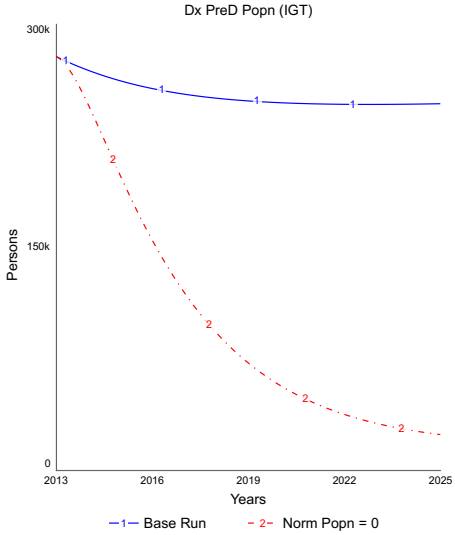


Figure 47 – Behavior of Dx PreD (IGT) Popn when Normoglycemic Popn is zero

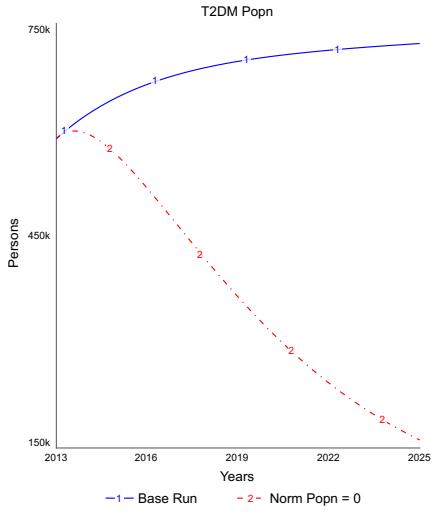


Figure 48 – Behavior of T2DM Population when Normoglycemic Popn is zero

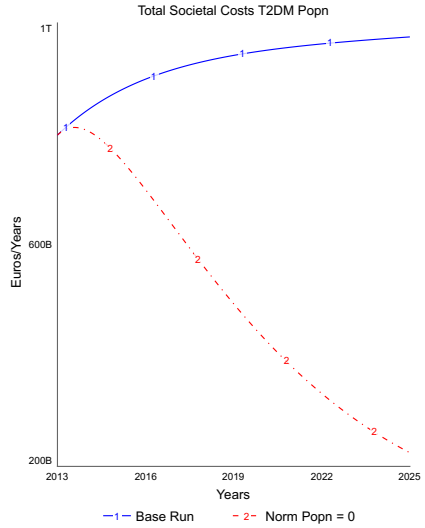


Figure 49 – Behavior of Total Societal Costs T2DM Popn if Normoglycemic Popn is zero

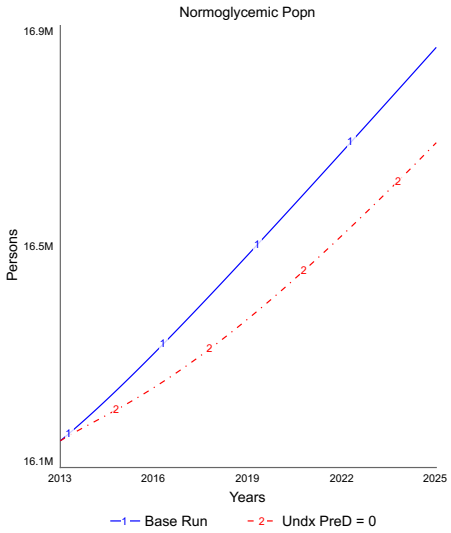


Figure 50 – Behavior of Normoglycemic Popn if Undx PreD Popn is zero

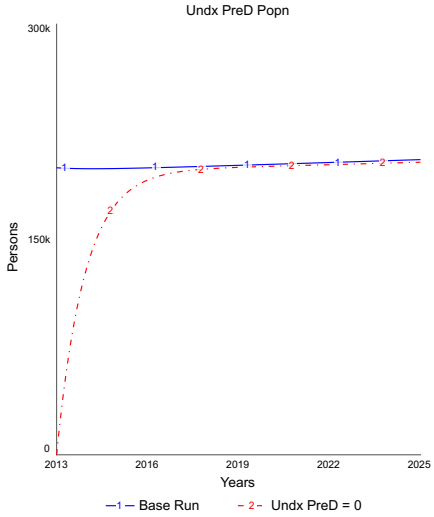


Figure 51 – Behavior of Undx PreD Popn if Undx PreD Popn is zero

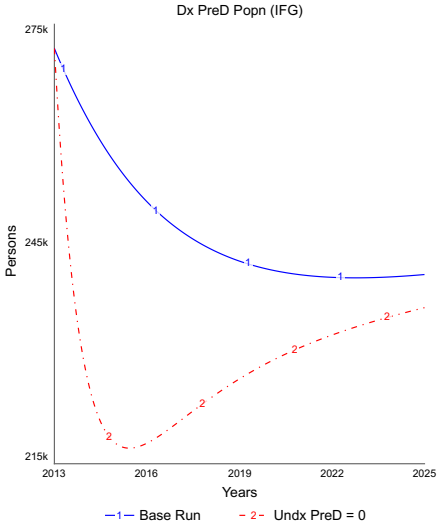


Figure 52 – Behavior of Dx PreD Popn (IFG) if Undx PreD Popn is zero

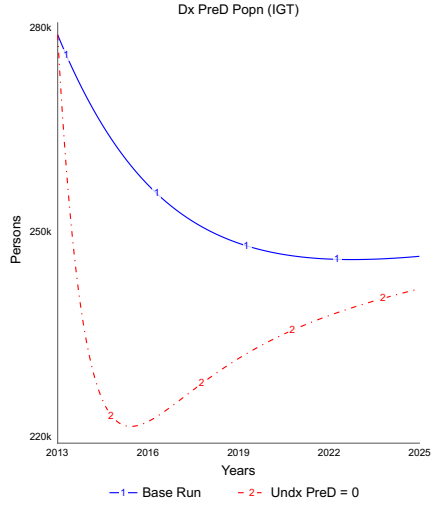


Figure 53 – Behavior of Dx PreD Popn (IGT) if Undx PreD Popn is zero

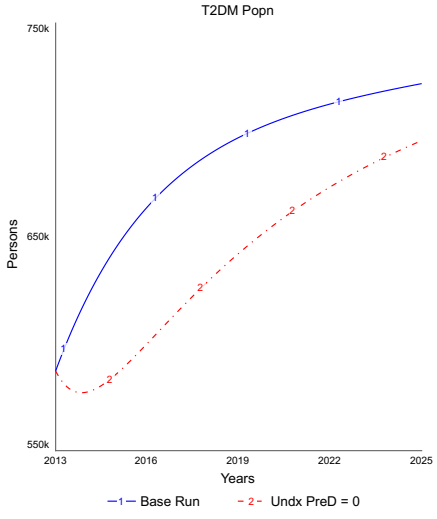


Figure 54 – Behavior of T2DM Popn if Undx PreD Popn is zero

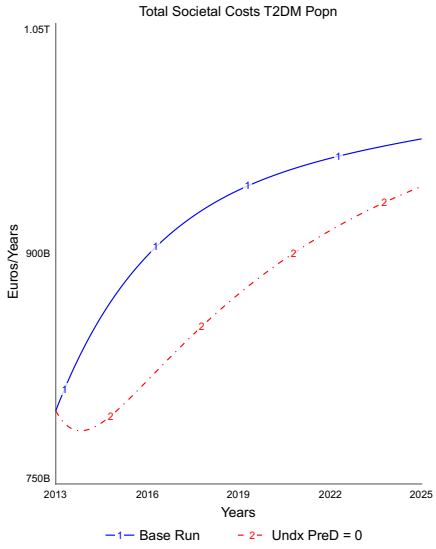


Figure 55 – Behavior of Total Societal Costs T2DM Popn if Undx PreD Popn is zero

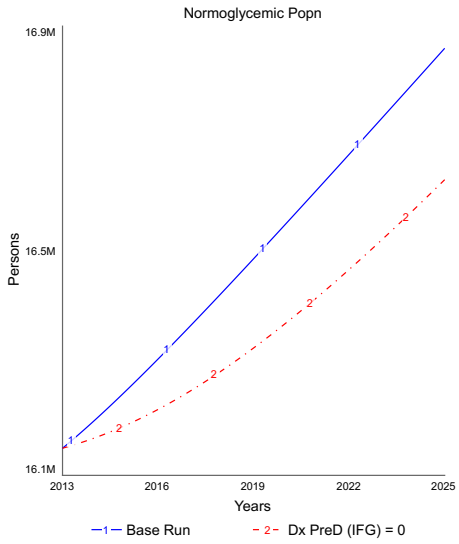


Figure 56 – Behavior of Normoglycemic Popn if Dx PreD Popn (IFG) is zero

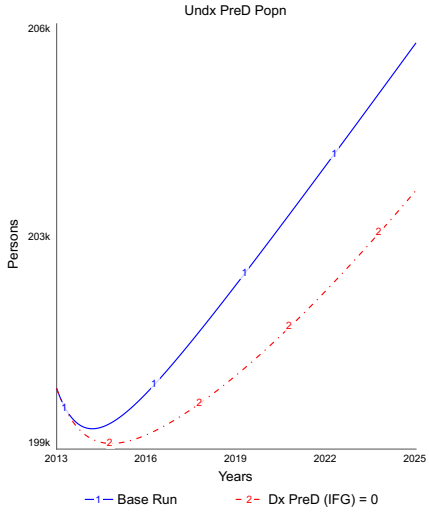


Figure 57 – Behavior of Undx PreD Popn if Dx PreD Popn (IFG) is zero

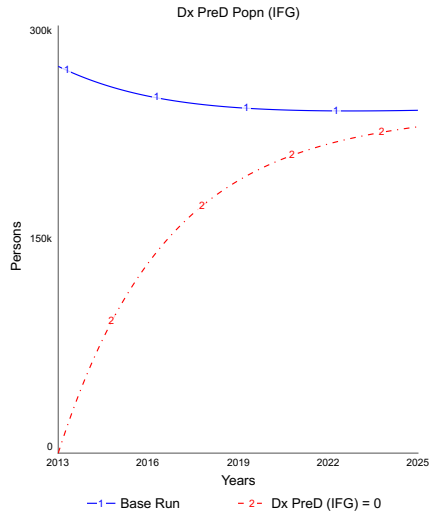


Figure 58 – Behavior of Dx PreD Popn (IFG) if Dx PreD Popn (IFG) is zero

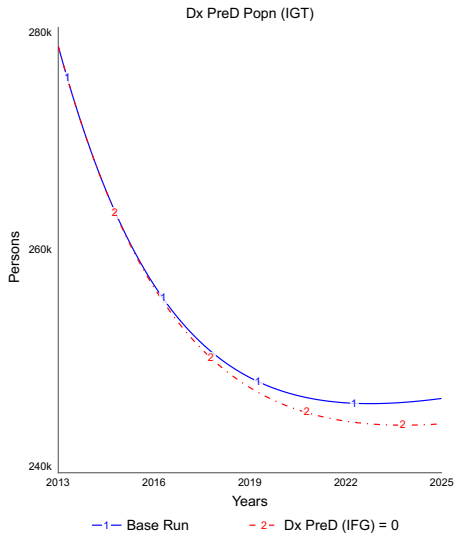


Figure 59 – Behavior of Dx PreD Popn (IGT) if Dx PreD Popn (IFG) is zero

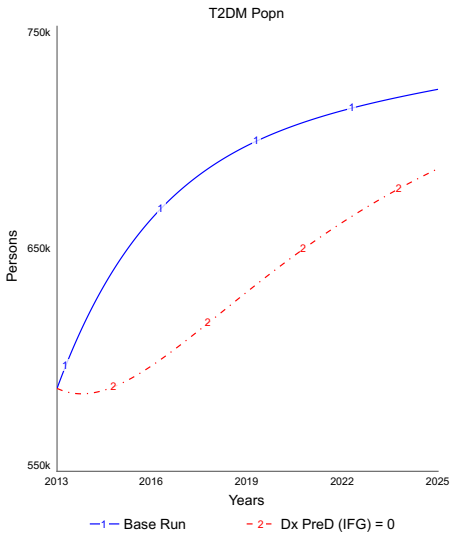


Figure 60 – Behavior of T2DM Popn if Dx PreD Popn (IFG) is zero

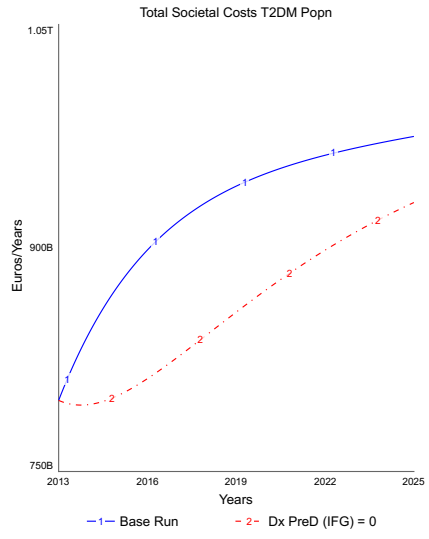


Figure 61 – Behavior of Total Societal Costs T2DM Popn if Dx PreD Popn (IFG) is zero

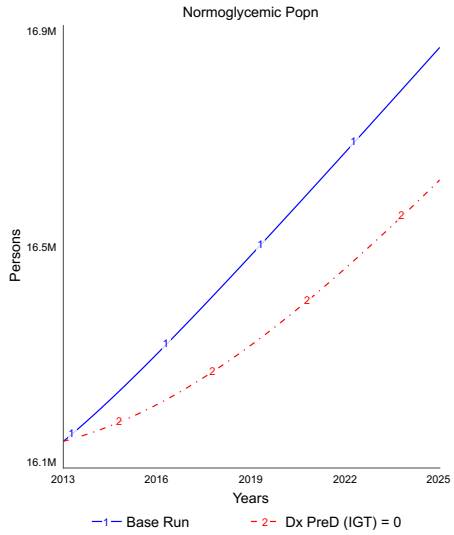


Figure 62 – Behavior of Normoglycemic Popn if Dx PreD (IGT) is zero

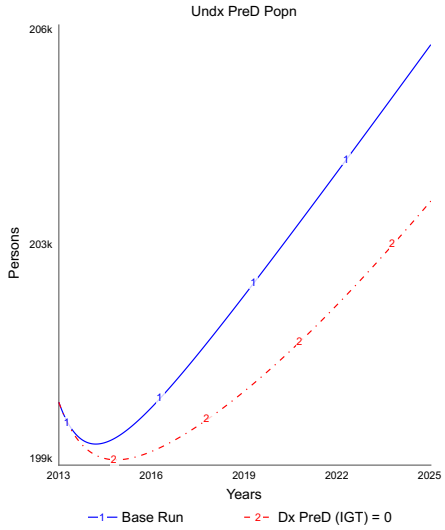


Figure 63 – Behavior of Undx PreD Popn if Dx PreD (IGT) is zero

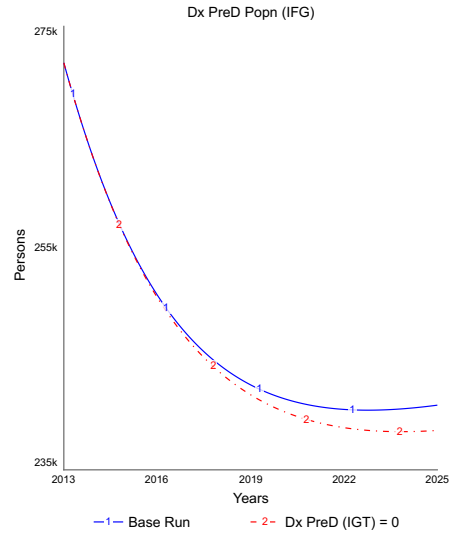


Figure 64 – Behavior of Dx PreD Popn (IFG) if Dx PreD (IGT) is zero

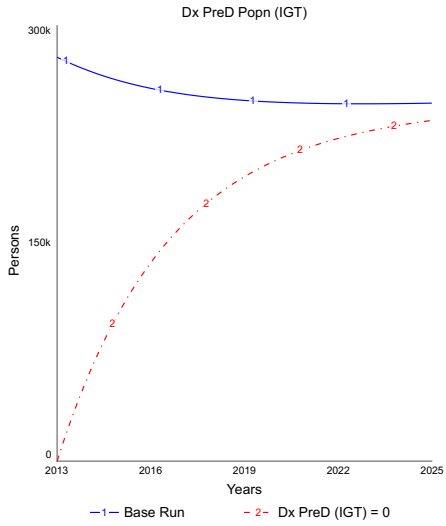


Figure 65 – Behavior of Dx PreD Popn (IGT) if Dx PreD (IGT) is zero

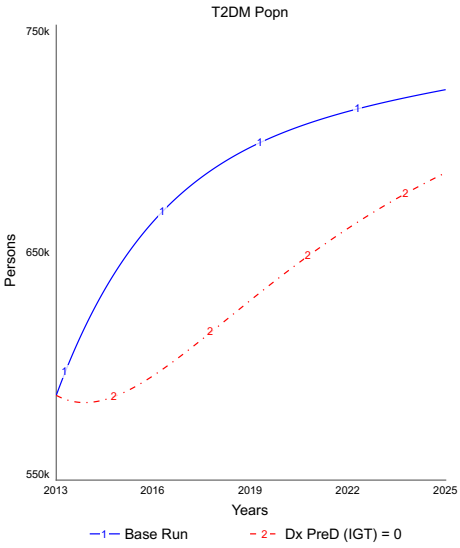


Figure 66 – Behavior of T2DM Popn if Dx PreD (IGT) is zero

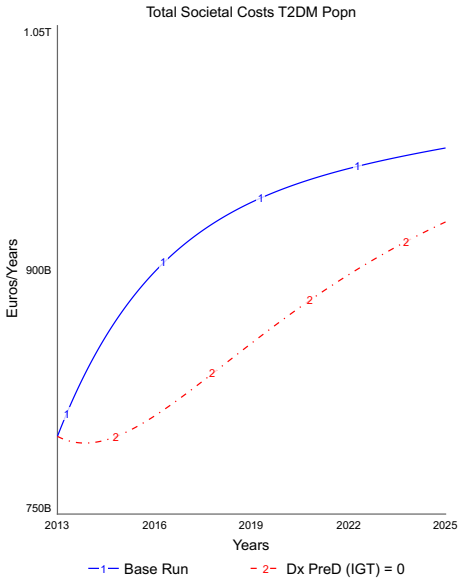


Figure 67 – Behavior of Total Societal Costs T2DM Popn if Dx PreD (IGT) is zero

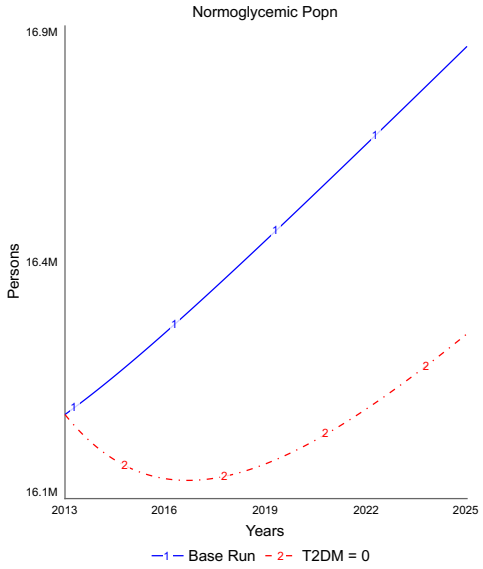


Figure 68 – Behavior of Normoglycemic Popn if T2DM Popn is zero

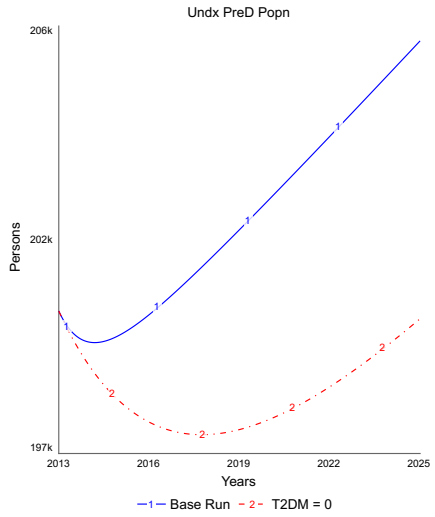


Figure 69 – Behavior of Undx PreD Popn if T2DM Popn is zero

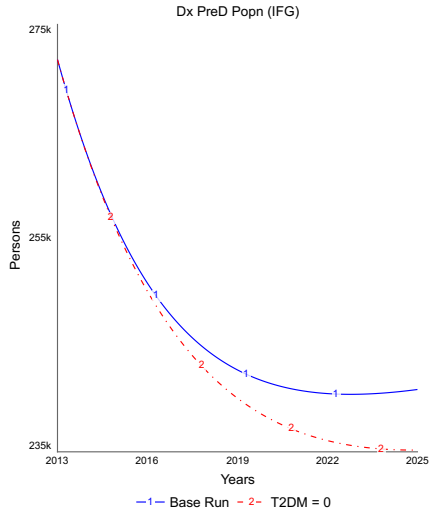


Figure 70 – Behavior of Dx PreD Popn (IFG) if T2DM Popn is zero

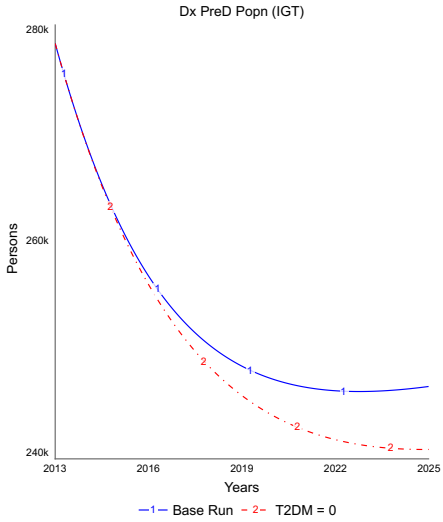


Figure 71 – Behavior of Dx PreD Popn (IGT) if T2DM Popn is zero

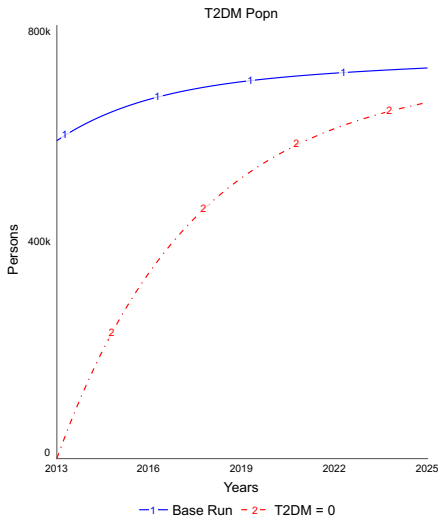


Figure 72 – Behavior of T2DM Popn if T2DM Popn is zero

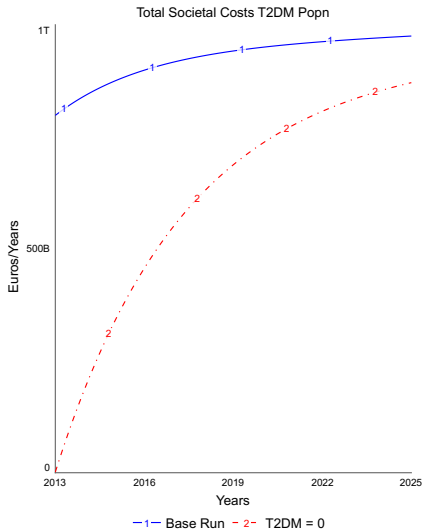


Figure 73 – Behavior of Total Societal Costs T2DM Popn if T2DM Popn is zero

Appendix 3.3 – Behavior Sensitivity Analysis Test

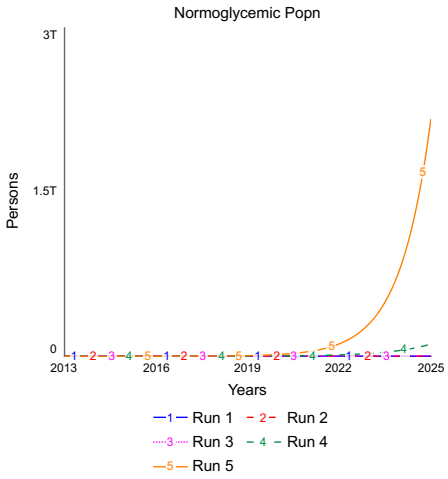


Figure 74 – Average Net Fractional Recruitment Rate on Normoglycemic Popn

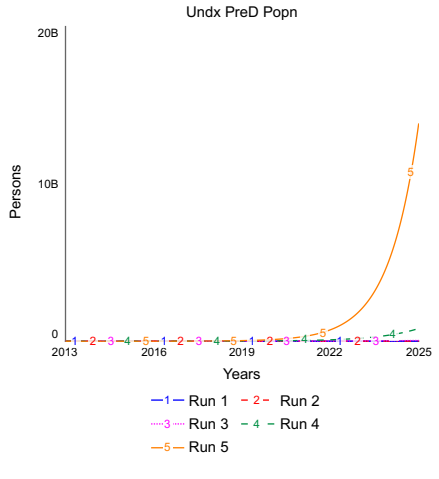


Figure 75 – Average Net Fractional Recruitment Rate on Undx PreD Popn

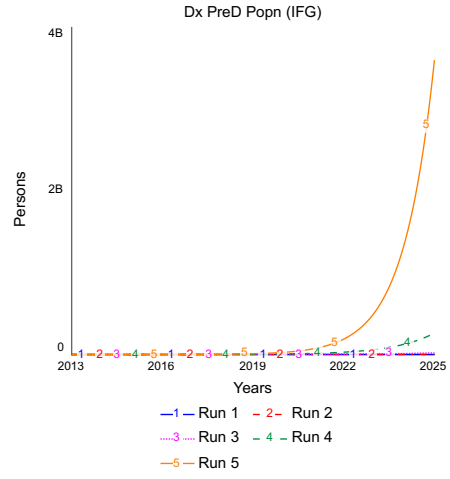


Figure 76 – Average Net Fractional Recruitment Rate on Dx PreD Popn (IFG)

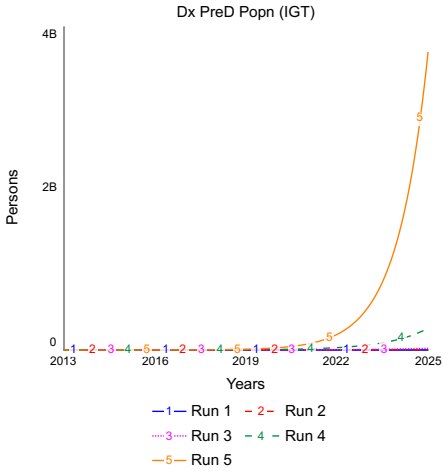


Figure 77 – Average Net Fractional Recruitment Rate on Dx PreD Popn (IGT)

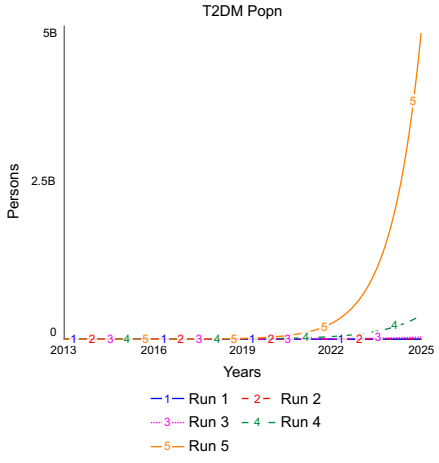


Figure 78 – Average Net Fractional Recruitment Rate on T2DM Popn

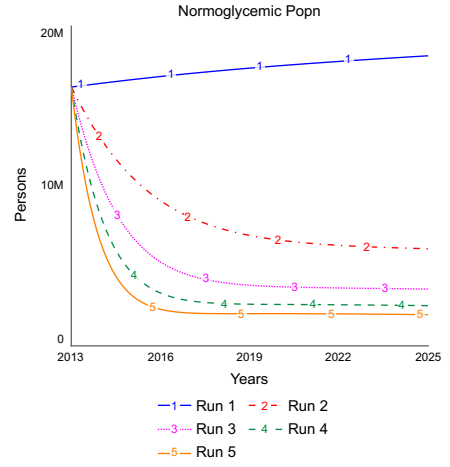


Figure 79 – Fraction Individuals developing PreD on Normoglycemic Popn

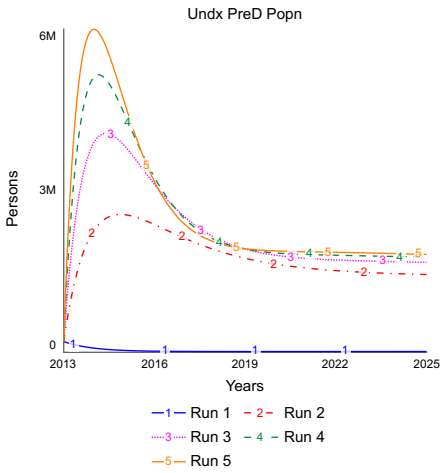


Figure 80 – Fraction Individuals developing PreD on Undx PreD Popn

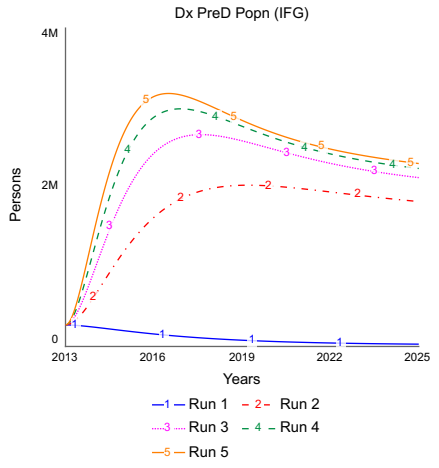


Figure 81 – Fraction Individuals developing PreD on Dx PreD Popn (IFG)

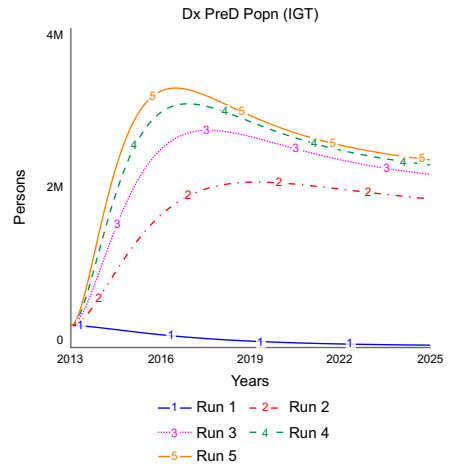


Figure 82 – Fraction Individuals developing PreD on Dx PreD Popn (IGT)

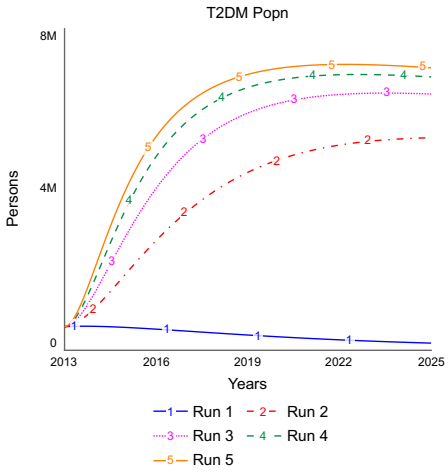


Figure 83 – Fraction Individuals developing PreD on T2DM Popn

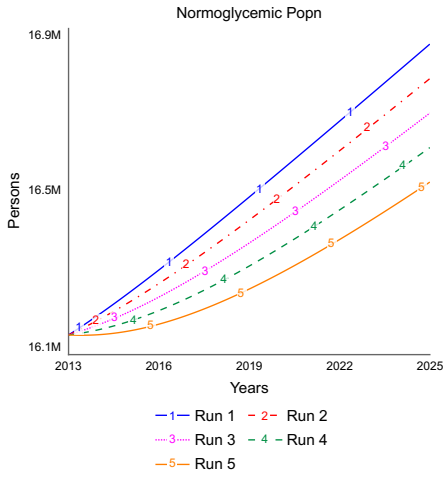


Figure 84 – Fraction Obese developing PreD (BMI) on Normoglycemic Popn

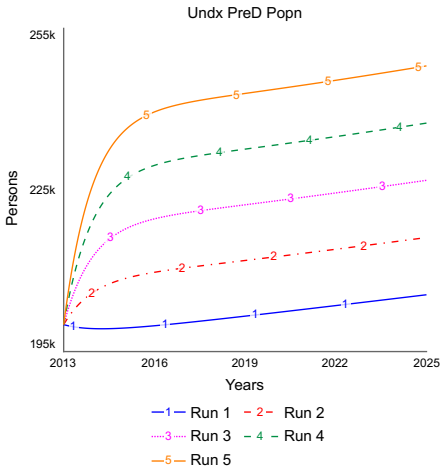


Figure 85 – Fraction Obese developing PreD (BMI) on Undx PreD Popn

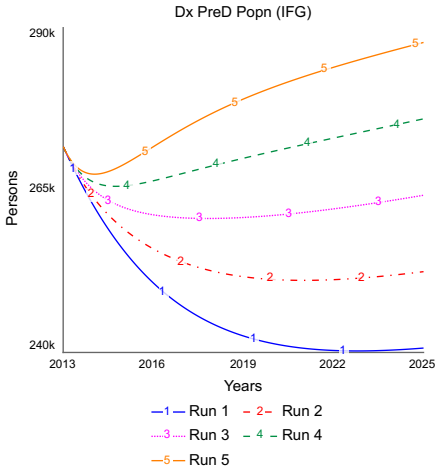


Figure 86 – Fraction Obese developing PreD (BMI) on Dx PreD Popn (IFG)

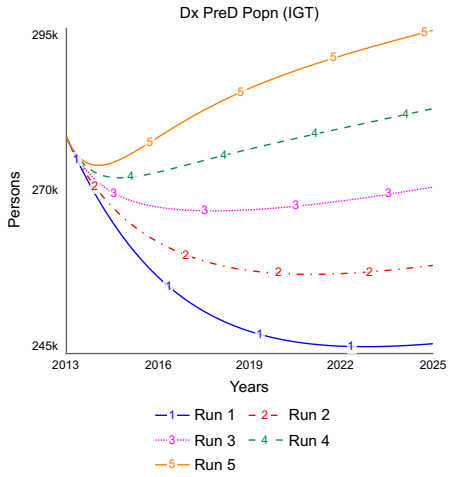


Figure 87 – Fraction Obese developing PreD on (BMI) Dx PreD Popn (IGT)

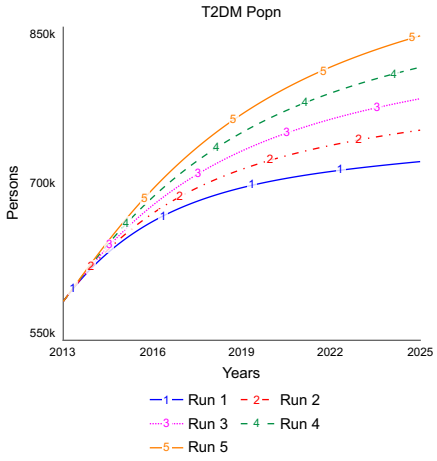


Figure 88 – Fraction Obese developing PreD (BMI) on T2DM Popn

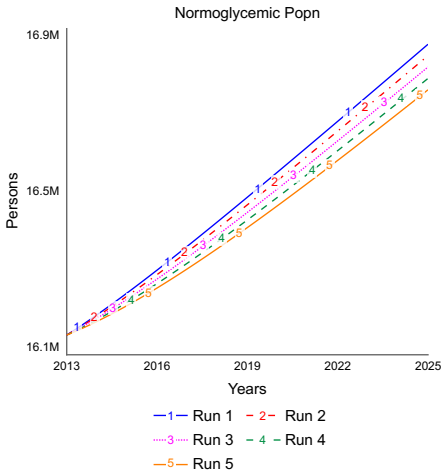


Figure 89 – Fraction Obese developing PreD (WC) on Normoglycemic Popn

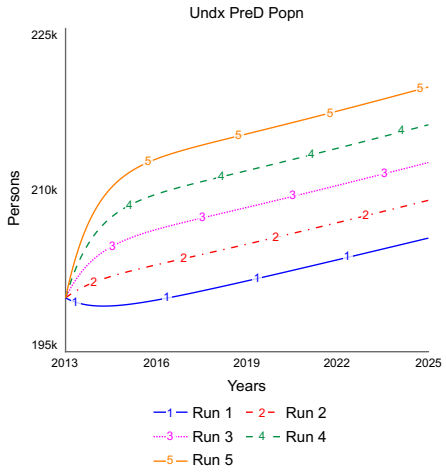


Figure 90 – Fraction Obese developing PreD (WC) on Undx PreD Popn

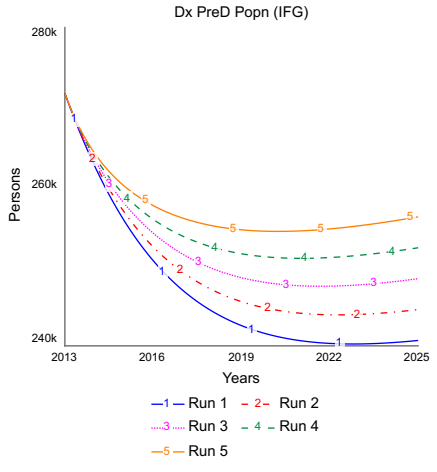


Figure 91 – Fraction Obese developing PreD (WC) on Dx PreD Popn (IFG)

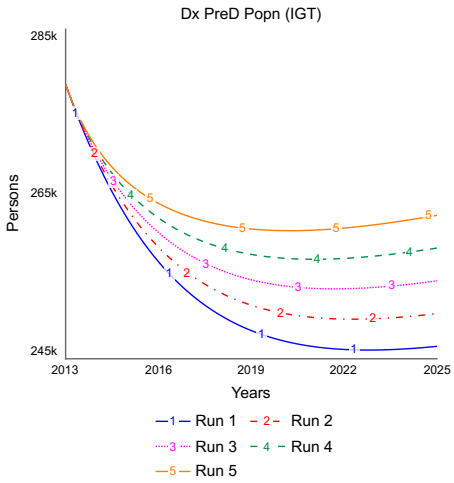


Figure 92 – Fraction Obese developing PreD on (WC) Dx PreD Popn (IGT)

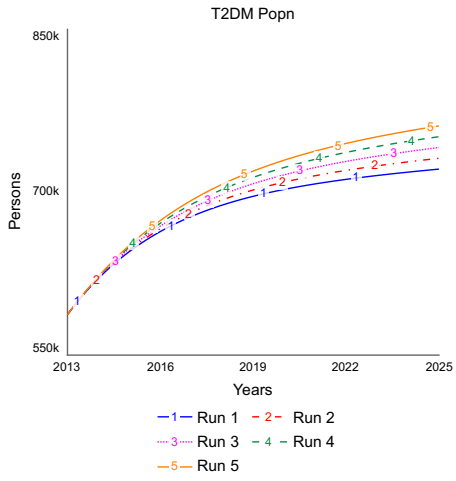


Figure 93 – Fraction Obese developing PreD (WC) on T2DM Popn

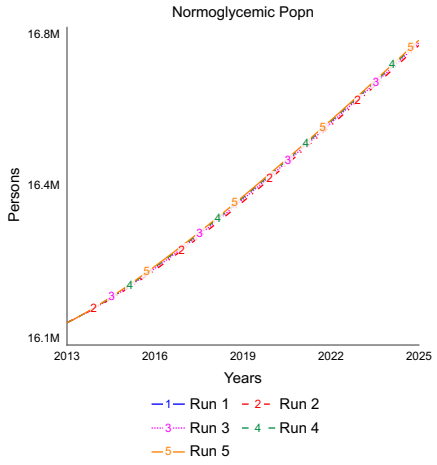


Figure 94 – Fraction Incidence (IFG) on Normoglycemic Popn

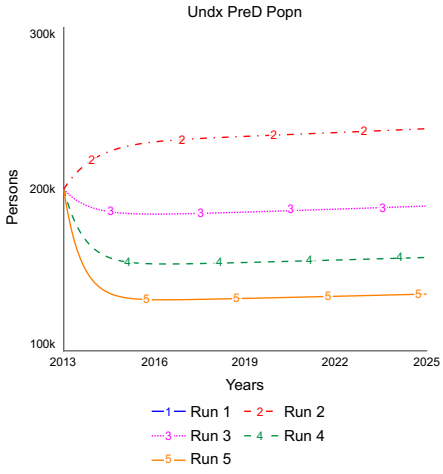


Figure 95 – Fraction Incidence (IFG) on Undx PreD Popn

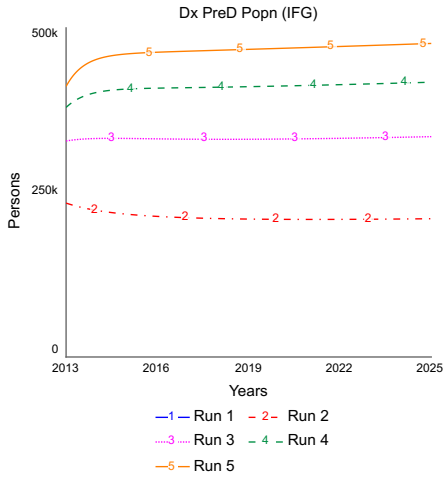


Figure 96 – Fraction Incidence (IFG) on Dx PreD Popn (IFG)

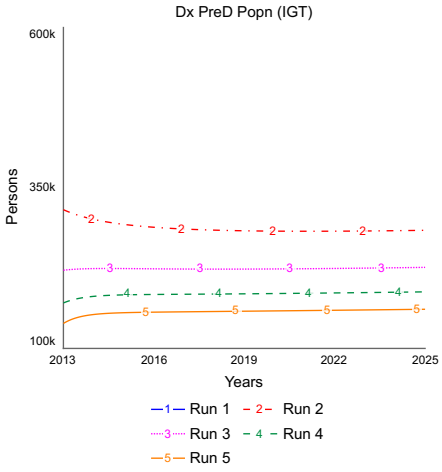


Figure 97 – Fraction Incidence (IFG) on Dx PreD Popn (IGT)

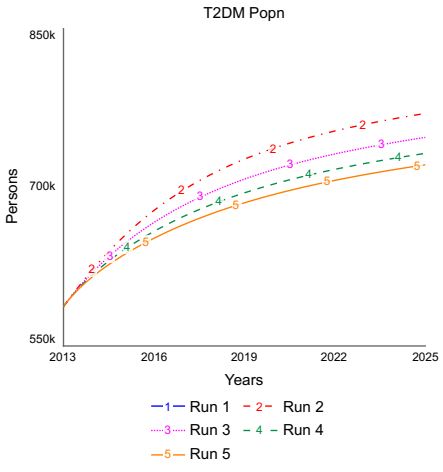


Figure 98 – Fraction Incidence (IFG) on T2DM Popn

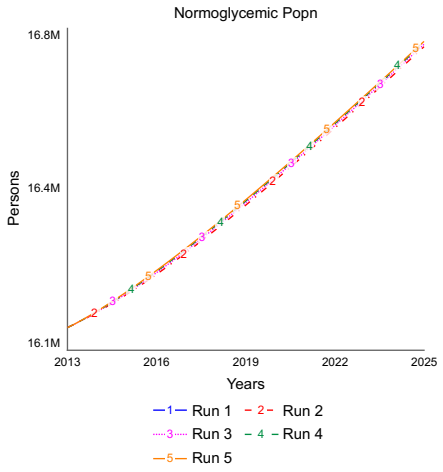


Figure 99 – Fraction Incidence (IGT) on Normoglycemic Popn

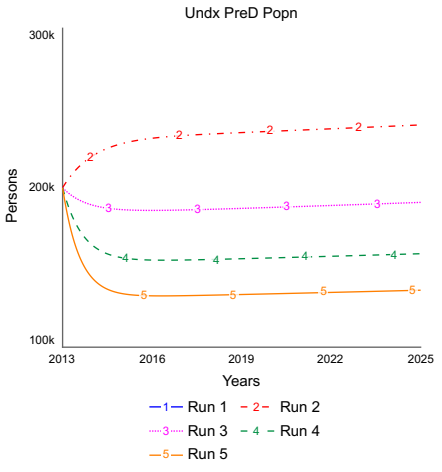


Figure 100 – Fraction Incidence (IGT) on Undx PreD Popn

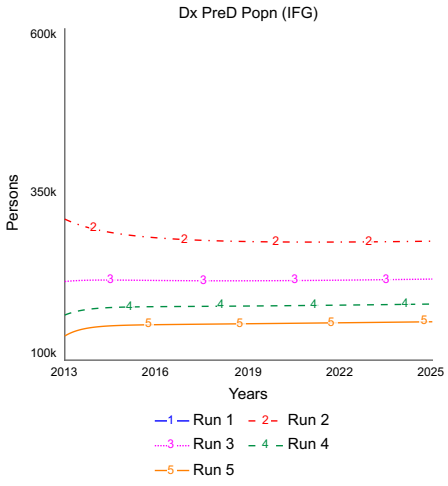


Figure 101 – Fraction Incidence (IGT) on Dx PreD Popn (IFG)

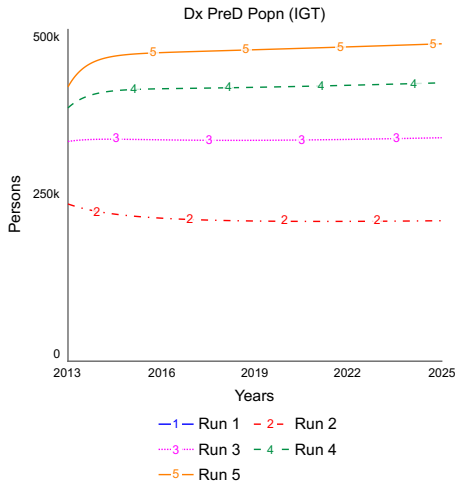


Figure 102 – Fraction Incidence (IGT) on Dx PreD Popn (IGT)

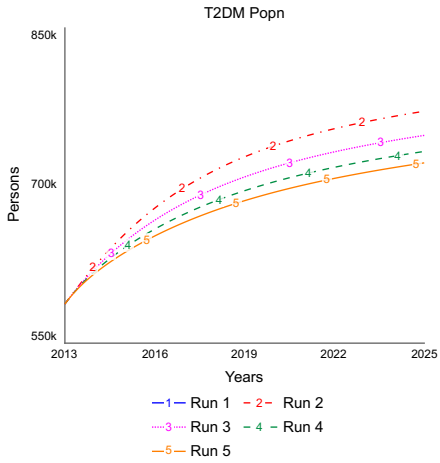


Figure 103 – Fraction Incidence (IGT) on T2DM Popn (IFG)

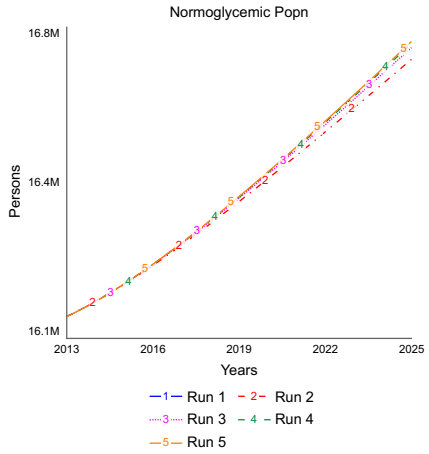


Figure 104 – Average Life Expectancy Undx PreD Patient on Normoglycemic Popn

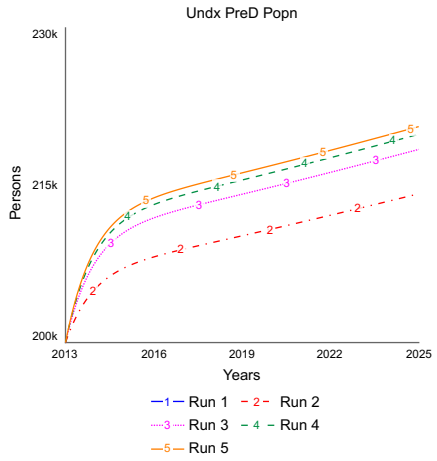


Figure 105 – Average Life Expectancy Undx PreD Patient on Undx PreD Popn

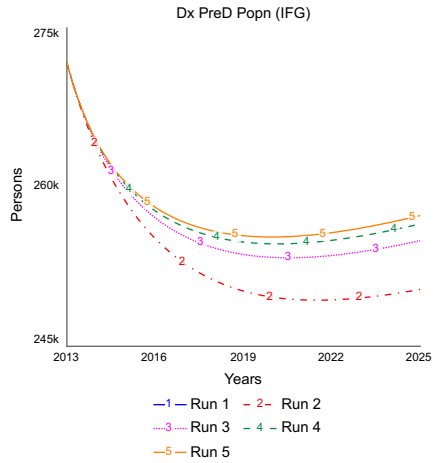


Figure 106 – Average Life Expectancy Undx PreD Patient on Dx PreD Popn (IFG)

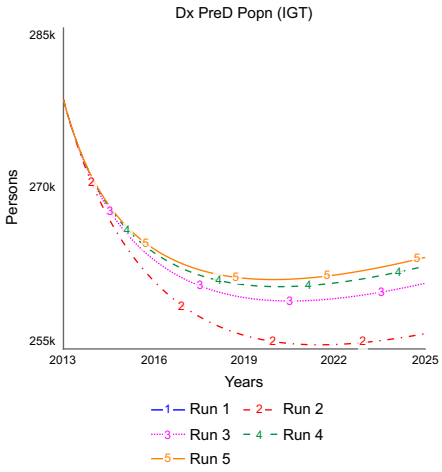


Figure 107 – Average Life Expectancy Undx PreD Patient on Dx PreD Popn (IGT)

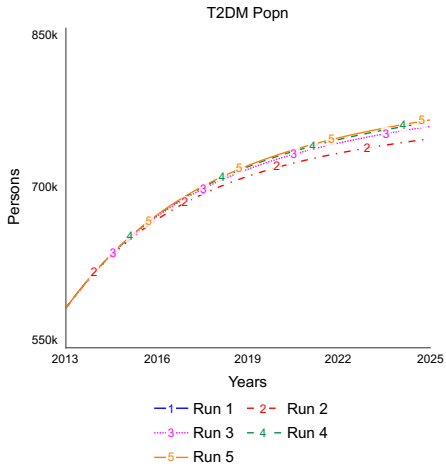


Figure 108 – Average Life Expectancy Undx PreD Patient on T2DM Popn

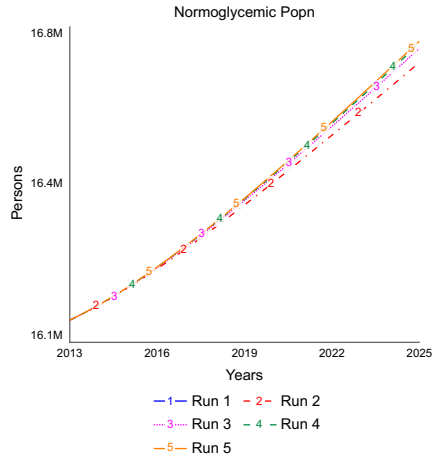


Figure 109 – Average Life Expectancy Dx PreD Patient (IFG) on Normoglycemic Popn

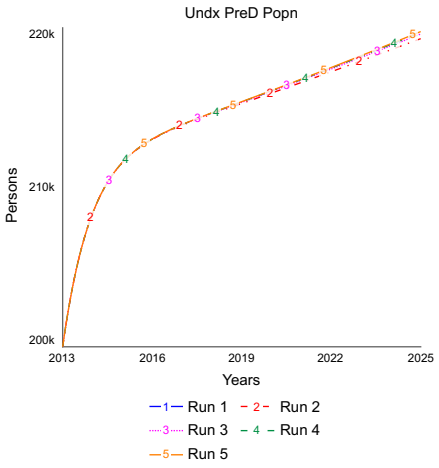


Figure 110 – Average Life Expectancy Dx PreD Patient (IFG) on Undx PreD Popn

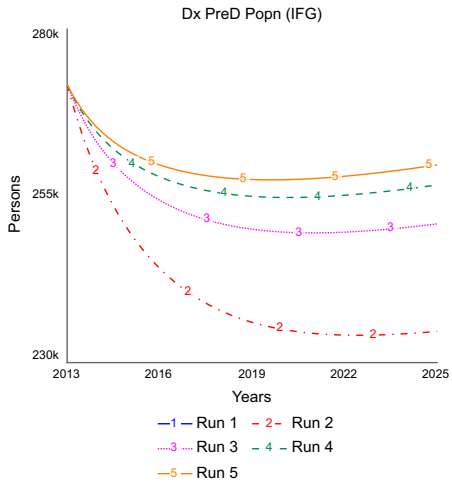


Figure 111 – Average Life Expectancy Dx PreD Patient (IFG) on Dx PreD Popn (IFG)

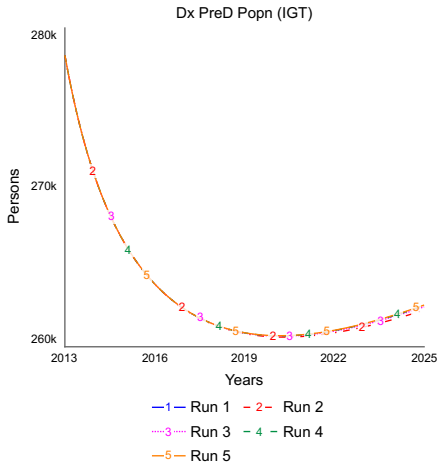


Figure 112 – Average Life Expectancy Dx PreD Patient (IFG) on Dx PreD Popn (IGT)

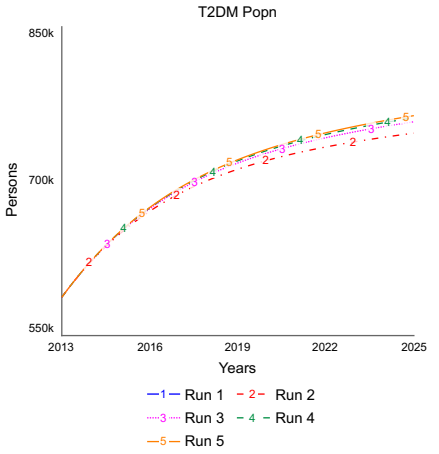


Figure 113 – Average Life Expectancy Dx PreD Patient (IFG) on T2DM Popn

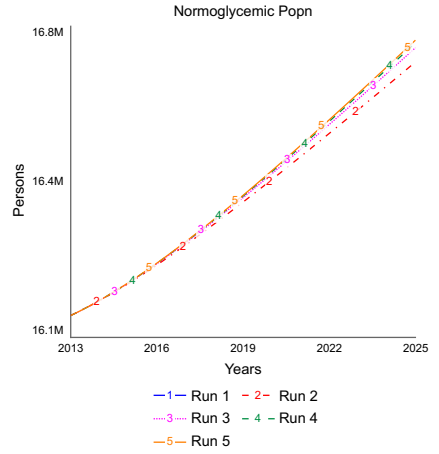


Figure 114 – Average Life Expectancy Dx PreD Patient (IGT) on Normoglycemic Popn

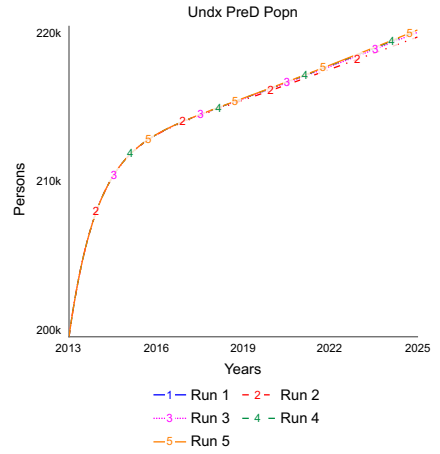


Figure 115 – Average Life Expectancy Dx PreD Patient (IGT) on Undx PreD Popn

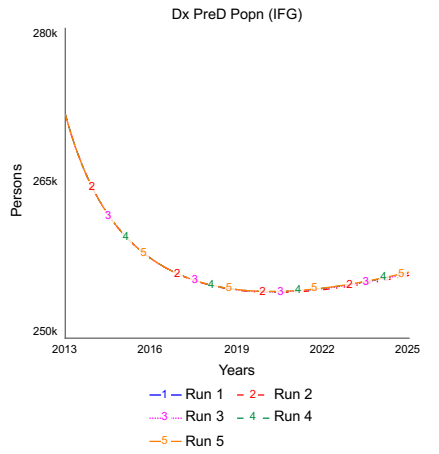


Figure 116 – Average Life Expectancy Dx PreD Patient (IGT) on Dx PreD Popn (IFG)

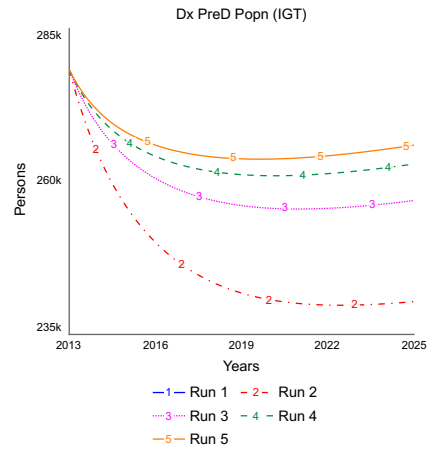


Figure 117 – Average Life Expectancy Dx PreD Patient (IGT) on Dx PreD Popn (IGT)

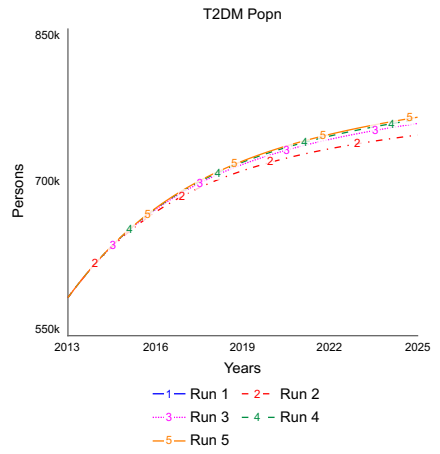


Figure 118 – Average Life Expectancy Dx PreD Patient (IGT) on T2DM Popn

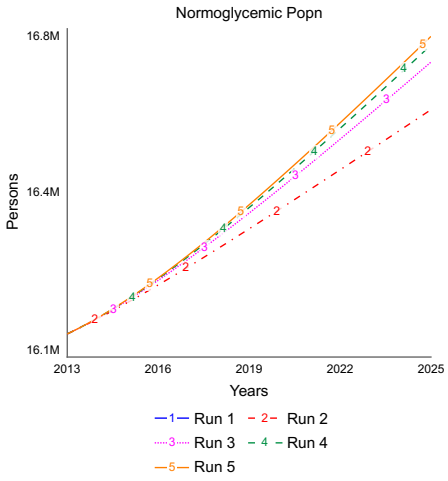


Figure 119 – Average Life Expectancy T2DM Patient on Normoglycemic Popn

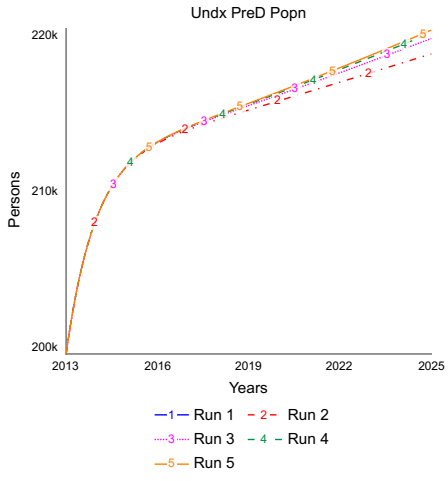


Figure 120 – Average Life Expectancy T2DM Patient on Undx PreD Popn

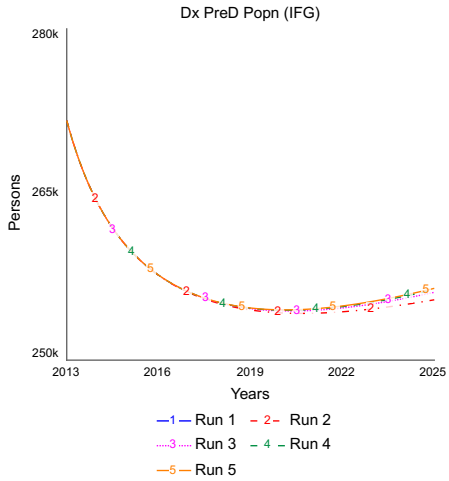


Figure 121 – Average Life Expectancy T2DM Patient on Dx PreD Popn (IFG)

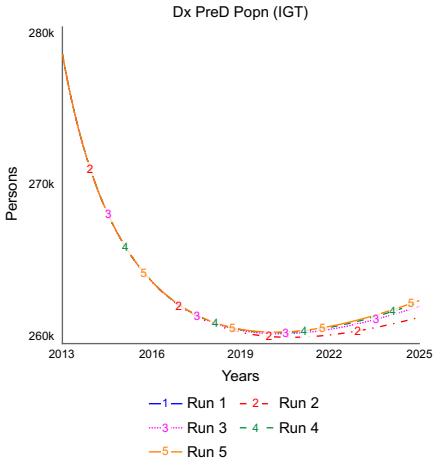


Figure 122 – Average Life Expectancy T2DM Patient on Dx PreD Popn (IGT)

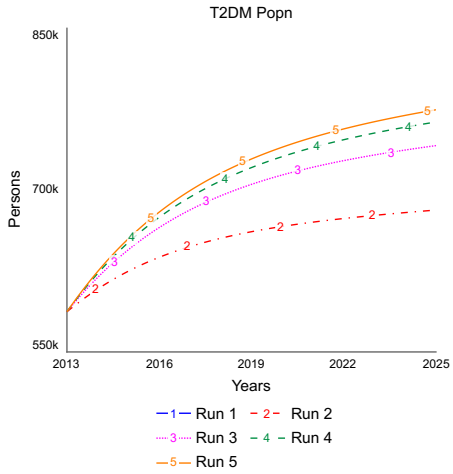


Figure 123 – Average Life Expectancy T2DM Patient on T2DM Popn

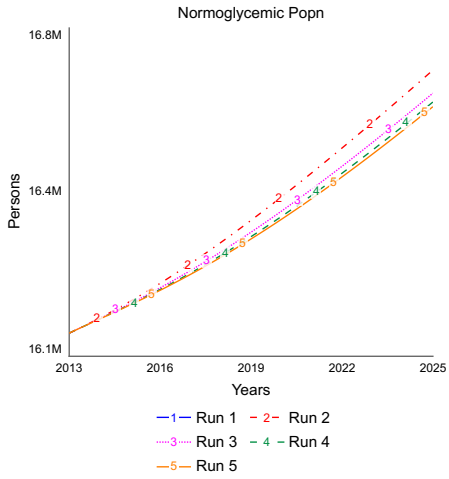


Figure 124 – Time Diabetes onset Undx PreD Patient on Normoglycemic Popn

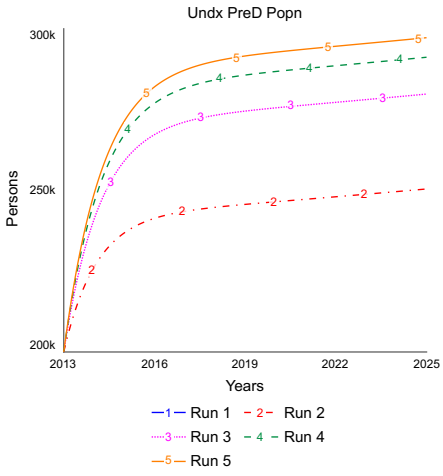


Figure 125 – Time Diabetes onset Undx PreD Patient on Undx PreD Popn

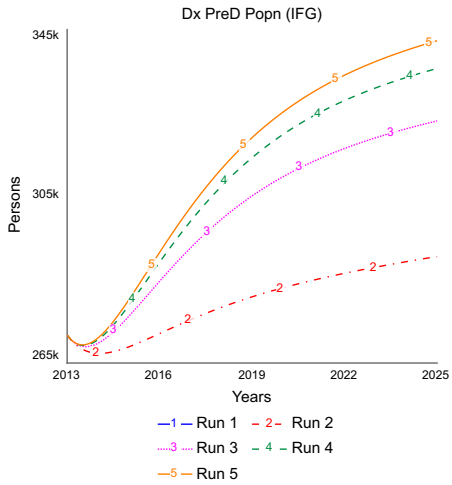


Figure 126 – Time Diabetes onset Undx PreD Patient on Dx PreD Popn (IFG)

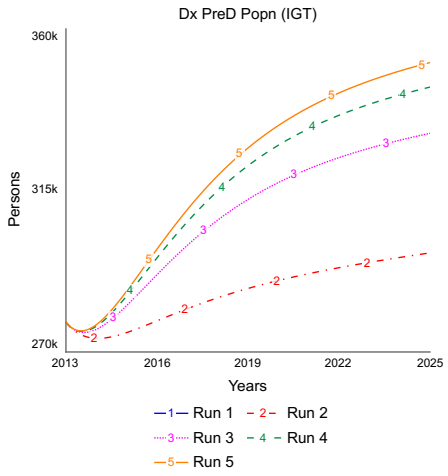


Figure 127 – Time Diabetes onset Undx PreD Patient on Dx PreD Popn (IGT)

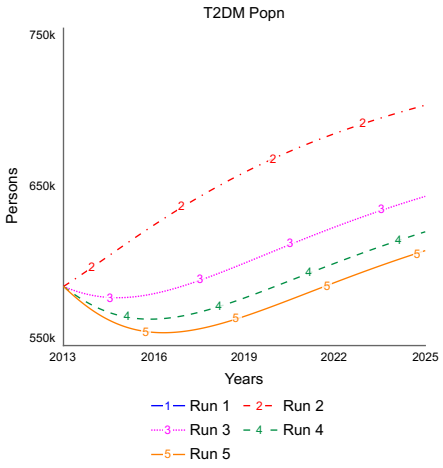


Figure 128 – Time Diabetes onset Undx PreD Patient on T2DM Popn

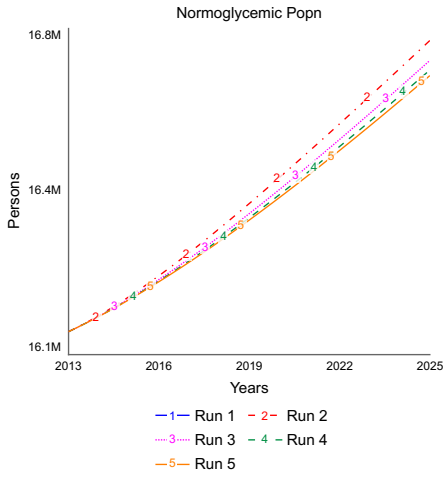


Figure 129 – Time Diabetes onset Dx PreD Patient (IFG) on Normoglycemic Popn

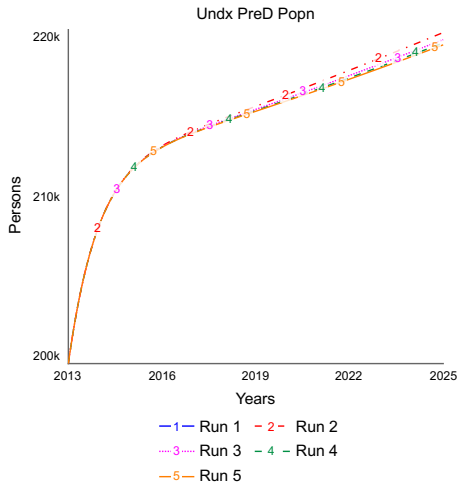


Figure 130 – Time Diabetes onset Dx PreD Patient (IFG) on Undx PreD Popn

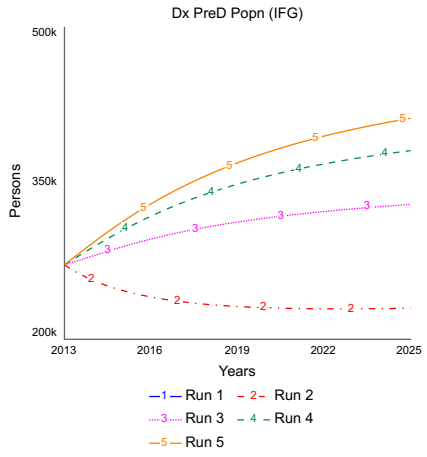


Figure 131 – Time Diabetes onset Dx PreD Patient (IFG) on Dx PreD Popn (IFG)

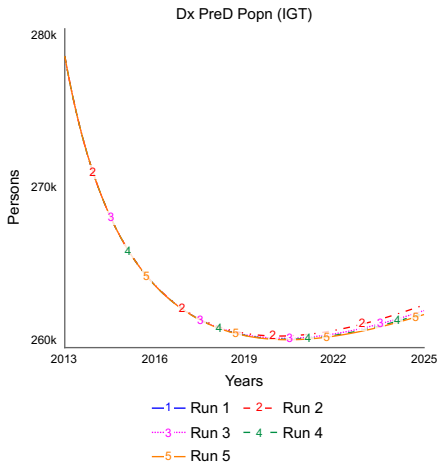


Figure 132 – Time Diabetes onset Dx PreD Patient (IFG) on Dx PreD Popn (IGT)

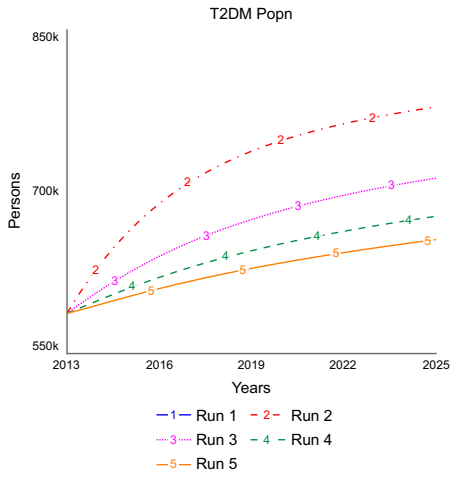


Figure 133 – Time Diabetes onset Dx PreD Patient (IFG) on T2DM Popn

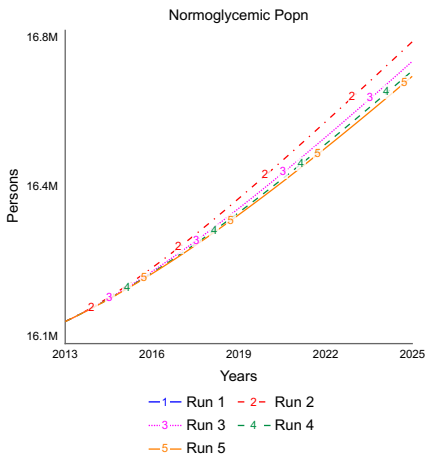


Figure 134 – Time Diabetes onset Dx PreD Patient (IGT) on Normoglycemic Popn

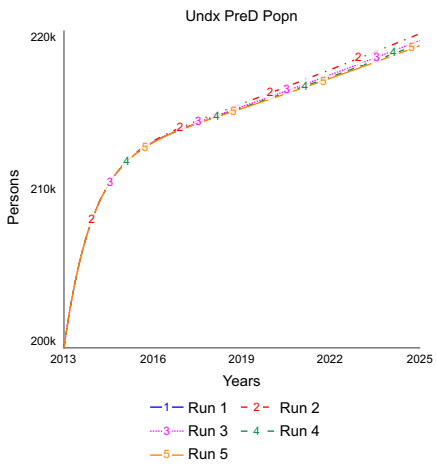


Figure 135 – Time Diabetes onset Dx PreD Patient (IGT) on Undx PreD Popn

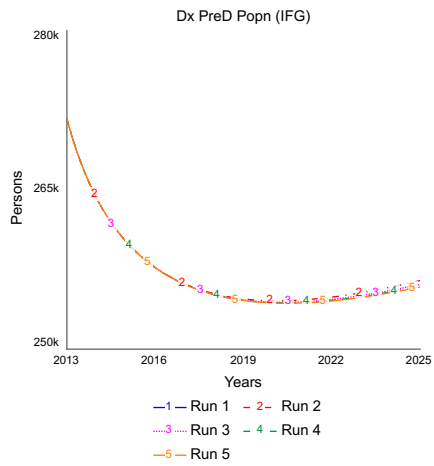


Figure 136 – Time Diabetes onset Dx PreD Patient (IGT) on Dx PreD Popn (IFG

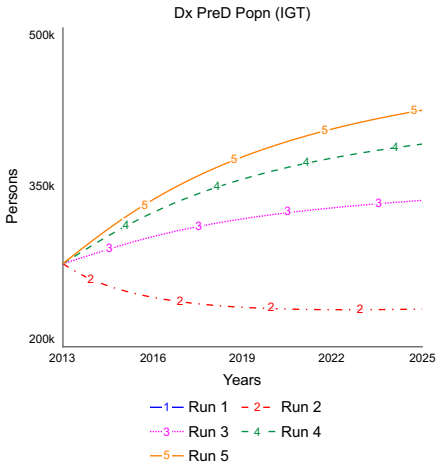


Figure 137 – Time Diabetes onset Dx PreD Patient (IGT) on Dx PreD Popn (IGT)

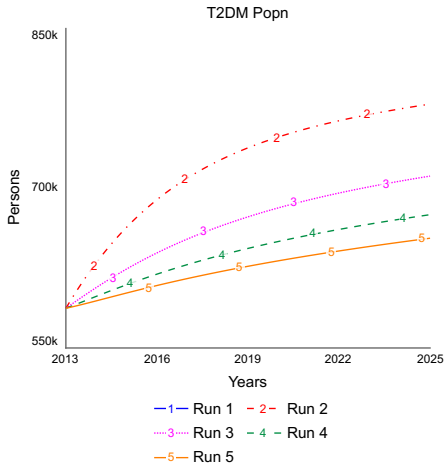


Figure 138 – Time Diabetes onset Dx PreD Patient (IGT) on T2DM Popn

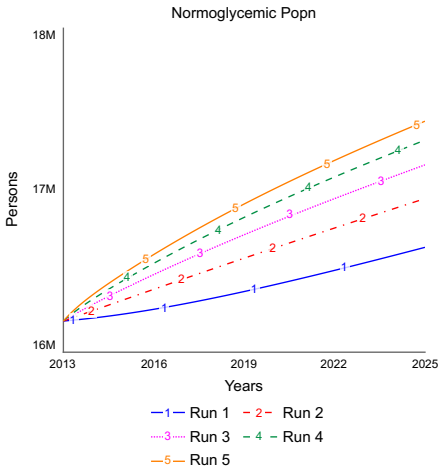


Figure 139 – Normal Recovery Fraction Undx PreD Popn on Normoglycemic Popn

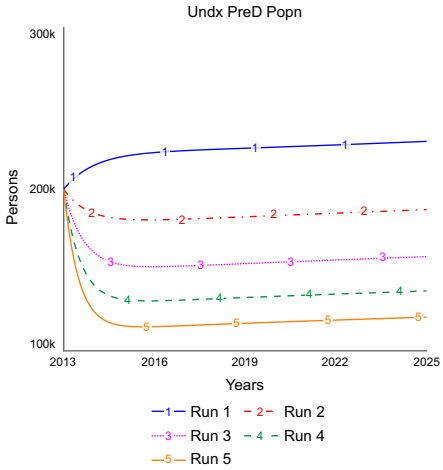


Figure 140 – Normal Recovery Fraction Undx PreD on Undx PreD Popn

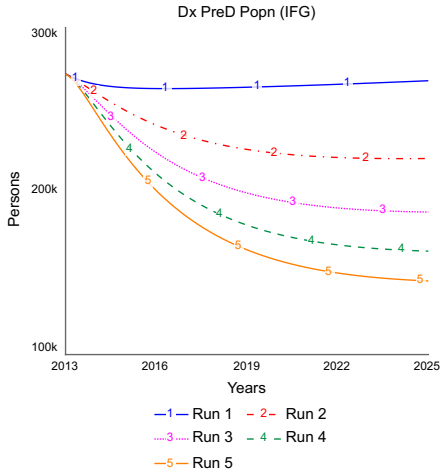


Figure 141 – Normal Recovery Fraction Undx PreD on Dx PreD Popn (IFG)

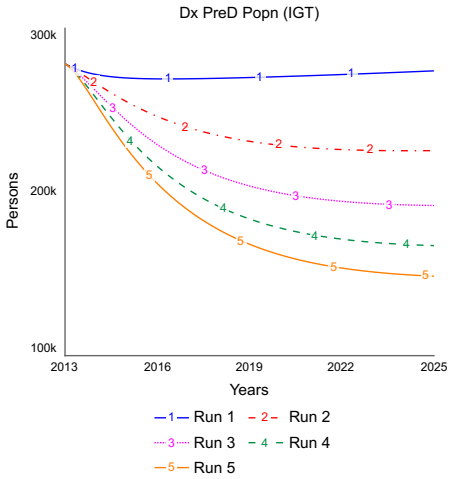


Figure 142 – Normal Recovery Fraction Undx PreD on Dx PreD Popn (IGT)

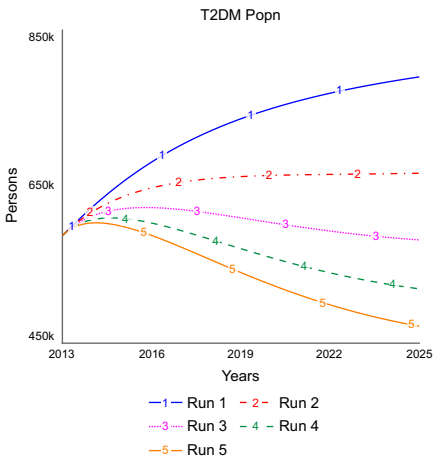


Figure 143 – Normal Recovery Fraction Undx PreD on T2DM Popn

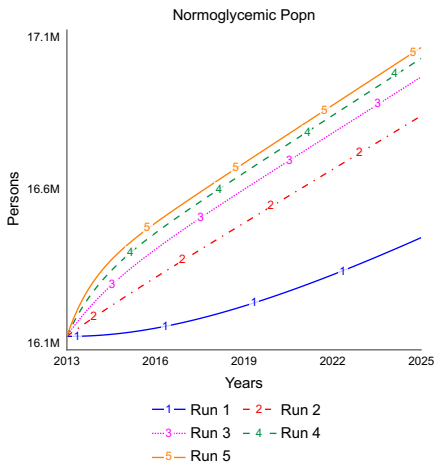


Figure 144 – Normal Recovery Fraction (IFG) on Normoglycemic Popn

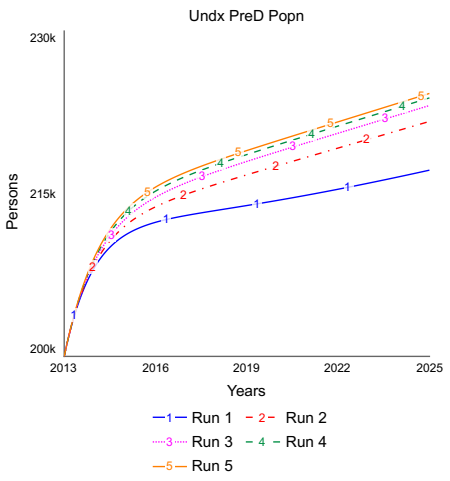


Figure 145 – Normal Recovery Fraction (IFG) on Undx PreD Popn

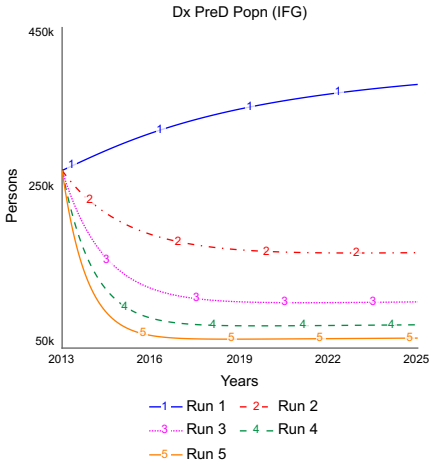


Figure 146 – Normal Recovery Fraction (IFG) on Dx PreD Popn (IFG)

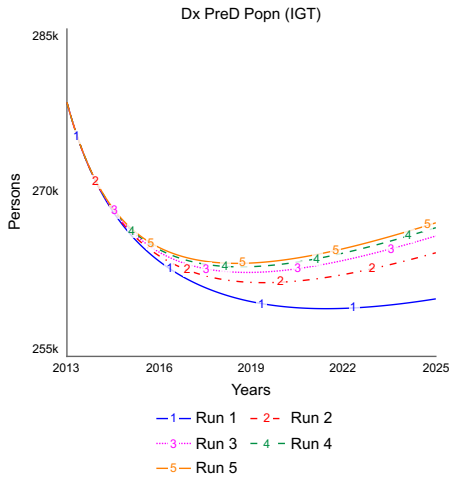


Figure 147 – Normal Recovery Fraction (IFG) on Dx PreD Popn (IGT)

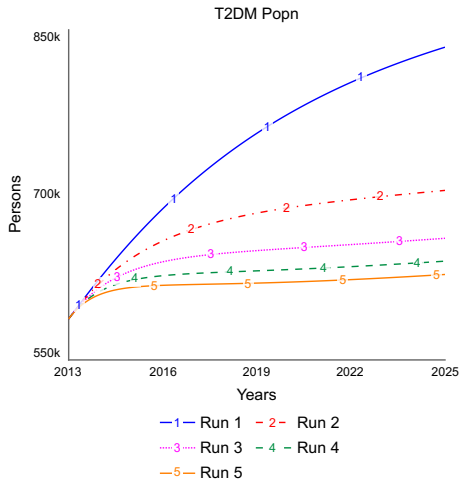


Figure 148 – Normal Recovery Fraction (IFG) on T2DM Popn

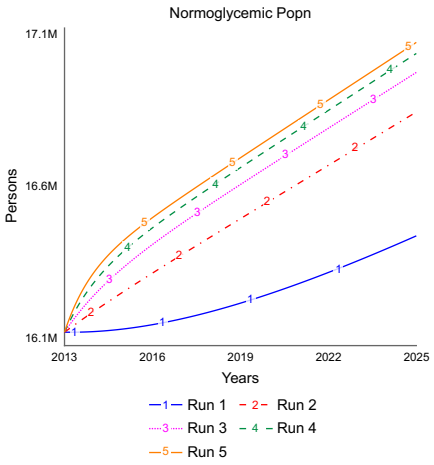


Figure 149 – Normal Recovery Fraction (IGT) on Normoglycemic Popn

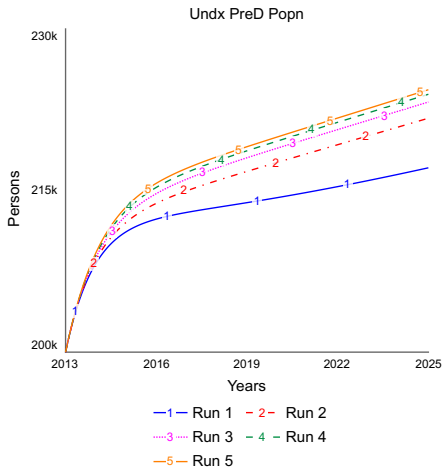


Figure 150 – Normal Recovery Fraction (IGT) on Undx PreD Popn

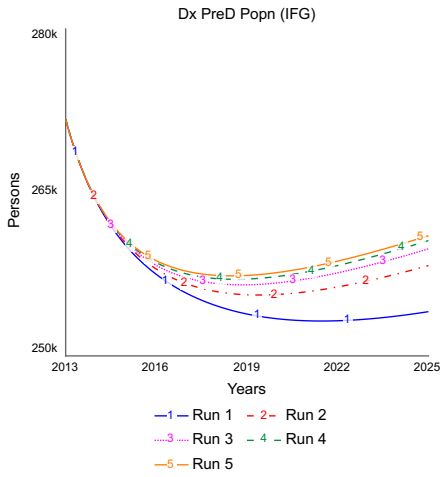


Figure 151 – Normal Recovery Fraction (IGT) on Dx PreD Popn (IFG)

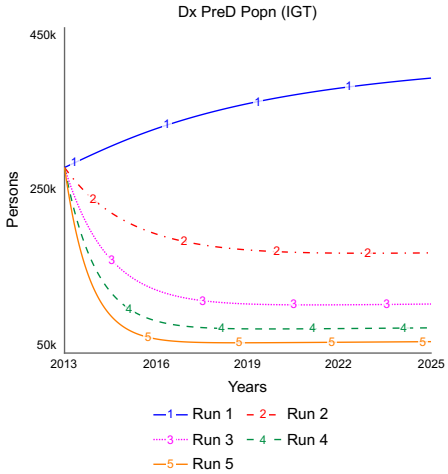


Figure 152 – Normal Recovery Fraction (IGT) on Dx PreD Popn (IGT)

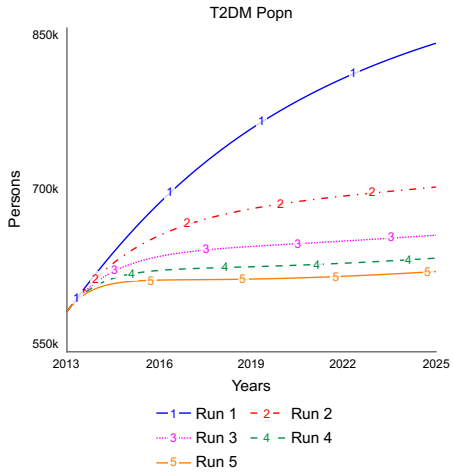


Figure 153 – Normal Recovery Fraction (IGT) on T2DM Popn

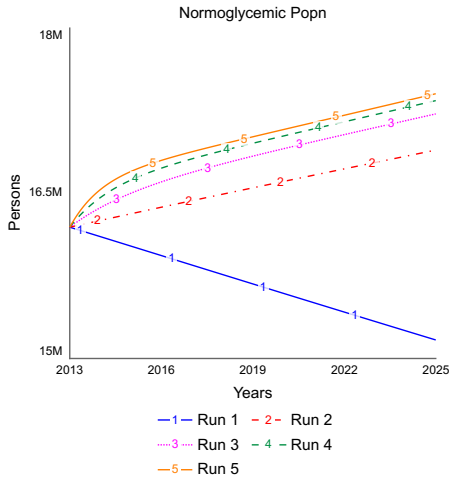


Figure 154 – Normal Recovery Fraction (T2DM) on Normoglycemic Popn

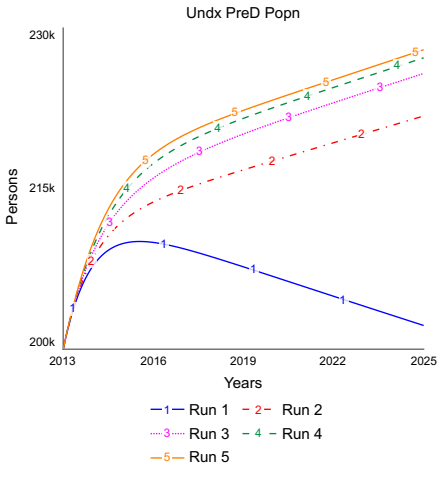


Figure 155 – Normal Recovery Fraction (T2DM) on Undx PreD Popn

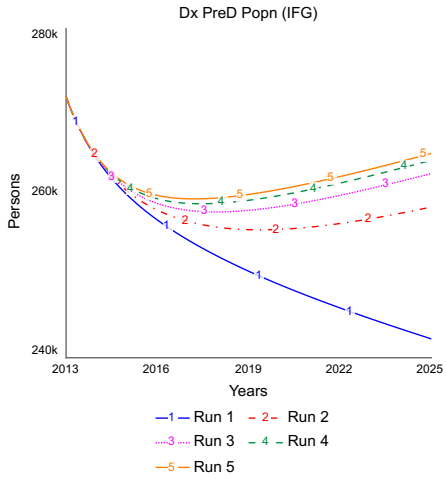


Figure 156 – Normal Recovery Fraction (T2DM) on Dx PreD Popn (IFG)

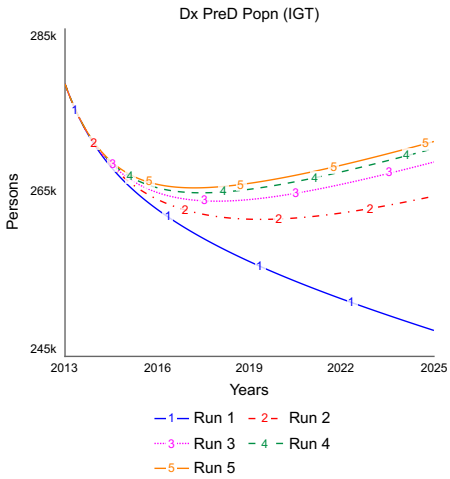


Figure 157 – Normal Recovery Fraction (T2DM) on Dx PreD Popn (IGT)

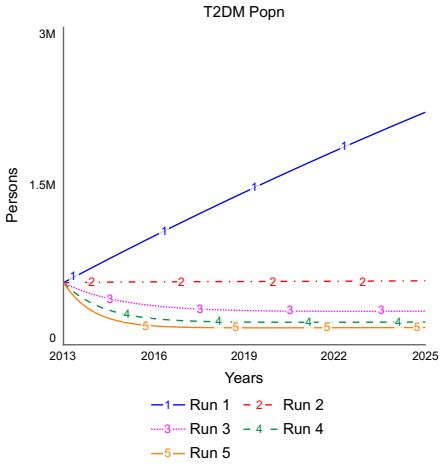


Figure 158 – Normal Recovery Fraction (T2DM) on T2DM Popn

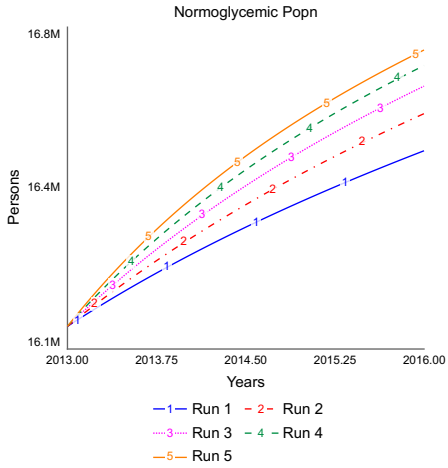


Figure 159 – LaM Success Rate (IFG) on Normoglycemic Popn

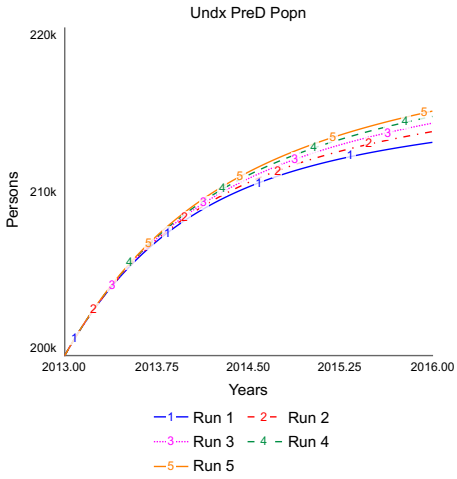


Figure 160 – LaM Success Rate (IFG) on Undx PreD Popn

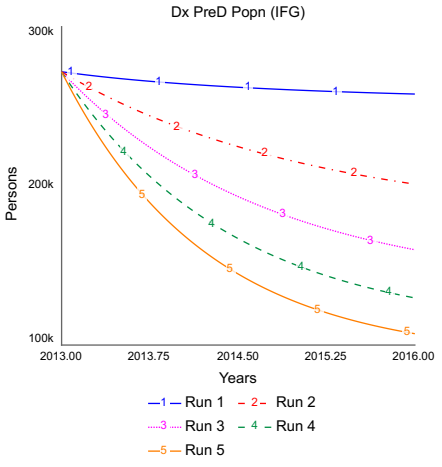


Figure 161 – LaM Success Rate (IFG) on Dx PreD Popn (IFG)

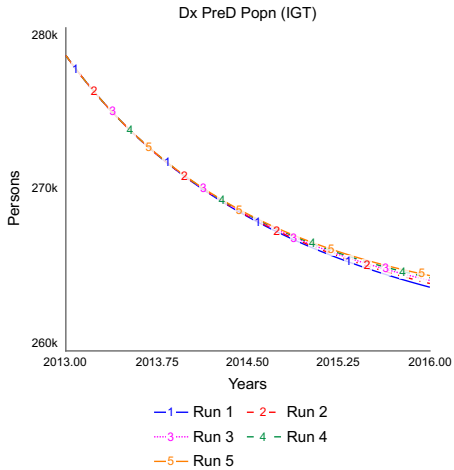


Figure 162 – LaM Success Rate (IFG) on Dx PreD Popn (IGT)

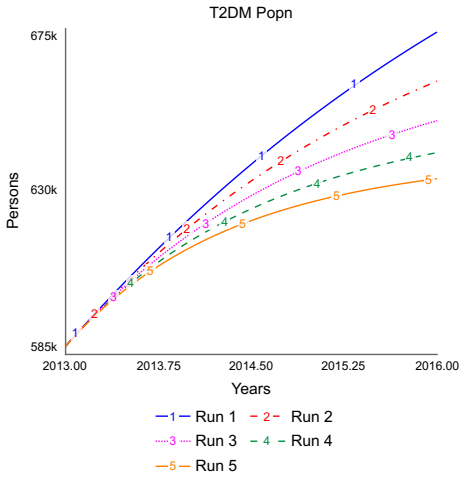


Figure 163 – LaM Success Rate (IFG) on T2DM Popn

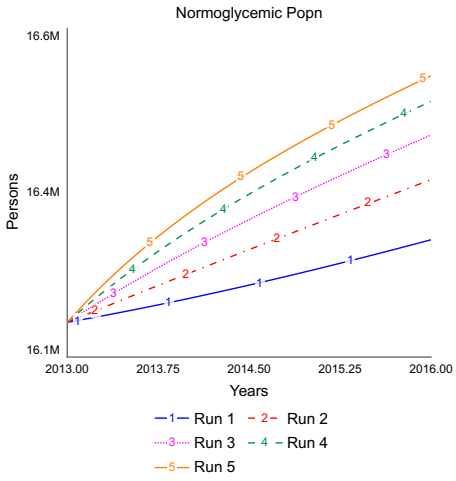


Figure 164 – LaM Success Rate (IGT) on Normoglycemic Popn

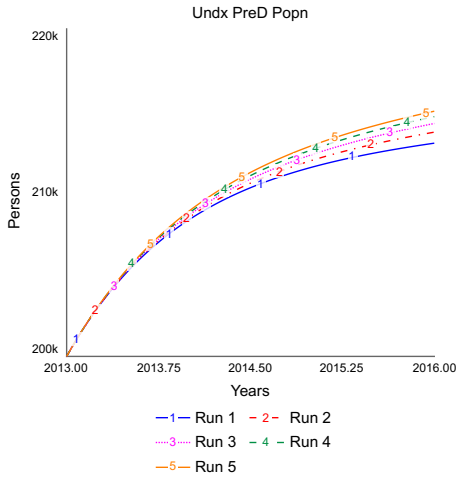


Figure 165 – LaM Success Rate (IGT) on Undx PreD Popn

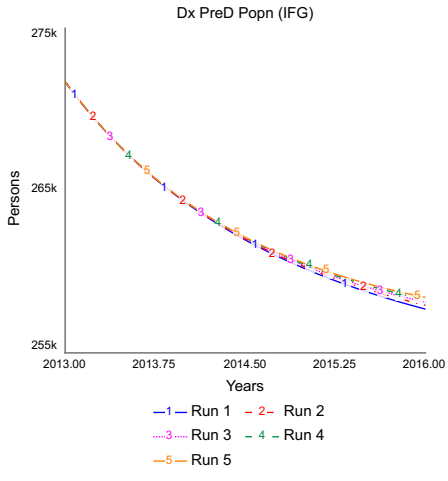


Figure 166 – LaM Success Rate (IGT) on Dx PreD Popn (IFG)

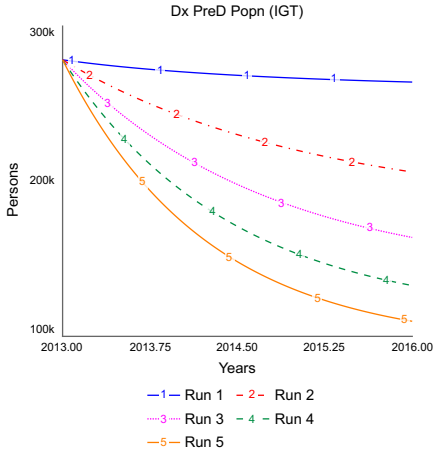


Figure 167 – LaM Success Rate (IGT) on Dx PreD Popn (IGT)

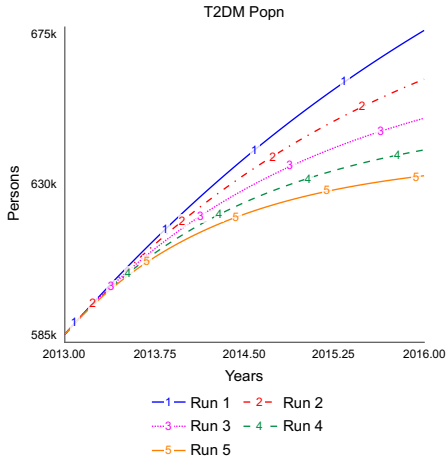


Figure 168 – LaM Success Rate (IGT) on T2DM Popn

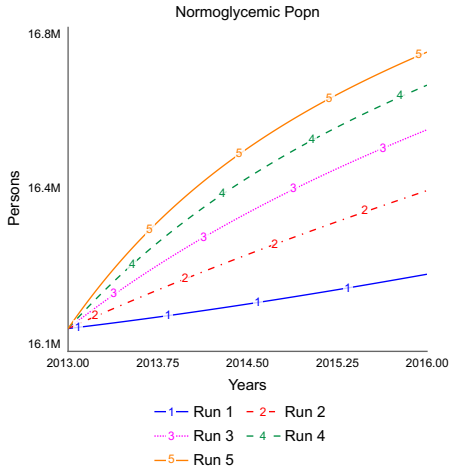


Figure 169 – LaM Success Rate (T2DM) on Normoglycemic Popn

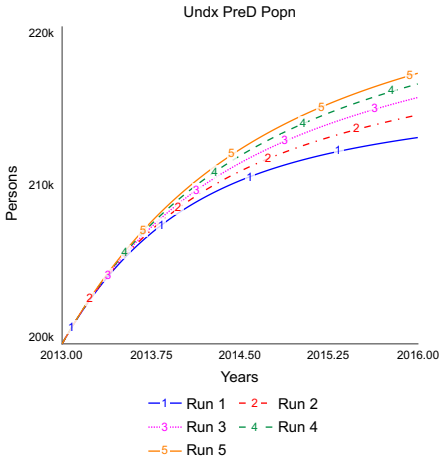


Figure 170 – LaM Success Rate (T2DM) on Undx PreD Popn

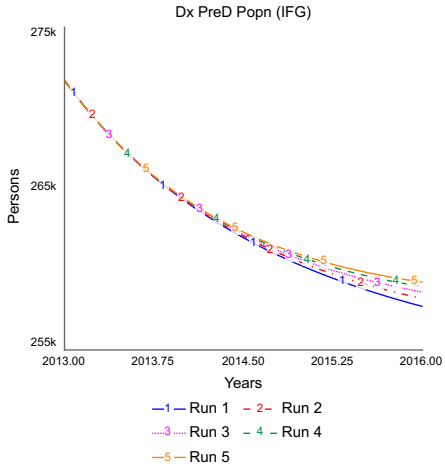


Figure 171 – LaM Success Rate (T2DM) on Dx PreD Popn (IFG)

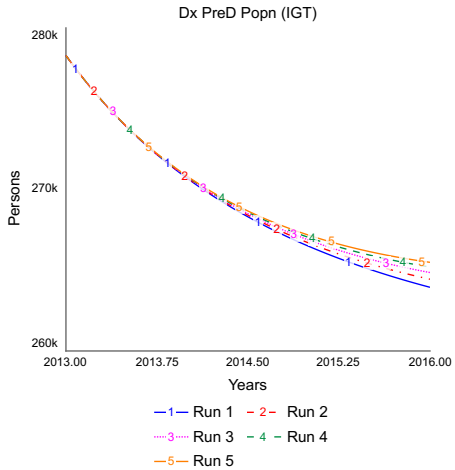


Figure 172 – LaM Success Rate (T2DM) on Dx PreD Popn (IGT)

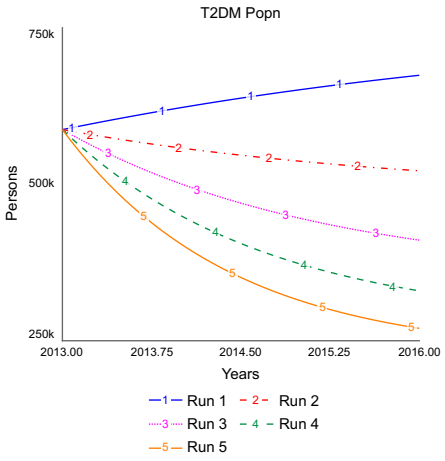


Figure 173 – LaM Success Rate (T2DM) on T2DM Popn

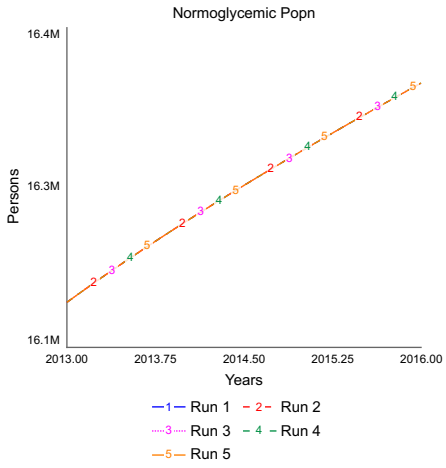


Figure 174 – Time to Recruit (IFG) on Normoglycemic Popn

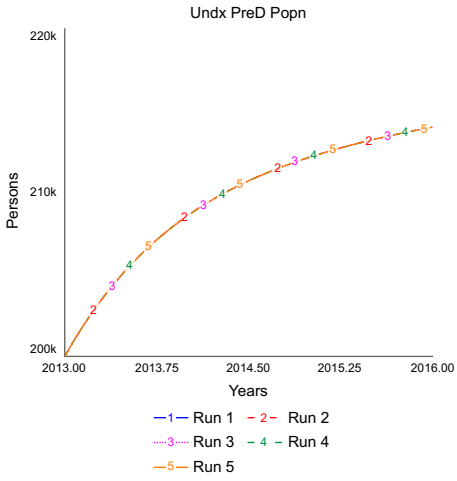


Figure 175 – Time to Recruit (IFG) on Undx PreD Popn

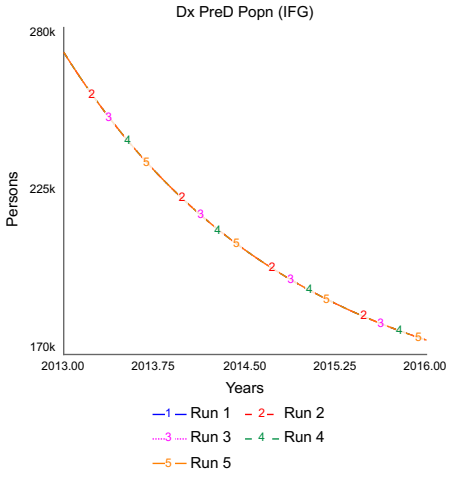


Figure 176 –Time to Recruit (IFG) on Dx PreD Popn (IFG)

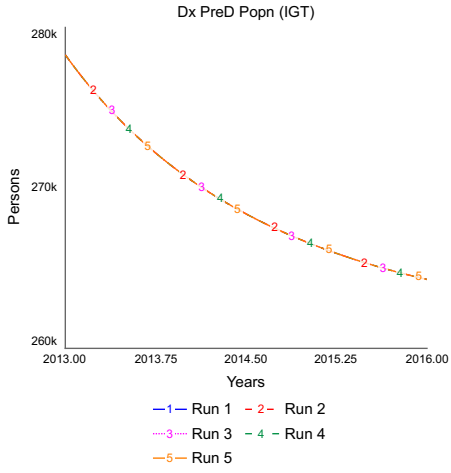


Figure 177 – Time to Recruit (IFG) Dx PreD Popn (IGT)

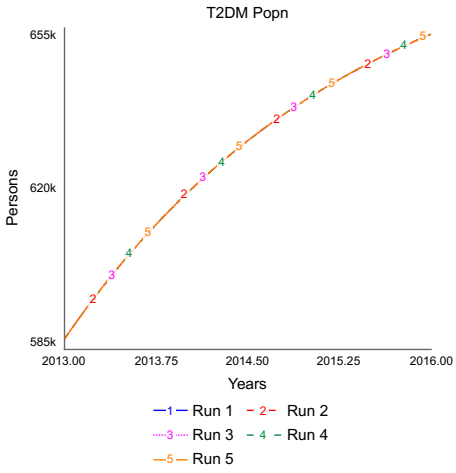


Figure 178 – Time to Recruit (IFG) on T2DM Popn

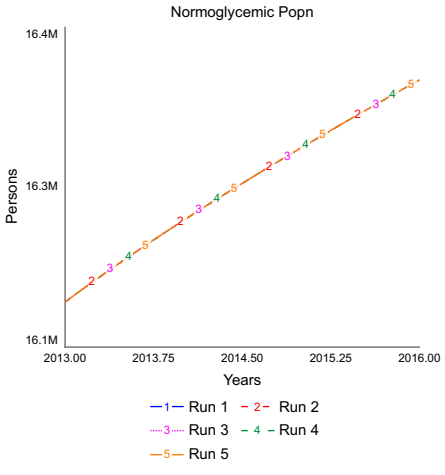


Figure 179 – Time to Recruit (IGT) on Normoglycemic Popn

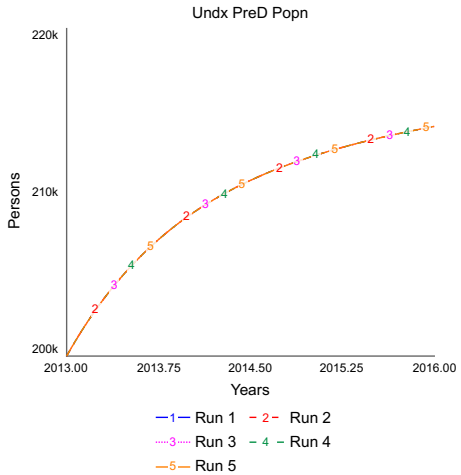


Figure 180 – Time to Recruit (IGT) on Undx PreD Popn

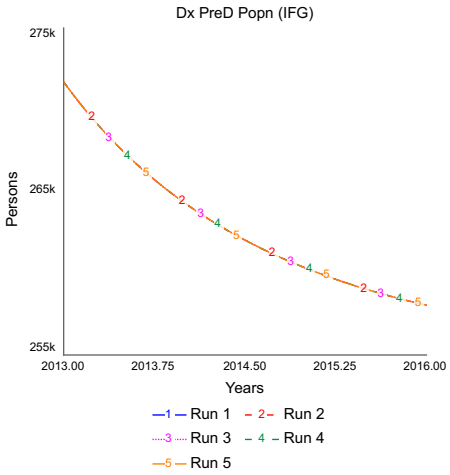


Figure 181 –Time to Recruit (IGT) on Dx PreD Popn (IFG)

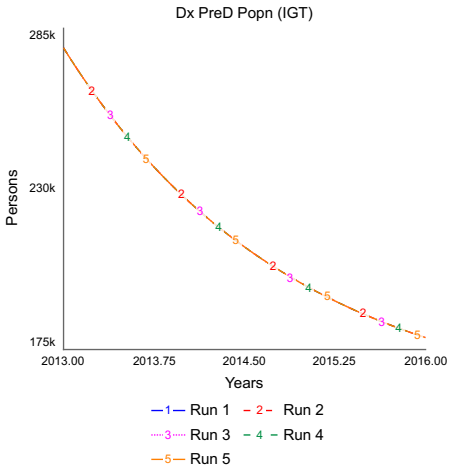


Figure 182 – Time to Recruit (IGT) Dx PreD Popn (IGT)

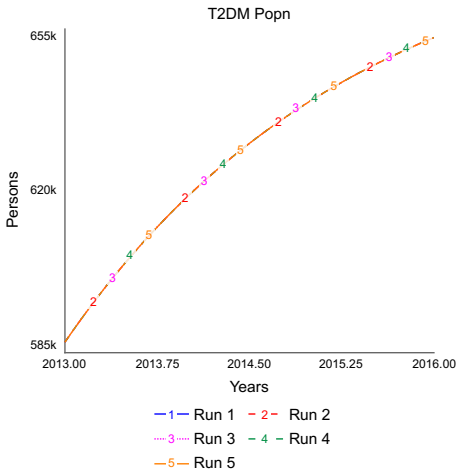


Figure 183 – Time to Recruit (IGT) on T2DM Popn

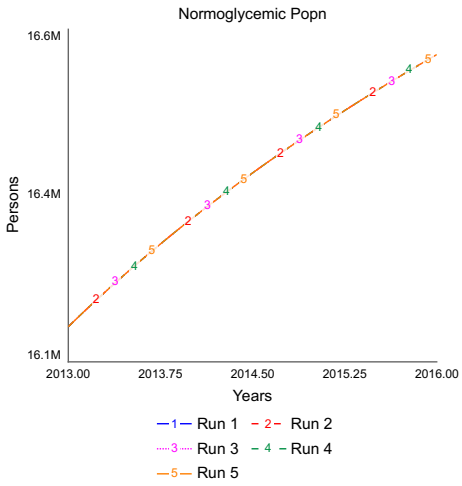


Figure 184 – Time to Recruit (T2DM) on Normoglycemic Popn

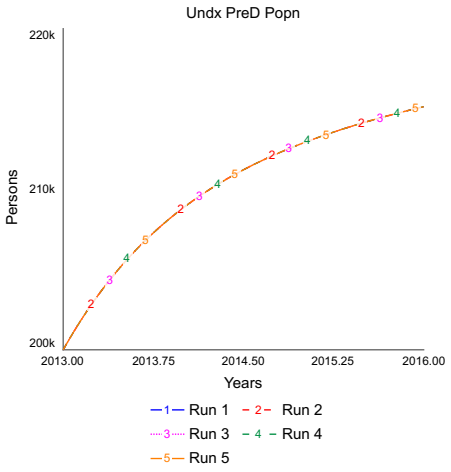


Figure 185 – Time to Recruit (T2DM) on Undx PreD Popn

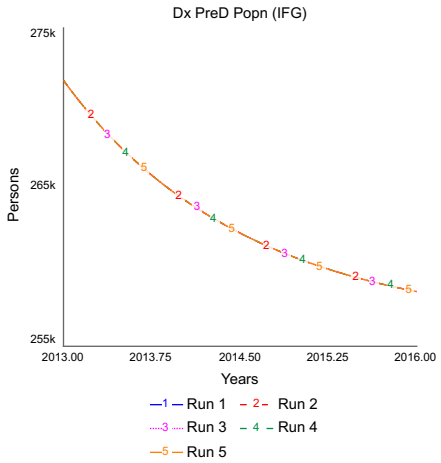


Figure 186 –Time to Recruit (T2DM) on Dx PreD Popn (IFG)

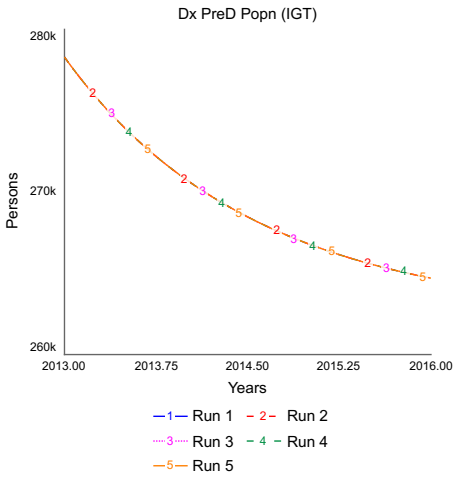


Figure 187 – Time to Recruit (T2DM) Dx PreD Popn (IGT)

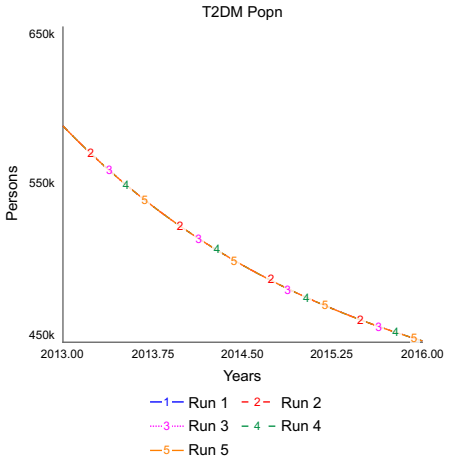


Figure 188 – Time to Recruit (T2DM) on T2DM Popn

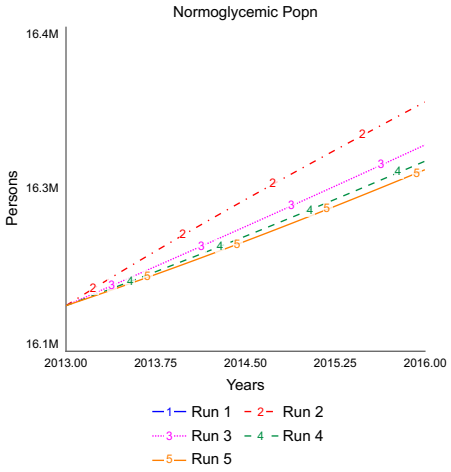


Figure 189 – Treatment Time (IFG) on Normoglycemic Popn

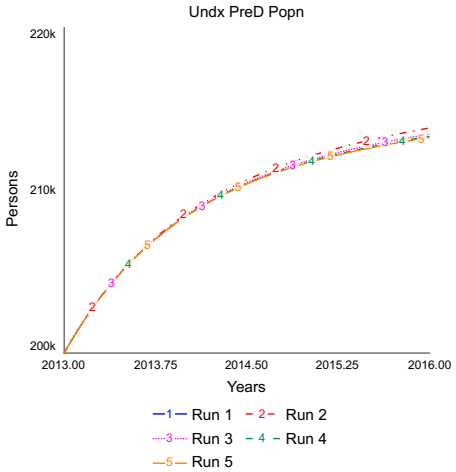


Figure 190 – Treatment Time (IFG) on Undx PreD Popn

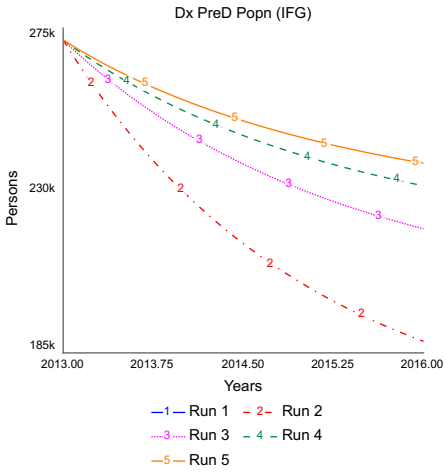


Figure 191 – Treatment Time (IFG) on Dx PreD Popn (IFG)

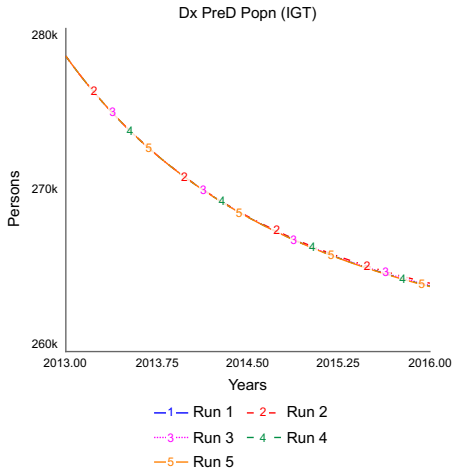


Figure 192 – Treatment Time (IFG) on Dx PreD Popn (IGT)

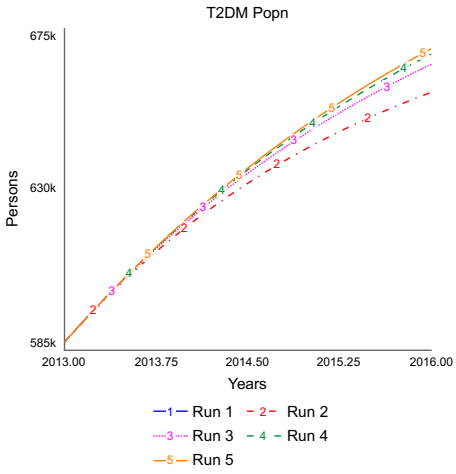


Figure 193 – Treatment Time (IFG) on T2DM Popn

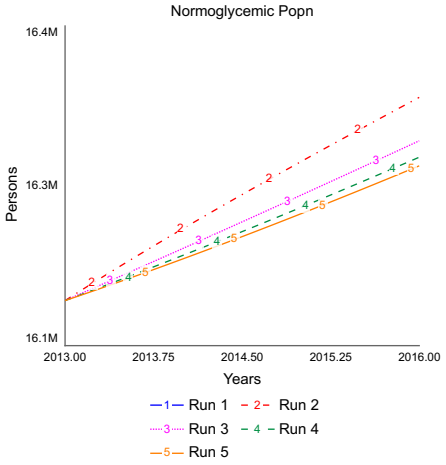


Figure 194 – Treatment Time (IGT) on Normoglycemic Popn

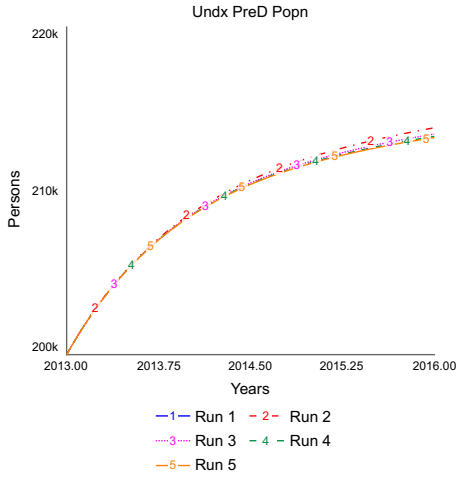


Figure 195 – Treatment Time (IGT) on Undx PreD Popn

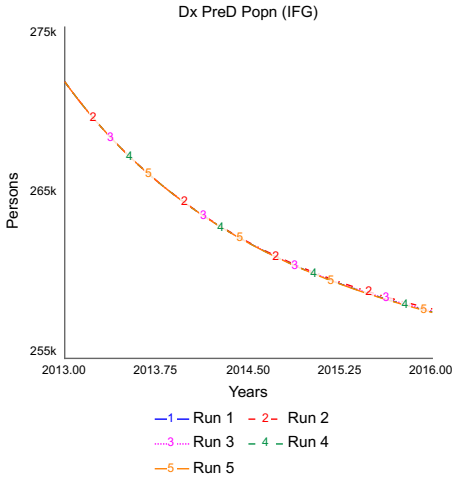


Figure 196 – Treatment Time (IGT) on Dx PreD Popn (IFG)

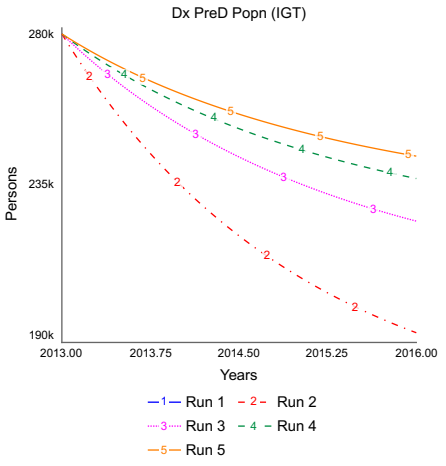


Figure 197 – Treatment Time (IGT) on Dx PreD Popn (IGT)

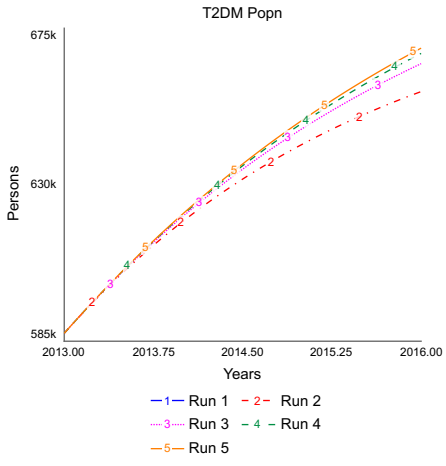


Figure 198 – Treatment Time (IGT) on T2DM Popn

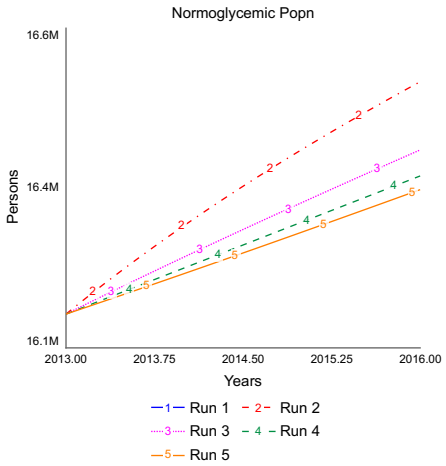


Figure 199 – Treatment Time (T2DM) on Normoglycemic Popn

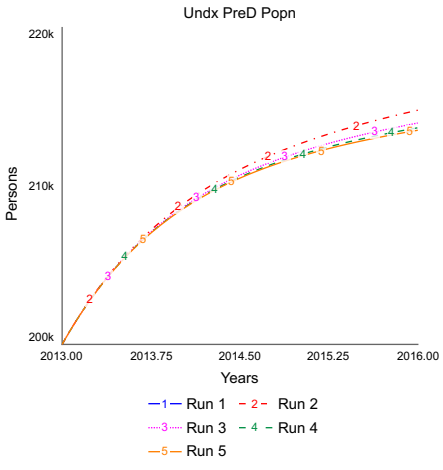


Figure 200 – Treatment Time (T2DM) on Undx PreD Popn

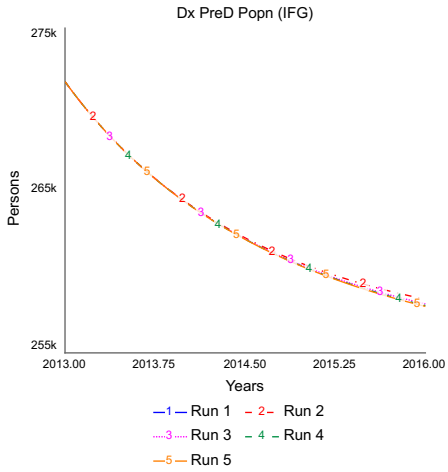


Figure 201 – Treatment Time (T2DM) on Dx PreD Popn (IFG)

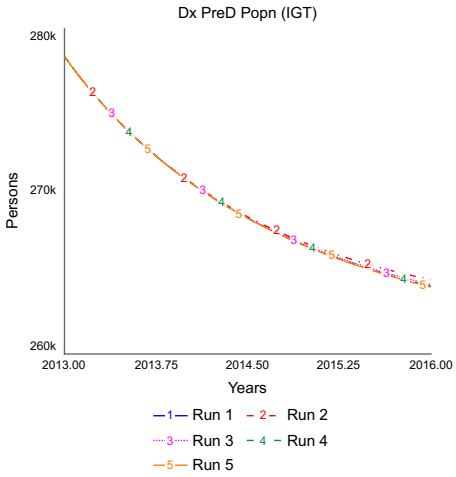


Figure 202 – Treatment Time (T2DM) on Dx PreD Popn (IGT)

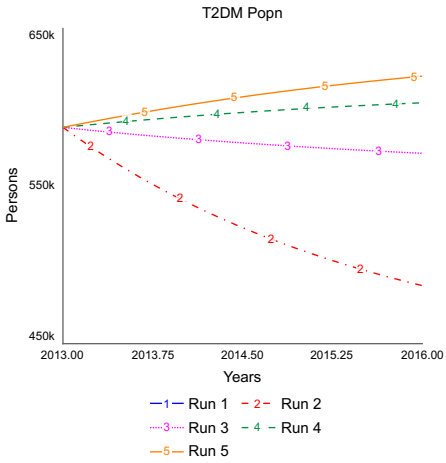


Figure 203 – Treatment Time (T2DM) on T2DM Popn

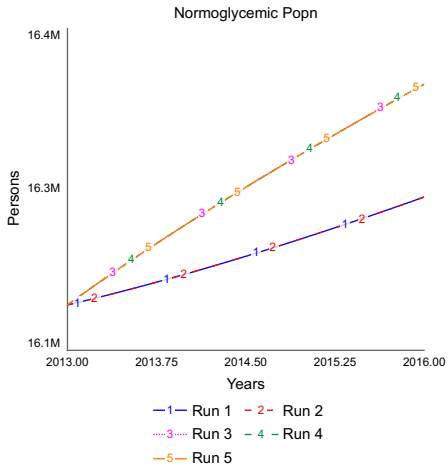


Figure 204 – Budget Stakeholders' Investments (IFG) on Normoglycemic Popn

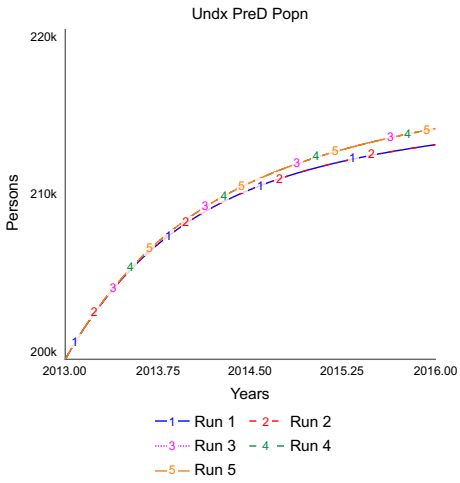


Figure 205 – Budget Stakeholders' Investments (IFG) on Undx PreD Popn

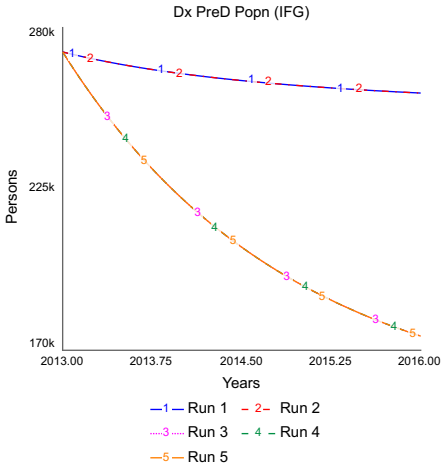


Figure 206 – Budget Stakeholders' Investments (IFG) on Dx PreD Popn (IFG)

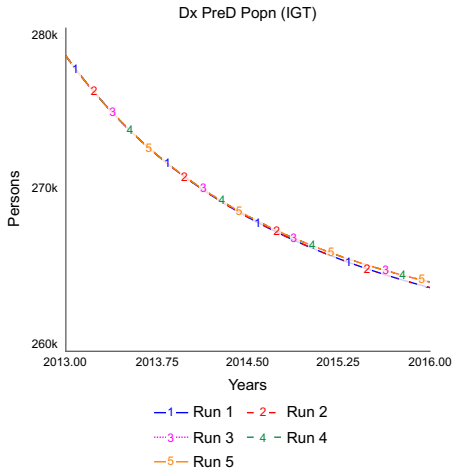


Figure 207 – Budget Stakeholders' Investments (IFG) on Dx PreD Popn (IGT)

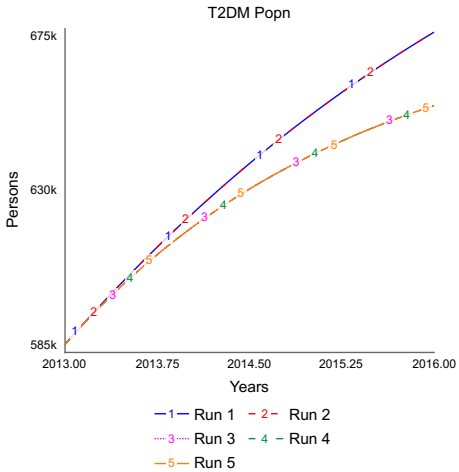


Figure 208 – Budget Stakeholders' Investments (IFG) on T2DM Popn

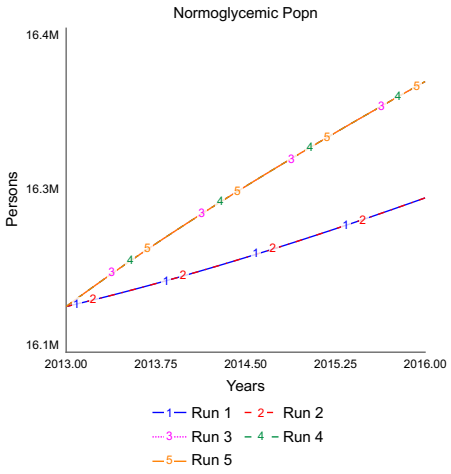


Figure 209 – Budget Stakeholders' Investments (IGT) on Normoglycemic Popn

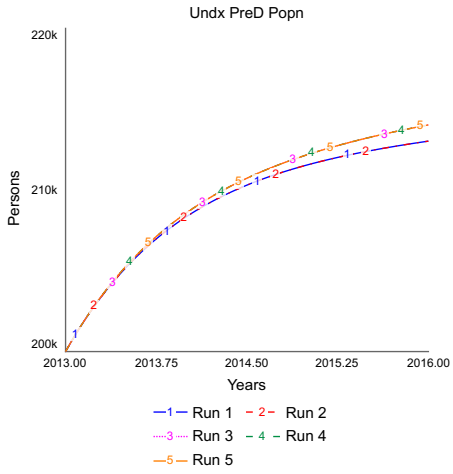


Figure 210 – Budget Stakeholders' Investments (IGT) on Undx PreD Popn

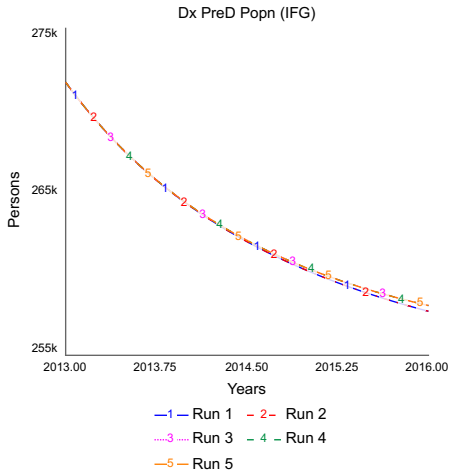


Figure 211 – Budget Stakeholders' Investments (IGT) on Dx PreD Popn (IFG)

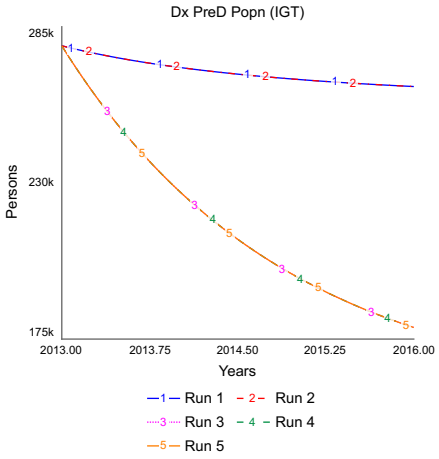


Figure 212 – Budget Stakeholders' Investments (IGT) on Dx PreD Popn (IGT)

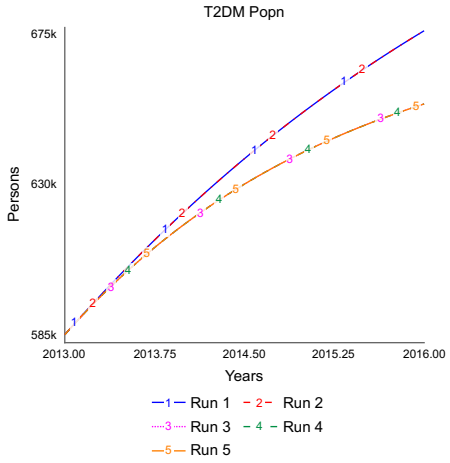


Figure 213 – Budget Stakeholders' Investments (IGT) on T2DM Popn

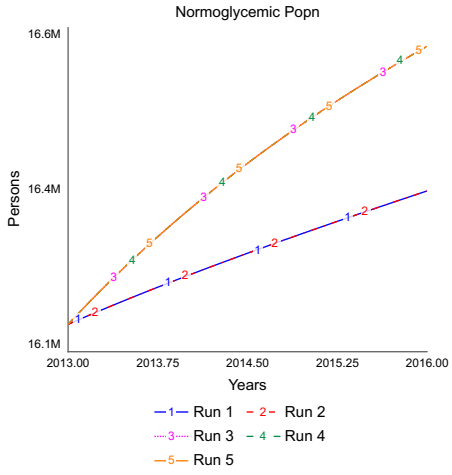


Figure 214 – Budget Stakeholders' Investments (T2DM) on Normoglycemic Popn

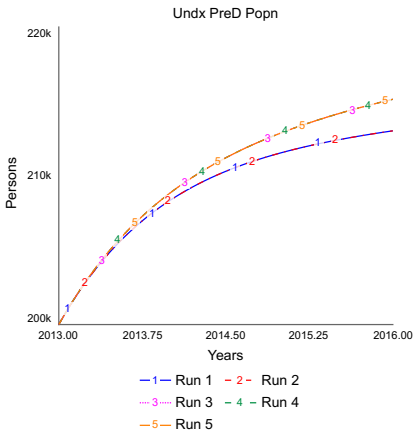


Figure 215 – Budget Stakeholders' Investments (T2DM) on Undx PreD Popn

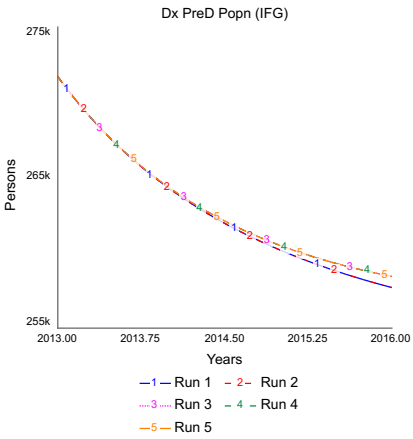


Figure 216 – Budget Stakeholders' Investments (T2DM) on Dx PreD Popn (IFG)

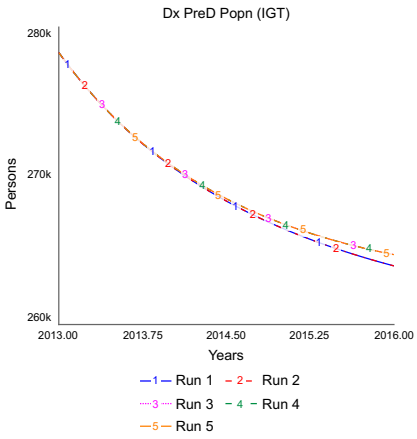


Figure 217 – Budget Stakeholders' Investments (T2DM) on Dx PreD Popn (IGT)

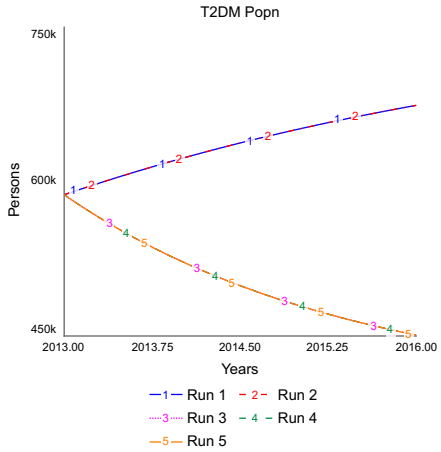


Figure 218 – Budget Stakeholders' Investments (T2DM) on T2DM Popn

Appendix 3.4 – Integration Error Test

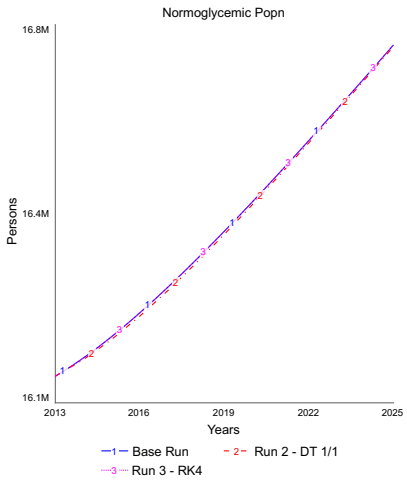


Figure 219 – Integration Error Test; Norm Popn

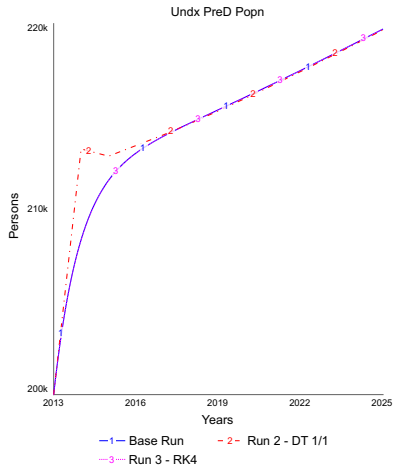


Figure 220 – Integration Error Test; Undx PreD Popn

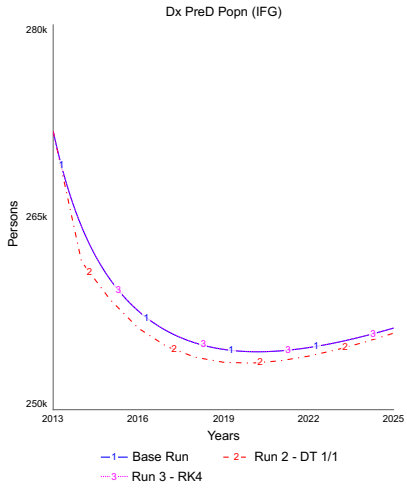


Figure 221 – Integration Error Test; Dx PreD Popn (IFG)

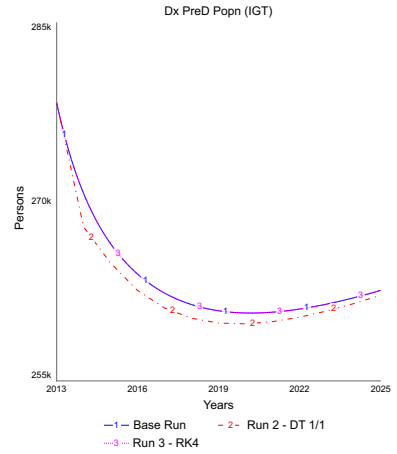


Figure 222 – Integration Error Test; Dx PreD Popn (IGT)

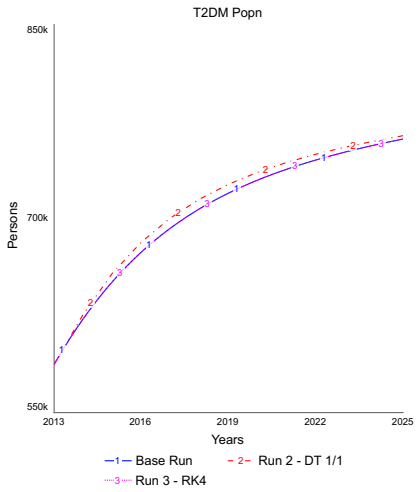


Figure 223 – Integration Error Test; T2DM Popn

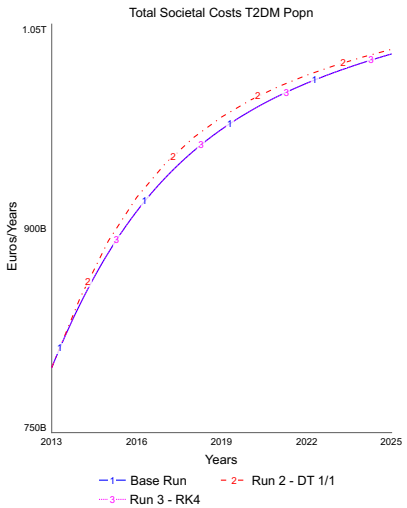


Figure 224 – Integration Error Test; Total Societal Costs T2DM Popn

Appendix 4 – Results

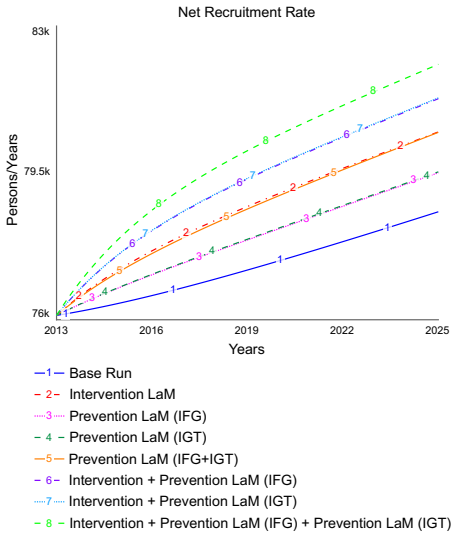


Figure 225 – Development of Net Recruitment Rate

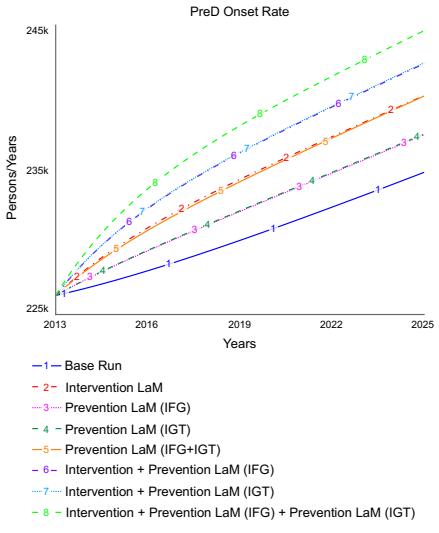


Figure 226 – Prediabetes Onset Rate

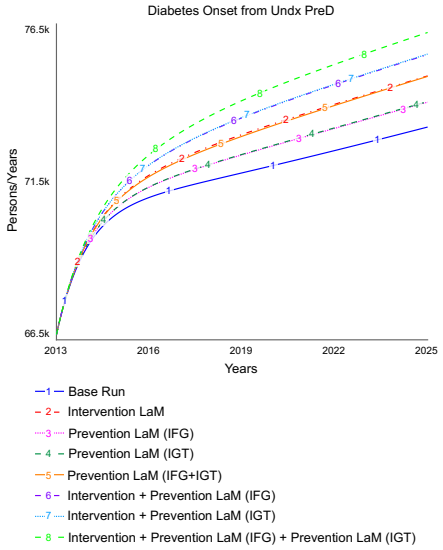


Figure 227 – Diabetes Onset Rate from Undiagnosed Prediabetes

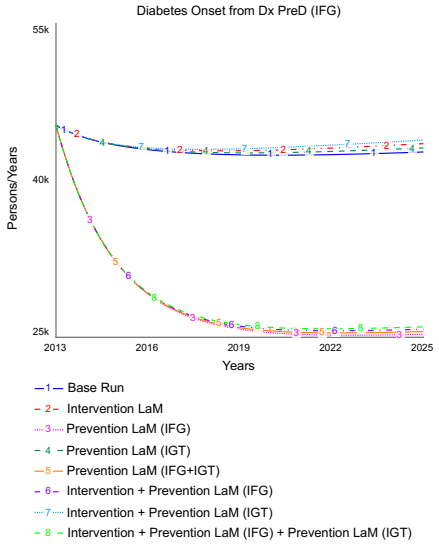


Figure 228 – Diabetes Onset Rate from Diagnosed Prediabetes (IFG)

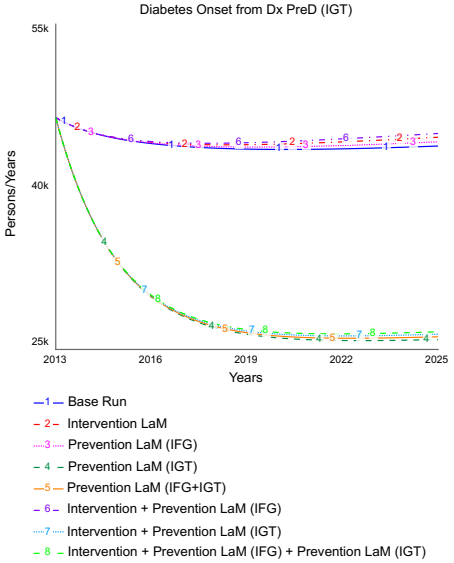


Figure 229 – Diabetes Onset Rate from Diagnosed Prediabetes (IGT)

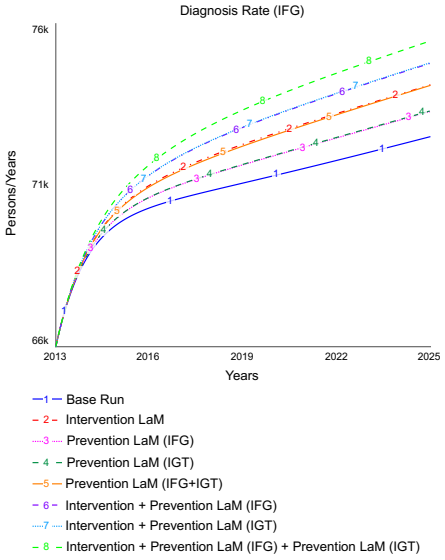


Figure 230 – Diagnosis Rate (IFG)

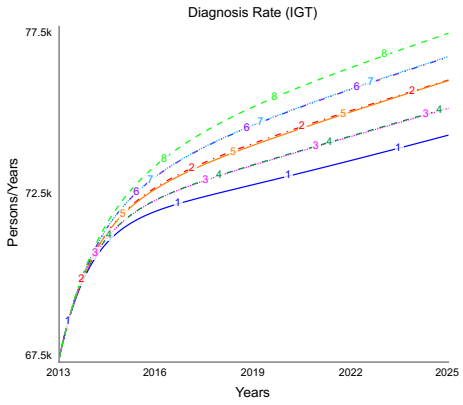


Figure 231 – Diagnosis Rate (IGT)

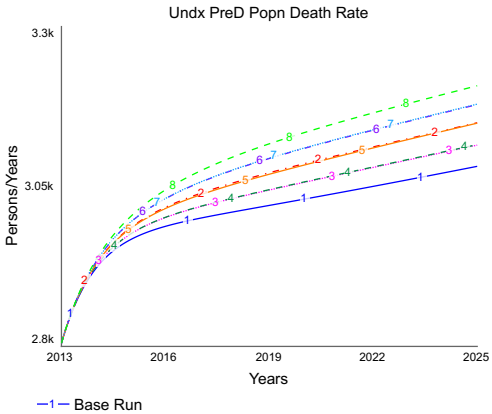


Figure 232 – Death Rate Undiagnosed Prediabetes

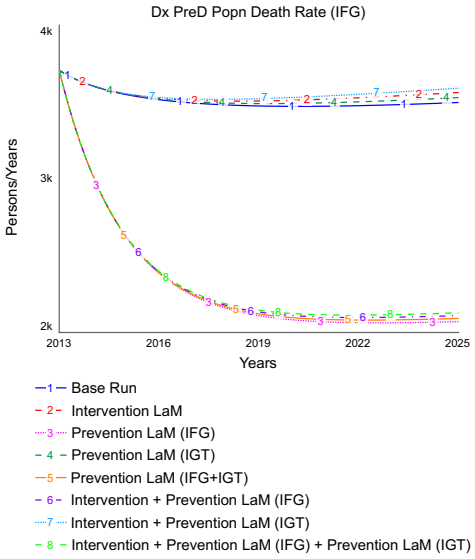


Figure 233 – Death Rate Diagnosed Prediabetes (IFG)

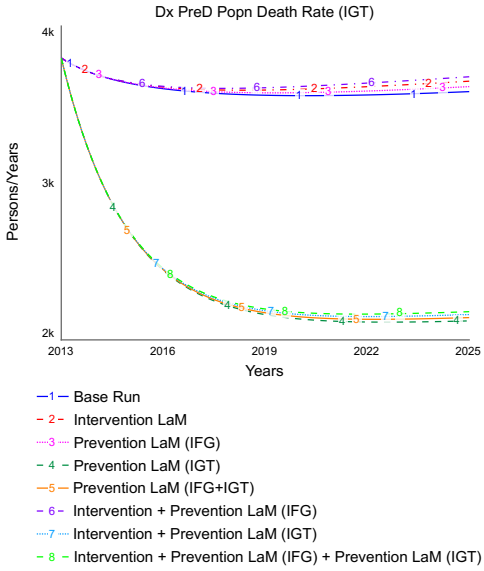


Figure 234 – Death Rate Diagnosed Prediabetes (IGT)

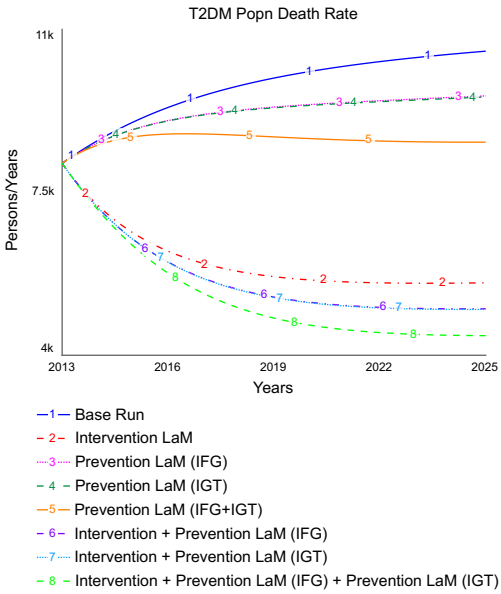


Figure 235 – Death Rate T2DM

Appendix 5 – Interview Guides

Appendix 5.1 – Interview Guide: Expert A

Interviewer: L.V. Lokkers

Expert: Expert A

Achtergrond expert:

Gezondheidswetenschappen aan de universiteit van Maastricht in de richtingen Gezondheidsvoorlichting & Beleid en Beheer. Gepromoveerd aan de universiteit van Maastricht op vraagstukken rond patiëntenlogistiek en organisatie van werkprocessen in ziekenhuizen. Werkzaam bij TNO sinds 2009. Inmiddels werkzaam in de functie van senior consultant bij Work Health Technology (parttime).

Afgenomen op: 13 februari 2017

Verwerkt op: 13 februari 2017

Tijd: 0.45.33 minuten

Voor de start van het interview is er gevraagd voor toestemming om het interview op te nemen en benadrukt dat de data anoniem en vertrouwelijk behandeld zal worden.

Model

De interviewer introduceert zichzelf en haar rol binnen het Complexity program. Vervolgens wordt het basismodel gepresenteerd en uitgelegd. Het model inclusief aantekeningen van de expert staan in Figure 236. De uitleg van het model start bij, beginnend bij de stock met mensen met normale bloedwaarden (*Normoglycemic popn*), die groter wordt doordat mensen geboren worden en kleiner wordt doordat mensen overlijden. Vervolgens krijgen mensen eerste symptomen van diabetes (de flow *PreD onset*). Deze mensen zijn nog ongediagnostiseerd, want ze zijn er dan nog niet mee naar huisarts gegaan en zijn weergegeven met de stock *Undx PreD popn*. Vervolgens hebben deze mensen twee keuzes: men gaat er niet mee naar de huisarts en wordt diabeet (de flow *Diabetes onset from Undx PreD* naar de stock *Diabetes*) of deze mensen gaan wel naar een huisarts en worden gediagnostiseerd (van stock *Undx PreD popn* naar *Dx PreD popn* via de flow *Diagnosis*) en gaan vervolgens ook naar de stock *Diabetes*. De stocks *Undx PreD popn*, *Dx PreD popn* en *Diabetes* worden kleiner doordat mensen overlijden.

Vervolgens wordt uitgelegd dat (de flow *Recovery from Undx PreD* of de flow *Recovery from Dx PreD*) staat voor het omkeren van mensen met diabetes type 2 dat zij weer normale bloedwaarden krijgen met als resultaat dat zij weer gezond worden en dus weer

instromen in de stock *Normoglycemic popn* en dat de vraag is wat werkt wel en wat werkt niet in de praktijk.

Levensstijl als Medicijn

De expert bevestigt bovenstaande en voegt eraan toe dat dat Levensstijl als Medicijn (LaM) een flow terug is naar de stock *Normoglycemic popn* vanuit de stock *Diabetes*. De expert geeft aan dat zij met name betrokken is bij hoe iemand van prediabetes kan herstellen naar gezond zijn, maar ook hoe iemand van diabetes type 2 kan herstellen naar gezond zijn. Dit programma heet Levensstijl als Medicijn. Verder geeft de expert aan dat zij zien dat die lijn van *Diabetes* naar *Normoglycemic popn* heel belangrijk is: wat kost het traditionele proces voor de maatschappij en wat levert het op als je mensen laat terugkeren naar andere fasen in het model. Het doel van het programma: (pre)diabeten omkeren naar normale glucosehuishouding. Conclusie: in de basis is het schema zoals gepresenteerd het traject van diabetes type II patiënten.

Interviewer geeft toe dat deze data bekeken is, maar dat het opgevallen is dat deze interventies vooral op medicijnen zijn gericht en de kosten van de medicijnen. Dit onderzoek wil zich meer richten op prediabetes en de recovery daarvan, terwijl LaM gericht is op de populatie diabetes en niet op prediabetes. De interviewer legt uit dat er een plan ligt om te gaan kijken waar zorg preventief ingezet kan worden en dus al voordat er kosten worden gemaakt. Aldus de expert wordt er niet alleen maar gekeken naar medicijnen, maar ook naar de medische kosten en dat zijn de kosten die gemaakt worden bij de eerste en tweede lijn zorg, dat onder de noemer integrale zorg valt.

Health Impact Bond

De expert geeft aan dat daar onderzoek wordt gedaan naar diabetes buiten de gezondheidszorg, dus bijvoorbeeld ook de WMO.

Zorgverzekeringswet (ZVW)

De expert geeft aan dat mensen met de diagnose diabetes onder deze wet vallen. Vanuit deze wet is er een integraal keten DBC-diabetes en een integraal zorgprogramma. Het nut en de noodzaak worden uitgelicht in het proefschrift van Arienne Elissen. Ook wordt hierin uitgelicht, dat men eigenlijk zou moeten differentiëren tussen verschillende personen. Bijvoorbeeld wanneer ga je als patiënt over naar de volgende fase en wanneer maak je bepaalde

kosten. Nu hangt daar een prijskaartje aan en wordt het door een zorggroep ingekocht, die dan ook de verantwoordelijkheid hebben voor het zorgprogramma diabetes. In de praktijk betekent dat dat de patiënt een heel groot deel van deze zorg via de huisarts ontvangt (eerste lijn) en sommige patiënten zijn dusdanig ingewikkeld ziek dat ze worden bijgestaan door een specialist (tweede lijn).

Zorgstandaard

De interviewer legt vervolgens uit dat integrale zorg wordt verleend op de flow *Diabetes onset from Dx PreD*. De expert uit twijfels bij die plaats in het model. Aldus de expert wordt er heel weinig gedaan aan de diagnostiek van prediabetes. Wanneer mensen met klachten bij de dokter komen en de diagnose van diabetes krijgen dan belanden ze al snel in de stock *Diabetes*. Eigenlijk gaat iedereen van ongediagnostiseerde prediabeet direct naar diabeet, dus via de flow *Diabetes onset from Undx PreD*. De expert voegt hieraan toe dat er ook alleen een zorgstandaard diabeet is ontwikkeld en geen zorgstandaard prediabeet.

De expert draagt het Nederlandse Huisartsen Genootschap (NHG) aan als tip om na te kijken of zij een standaard hebben voor prediabetes. Er bestaat al een richtlijn voor diabetes vanuit het NHG. Zij maken alle behandelrichtlijnen voor een huisartsenpraktijk. Hier kan informatie gevonden worden over de zorgstandaard en het zorgprogramma is dan een bepaalde invulling daarvan.

Het ontbreken van de richtlijn is de reden voor LaM. Nu is de houding: "… dan kijken we er even naar." en dat is aldus TNO te weinig. Mensen krijgen dan drie maanden de tijd om hun glucose onder controle te krijgen. TNO zegt dat dat niet goed is want mensen kunnen met diabetes ook echt genezen, net als dat je met prediabetes kunt genezen, door een andere levensstijl. De interviewer vraagt bevestiging of de expert hiermee aangeeft dat deze zorg dus bij de flow *Diabetes onset from Undx PreD* zit. De expert bevestigt dit.

Effectiviteit

De expert geeft aan dat er niet veel bekend is over de effectiviteit van de verschillende componenten binnen de integrale zorg. Er is wel veel bekend over de kosteneffectiviteit van de zorgstandaard, het keten DBC en dat er gesproken is over modulaire zorg; dat er verschillende modules zijn en daarom meer persoonsgerichte zorg. Aldus TNO is zorg op maat heel belangrijk, omdat dat effectiever werkt.

LaM

Bekijkt wat een levensstijlprogramma ongeveer kost en wat het kost om het te onderhouden in de komende 20 jaar. Dit zijn gemiddelden en er zitten heel veel nuanceringen in, maar het geeft wel een overzicht van wat een diëtist, een beweegprogramma etc. kost. LaM is opgezet dat een populatie met bepaalde kenmerken een bepaald prijskaartje krijgt.

Populatie: Prediabeten en Diabeten

De interviewer kaart aan dat bovengenoemde informatie vooral betrekking heeft op de populatie die al diabetes heeft en vraagt of de expert ook bekend is met de integrale zorg die aan preventie doet. Aldus de expert wordt dat heel weinig gedaan, omdat Nederland een ziekte-economie zijn. Wij betalen voor ziekte en de ZVW koopt in voor alle ziektes waar een diagnose aan vast zit. Dat betekent dus dat er met name wordt gefocust op mensen die al ziek zijn, omdat daar een potje voor bestaat waaruit zorg betaald kan worden. Dit is ook een reden voor LaM; omdat de politiek op die manier is opgebouwd (potjes per ziekte). Conclusie: ziekte-geïndiceerde preventie is makkelijker, omdat er een potje is waaruit het betaald kan worden.

Verder vraagt de interviewer of bij LaM ook componenten preventief kunnen worden ingezet. Aldus de expert wel en dan gaat het om voeding, beweging, stress, slaap, etc.

Omgeving 1

De expert noemt Albert Heijn (en Jumbo) als belangrijke speler met betrekking tot personalized nutrition; voedingsadvies op maat om uiteindelijk ervoor te zorgen dat mensen gezonde voeding tot zich nemen. Hier is op dit moment geen onderscheid gemaakt tussen zieke en niet-zieke mensen. Verder geeft de expert aan dat levensstijl ingezet kan worden bij werkenden: levensstijl inzetten om niet ziek te worden en dus niet uit te vallen. Echter, beide is nu niet specifiek gefocust op diabetes.

Verder geeft de expert aan dat voor de beginfase aan alles een huisarts gelinkt moet zijn, omdat anders mensen het niet vertrouwen/geloven en dan zit je toch weer aan de niet preventieve kant.

De interviewer vraagt bevestiging of de Albert Heijn en Jumbo zoals gepresenteerd invloed uitoefenen op beide recovery flows (*Recovery from Undx PreD* en *Recovery from Dx PreD*). Dit wordt beaamd door de expert.

De interviewer vraagt ook specifiek naar andere bedrijven of instanties die invloed hebben op dit soort dingen. De expert start met het uitleggen van de obesogene samenleving

of -omgeving. De huidige samenleving is dusdanig ingericht dat het niet uitnodigt tot bewegen, er zijn bijvoorbeeld overal liften of te weinig fietspaden. De expert noemt hier de rol van de gemeente, naast de rol van de supermarkten en fastfoodketens, zoals McDonalds. Verder geeft de expert aan dat ook de financiële prikkel hier een rol speelt. Er is geen financiële prikkel voor dit, maar wel een financiële prikkel om medicatie uit te schrijven. Met andere woorden: de financiële prikkels werken ook niet mee. Conclusie: "Er zijn veel facetten aan het probleem die ervoor zorgen dat we wel veel aan die diabetes betalen nu, maar dat we het dus heel ingewikkeld vinden om erin te investeren in het omkeren ervan". Dit is vooral de farmaceutische- en voedingsindustrie. Zij verdienen veel geld aan het uitgeven ervan. Ook liggen in de supermarkt de ongezondere producten op ooghoogte bijvoorbeeld. De lobby is zo groot, dat deze mee omgekeerd moeten worden wil het effectief zijn. Daarnaast werkt geld mee omdat je moet laten zien wat het brengt en daarom zijn dit soort modellen heel belangrijk.

Patiënt zelf

De interviewer vraagt naar de invloed van sociale kenmerken (bijvoorbeeld inkomen en opleiding). De expert legt uit dat mensen met een lage economische status (laagopgeleid en laag inkomen) meer risico lopen op het ontwikkelen van diabetes en dat het ook vaak moeilijker is om het om te keren. De expert geeft aan dat in het algemeen gedragsverandering heel lastig is. Daarnaast geeft de expert aan dat diabetes ook een welvaartsziekte is, maar daar vertelt de expert wel bij dat hoe meer geld en kennis iemand heeft, hoe groter het vermogen is om gezonde producten te bereiden, te bewegen en het in je omgeving meer een onderwerp is; dus de sociale context stimuleert daarbij.

Omgeving 2

De expert geeft aan het belangrijk te vinden om te noemen dat de Nederlandse dokters opgeleid worden om medicijnen voor te schrijven en dat zij dus nog steeds opgeleid moeten worden om te genezen zonder medicijnen. Daarnaast is de maatschappij ingesteld dat als iemand ziek is, er voor je gezorgd wordt en dat je dus niet leert zelfstandig zorg te dragen; wij betalen bijvoorbeeld premie en daar verwachten wij zorg voor terug. Men leert niet zelf regie te nemen voor gezond zijn en ziek zijn; zodra iemand ziek wordt, wordt diegene patiënt en dan wordt er voor hem of haar gezorgd. Terwijl als mensen weten dat ze daar meer zelf kunnen doen, dit al in de kosten scheelt. De interviewer vraagt of dit dus ook een soort bewustwordingsproces is. De expert beaamt dit en noemt dat dit ook te maken heeft met cultuur. De interviewer vraagt

of er dan bijvoorbeeld een verschil zit tussen de westerse en oosterse cultuur. Hierop antwoordt de expert dat daar geen verschil tussen zit, maar dat Nederland deze cultuur heeft door de sociale zekerheid; iedereen vindt dat alles betaald moet worden. Maar er zitten grenzen aan dit systeem. Niet alles kan nog betaald worden. De expert geeft aan dat dat dan ook de vraag is: "Hoe ga je dat voor diabetes type II oplossen?" Gaat men ervoor zorgen dat er een cultuur gecreëerd wordt waarin dit kan? Daarom is ook gekozen voor de LaM, want nu is een diagnose nodig om aanspraak te maken op de ZVW en dan kan er zorg worden ingekocht vanuit de zorgverzekeraar. Echter op het moment dat je genezen bent, dan maak je daar geen aanspraak meer op, omdat wanneer je omgekeerd bent, je een ander "label" krijgt. De expert legt uit aan de hand van het door de interviewer uitgelegd model, dat er geld beschikbaar is voor wanneer iemand diabeet is, iets minder geld voor wanneer iemand prediabeet is en geen geld wanneer iemand gezond is. Daarom is dus alles gericht op wanneer iemand al diabetes heeft. De interviewer vraagt of dit dan eigenlijk "fout" is. De expert geeft aan dat het niet fout is, maar een ingang omdat het anders heel moeilijk is. Hierop vraagt de interviewer of de expert er dan ook niet in gelooft om op preventie in te gaan zetten. De expert gelooft dat het wel kan, maar alleen nu niet: "…omdat de prikkels zo verkeerd zijn." Maar de vraag van de expert is eigenlijk: "Waarom lukt het niet om er een interessante economie omheen te maken?" "Zonder dat daar de Health Impact Bond en tien gezondheidsstudies voor nodig zijn."

Ecosystemen in het model

Tot slot geeft de expert aan dat het model eigenlijk in twee ecosystemen verdeeld kan worden. De eerste die afhangt van algemene preventie, WMO, jeugd wet en privé inzet en de tweede die afhangt van de ZVW. Dit is aangegeven met twee gemarkeerde cirkels in Figure 236.

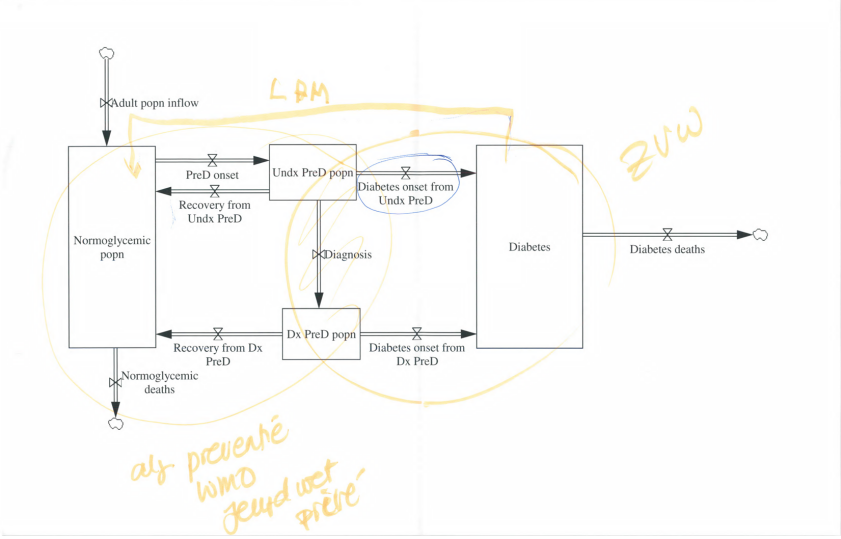


Figure 236 – Preliminary Model including Notes Expert A

Appendix 5.2 – Interview Guide: Expert B

Interviewer: L.V. Lokkers

Expert: Expert B

Achtergrond expert:

Achtergrond in Moleculaire biologie. Nu business developer op het gebied van voeding en gezondheid bij TNO. Werkzaam bij TNO sinds 1985.

Afgenomen op: 17 februari 2017

Verwerkt op: 17 februari 2017

Tijd: 0.58.34 minuten, inclusief 10 minuten onderbreking.

Voor de start van het interview is er gevraagd voor toestemming om het interview op te nemen en benadrukt dat de data anoniem en vertrouwelijk behandeld zal worden.

Levensstijlproblemen

De expert geeft aan dat wij in een obesogene samenleving wonen, waar overal goedkoop eten te vinden is, wat niet allemaal de optimale samenstelling heeft om gezond te kunnen blijven met als gevolg dat dus heel veel mensen met levensstijlproblemen op zak lopen.

Model

De interviewer introduceert zichzelf en haar rol binnen het Complexity program. Vervolgens wordt het basismodel gepresenteerd en uitgelegd. Het model inclusief aantekeningen van de expert zijn te zien in Figure 237. De uitleg van het model start bij de stock met mensen met normale bloedwaarden (Normoglycemic popn), die groter wordt doordat mensen geboren worden en kleiner wordt doordat mensen overlijden. Vervolgens krijgen mensen eerste symptomen van diabetes (de flow PreD onset). Deze mensen zijn nog ongediagnostiseerd, want zij zijn er dan nog niet mee naar huisarts gegaan en zijn weergegeven met de stock Undx PreD popn Vervolgens hebben deze mensen twee keuzes: men gaat er niet mee naar de huisarts en wordt diabeet (de flow Diabetes onset from Undx PreD naar de stock Diabetes) of deze mensen gaan wel naar een huisarts en worden gediagnostiseerd (van stock Undx PreD popn naar Dx PreD popn via de flow Diagnosis) en gaan vervolgens ook naar de stock Diabetes. De stocks Undx PreD popn, Dx PreD popn en Diabetes worden kleiner doordat mensen overlijden. De expert vraagt zelf bevestiging of de stock “Diabetes” de echte medicijngebruikers zijn, waarop de interviewer dit bevestigt. Vervolgens wordt uitgelegd dat de flow *Recovery from Undx PreD*

of de flow *Recovery from Dx PreD* staat voor het omkeren van mensen met diabetes type II dat zij weer normale bloedwaarden krijgen met als resultaat dat zij weer gezond worden en dus weer instromen in de stock *Normoglycemic popn* en dat de vraag is wat werkt wel en wat werkt niet in de praktijk. Verder geeft de interviewer aan dat in dit model kosten een grote rol spelen, omdat T2DM patiënten erg duur zijn. Verder geeft de interviewer aan dat LaM erin verwerkt wordt als interventiemaatregel, omdat T2DM (soms) omkeerbaar is.

Populatie: Prediabeten en Diabeten

De interviewer geeft aan dat er nu weinig gedaan wordt met interventies voor prediabeten. Dit blijkt uit wanneer men naar de huisarts gaat, zij dan al snel de diagnose diabetes krijgen. De expert geeft aan dat patiënten een bloedtest kunnen krijgen bij de huisarts en dat daar de glucosewaardes in het bloed gemeten worden. Wanneer deze waarde hoger is dan normaal maar wel nog in de buurt van normaal, dan is de patiënt prediabeet en wanneer deze waarde heel hoog is en aan de risicokant zit, dan is de patiënt diabeet. Aldus de expert is de vraag: Wanneer en op welk moment wordt vastgesteld dat iemand prediabetes heeft? Ook geeft de expert aan dat als het de patiënt lukt om met een verandering in het eetpatroon de glucosewaarden weer normaal te krijgen, de patiënt eigenlijk weer gezond is. De expert wijst hierbij op de flow van de stock *Undx PreD popn* naar de stock *Normoglycemic popn*. Echter geeft de expert ook aan dat de patiënt dit wel moet proberen vol te houden en dus kennis moet hebben van voeding; een heel zoet product bevat suiker, maar zetmeelrijke producten worden in de maag en darmen omgezet in suikers en dat weet niet iedereen. “Dus de onkundigheid van mensen speelt erbij een rol vaak.”

De interviewer vraagt of de diabetes populatie bedoeld wordt wanneer de expert het heeft over mensen bewust maken. De expert antwoordt hierop dat de situatie ook al in de stock *Undx PreD popn* kan voorkomen; als de huisarts een verhoogde (maar geen riscioverhoging) glucosewaarde vindt in het bloed, dan krijgt de patiënt ook het advies om te letten op wat hij of zij eet en de patiënt krijgt eventueel een dieetadvies van de diëtist verbonden aan de huisartsenpraktijk of je bent zelf geïnteresseerd en gaat kijken welke voeding bij je past. De expert geeft ook aan dat de prediabetes populatie groot is en dat het een continuüm is van gezond naar prediabetes en weer terug. En de vraag is dus: “Hoe kun je deze populatie bewust maken van dat ze nog geen medicijnen nodig hebben maar wel moeten letten op hun eetgedrag?”. De expert geeft aan dat dat een stukje voorlichting is en een stukje intrinsieke motivatie (interesse) om daarmee aan de slag te gaan.

Sociale status

De interviewer reageert hierop met de vraag: “Is deze groep relatief klein? Want mensen krijgen overgewicht en/of diabetes omdat ze dit [intrinsieke motivatie] missen.”. De expert geeft aan dat het een soort alarmbel is die de patiënt hoort klinken en sommige mensen gaan daarmee aan de slag, minderen met eten, meer bewegen, etc., en andere mensen niet. “Zeker mensen die laagopgeleid zijn, die überhaupt niet weten wat glucose is. Die hebben meer steun nodig. Zij moeten inderdaad een coach hebben en dat zorgmechanisme ontbreekt in de huidige gezondheidszorg.” De interviewer vraagt of dit mechanisme er helemaal niet is. De expert antwoordt dat het er wel is, als je er zelf bewust naar op zoek gaat, maar dan komt het weer neer op de eigen intrinsieke motivatie, maar veel mensen hebben die interesse en drive niet om het te willen weten. De expert geeft aan dat hoogopgeleiden wel vaker geïnteresseerd zijn hierin. Bijvoorbeeld door te sporten, hoogopgeleiden doen dit omdat het bij een gebalanceerde levensstijl hoort, terwijl er ook mensen zijn die sporten “omdat het wedstrijdje leuk is, maar daarna hangen ze weer in de bar en wordt er AA-drink gedronken. Zij sporten niet voor de intrinsieke gezondheid voor hun lijf. ” Dat is wat gezien wordt in de sportkantines en ook al bij jonge kinderen. Dat geeft aan dat de opvoeding van gezond gedrag al heel jong begint en wanneer kinderen dit niet meekrijgen, zeker in de pubertijdsfase, dan is de kans op overgewicht later groter. Ter verduidelijking vraagt de interviewer: “Dus het risico is dan heel erg groot?” Waarop de expert antwoordt: “Ja.”.

Als gevolg van deze informatie vraagt de interviewer of dit probleem dan met name leeft onder laagopgeleiden. De expert antwoordt hierop dat het een groep is waar het gemiddeld meer aanwezig is dan bij hoogopgeleiden, maar dat het ook voorkomt onder hoogopgeleiden. Er wordt vervolgens een voetnoot bijgeplaatst dat het niet een dusdanige zwart-wit situatie is. De interviewer geeft aan dat de voorstelling ook gemaakt kan worden dat hoogopgeleiden vaker kantoorbanen hebben en daardoor meer stilzitten. De expert geeft aan dat dit klopt, maar zegt hierbij dat hoogopgeleiden meer bloot staan aan stress, waardoor ze ongezond eetgedrag vertonen. Hierop laat de expert de “Obesity map” zien (http://www.shiftn.com/obesity/Full-Map.html), die gaat over de energy balans: je eet energie of en je verbrandt energie en als die uit balans is, word je dik.

Stress

De interviewer vraagt naar de gevolgen van stress. De expert legt uit dat stress kan ontstaan door de druk die wordt uitgeoefend door de leidinggevende, familie of collega’s. Dat is

chronische stress die geen adrenaline meer vrijmaakt, maar cortisol dat aangemaakt wordt en dat richt schade aan op lange termijn.

Overgewicht

De interviewer vraagt of T2DM een direct gevolg is van overgewicht. De expert antwoordt hierop dat dit niet per se het geval hoeft te zijn, maar dat het wel vaak voorkomt omdat het lijf van mensen met overgewicht voortdurend onder druk staat dat ze eten en dat de alvleesklier hierin gaat falen om het bij te houden. Deze maakt insuline en zorgt ervoor dat de insuline opgenomen wordt in de spieren en cellen. Het gevolg is dat het lichaam niet meer reageert op glucose en de glucoseniveaus oplopen en de patiënt dus diabetes heeft. Echter, het is niet de regel dat mensen met een zwaargewicht altijd diabetes oplopen. Er zijn ook mensen met een gezond gewicht die T2DM ontwikkelen door erfelijkheid (DNA). Deze laatste vorm is niet terug te draaien. Ook vanuit een kostenperspectief is het interessanter om op de mensen met overgewicht en T2DM te focussen.

Verder geeft de expert aan dat mensen met overgewicht een hogere slijtage aan het lichaam hebben, een lagere arbeidsproductiviteit en hogere uitval hebben en lager zelfbeeld hebben. Hiermee geeft de expert aan dat overgewicht al een kostenverhogende ziekte is, terwijl mensen eigenlijk niet ziek hoeven te zijn. Daarnaast, omdat veel mensen toch T2DM ontwikkelen, wordt er nog meer schade aan het lichaam aangericht, bijvoorbeeld aan ogen, nieren, gewrichten, doorbloeding van voeten, etc.; dus de multi-mobiliteit van diabetes neemt toe. Het is een progressieve ziekte, waardoor ook de zorgkosten stijgen en die worden hoger naarmate iemand ouder wordt.

Interventie vs. Preventie

De interviewer kaart aan dat interventiemethoden gefocust zijn op diabeten in plaats van prediabeten door de Zorgverzekeringswet, wat inhoud dat er alleen geld vrijkomt voor iemand met een diagnose. Vervolgens vraagt de interviewer aan de expert of het niet mogelijk is om methoden in te zetten op prediabeten. De expert geeft aan dat het wel moet lukken en dat het dan gaat om preventie, want “een prediabeet is nog niet ziek en kan dus nog veel doen aan zichzelf.”. Grote steden en zorgverzekeraars hebben interesse in preventiemaatregelen. Aldus de expert is het uiteindelijke doel om de toestroom van diabeten te verminderen en dan moet er ook gedacht worden een preventieve maatregelen.

Stakeholders

Stakeholders volgens de expert zijn werkgevers, omdat zij te maken hebben met uitval/ziekteverzuim en verlies van productiviteit. Gemeentes ook, omdat mensen die in de ziektewet belanden een beroep doen op sociale voorzieningen en werkloosheidsuitkeringen krijgen vanuit de gemeente. Zorgverzekeraars worden ook genoemd, omdat zij de rekeningen moeten vergoeden. En tot slot commerciële partijen, zoals de Albert Heijn en McDonalds, zij moeten hun aanbod aanpassen als er een behoefte is vanuit de maatschappij aan gezonde producten. De interviewer vraagt of de expert de patiënt ook als stakeholder ziet. Volgens de expert zijn zij zeker stakeholder, omdat zij bepalen wat er moet gebeuren.

Rol van financiële middelen

Sommige mensen hebben financiële middelen nodig om gezond te blijven, omdat zij het zich niet kunnen veroorloven om gezonde producten te kopen, een sportabonnement en/of sportspullen aan te schaffen. De overheid is een belangrijke partij die kwetsbare groepen moet beschermen en helpen. De expert noemt ook bijvoorbeeld de acties van de Lidl met het aanbieden van sportkleding tegen een lage prijs als een belangrijke factor, omdat het dan makkelijker wordt voor mensen met een laaginkomen om deze spullen dan toch aan te schaffen.

Implementatie LaM

De interviewer vraagt naar hoe dit programma geïntroduceerd moet worden om het geloofwaardigheid te geven: via de huisarts of via overheidscampagnes. De expert geeft aan dat beide middelen ingezet moeten worden. De huisarts is het eerste contactpunt waar wordt geconstateerd dat de patiënt een probleem heeft en het is de eerstelijnszorg waar iedereen verplicht is om naartoe te gaan. Dus de huisarts signaleert en diagnosticeert, maar dan is het spreekuur voorbij en dan is het aan de patiënt om het op te pakken en dan kan het helpen dat de patiënt daarnaast in zijn of haar omgeving wordt gestimuleerd door overheidscampagnes en buurtinitiatieven. Echter speelt de thuissituatie ook een grote rol, omdat het lastig is vol te houden als jij de enige bent in het gezin die ervan bewust is en ermee aan de slag gaat en dan nog andere gezinsleden moet overtuigen.

De interviewer vraagt ter bevestiging dat dus de directe omgeving veranderd moet worden, maar ook de leefomgeving. Bijvoorbeeld minder liften en meer fietspaden. De expert beaamt dit, maar geeft ook aan dat dit situaties zijn die er gewoon al zijn maar dat mensen de juiste keuzes moeten maken om ze te gebruiken en dat een architect bijvoorbeeld moet

nadenken met het ontwerpen van het gebouw om de trap meer zichtbaar te maken. Dit is een onderdeel van het systeemprobleem weergeven in de “Obesity map”. De vraag is dus: “Waar moet er nu gestart worden?”

Novo Nordisk

De expert kaart verder nog de website van Novo Nordisk aan: http://www.citieschangingdiabetes.com/. Novo Nordisk is een producent van insuline en is ook bezig met het opzetten van T2DM omkeerprogramma’s, aldus de expert.

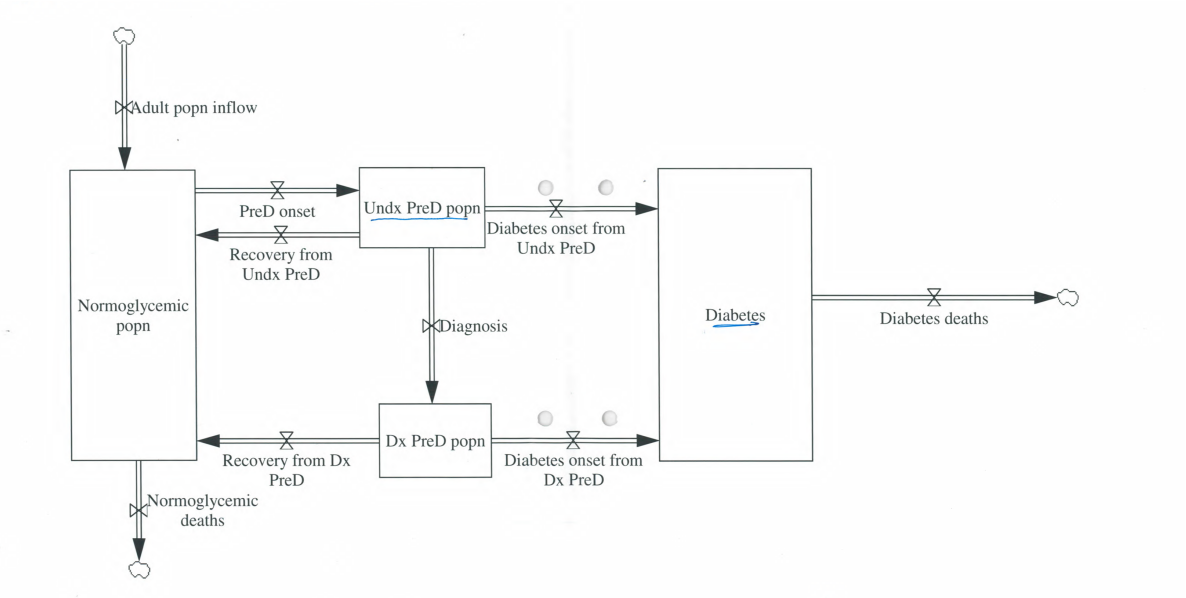


Figure 237 – Preliminary Model including Notes Expert B

Appendix 5.3 – Interview Guide: Expert C

Interviewer: L.V. Lokkers

Expert: Expert C

Achtergrond expert:

Afgestudeerd in Moleculaire Wetenschappen en werkzaam bij TNO sinds 1988.

Afgenomen op: 22 februari 2017

Verwerkt op: 22 februari 2017

Tijd: 0.27.52 uur

Voor de start van het interview is er gevraagd voor toestemming om het interview op te nemen en benadrukt dat de data anoniem en vertrouwelijk behandeld zal worden.

Model

De interviewer introduceert zichzelf en haar rol binnen het Complexity program. Vervolgens wordt het basismodel gepresenteerd en uitgelegd. Het model inclusief aantekeningen van de expert zijn te zien in Figure 238. De uitleg van het model start bij de stock met mensen met normale bloedwaarden (*Normoglycemic popn*), die groter wordt doordat mensen geboren worden en kleiner wordt doordat mensen overlijden. Vervolgens krijgen mensen eerste symptomen van diabetes (de flow *PreD onset*). Deze mensen zijn nog ongediagnostiseerd, want ze zijn er dan nog niet mee naar huisarts gegaan en zijn weergegeven met de stock *Undx PreD popn*. Vervolgens hebben deze mensen twee keuzes: men gaat er niet mee naar de huisarts en wordt diabeet (de flow *Diabetes onset from Undx PreD* naar de stock *Diabetes*) of deze mensen gaan wel naar een huisarts en worden gediagnostiseerd (van stock *Undx PreD popn* naar *Dx PreD popn* via de flow *Diagnosis*) en gaan vervolgens ook naar de stock *Diabetes*. De stocks *Undx PreD popn*, *Dx PreD popn* en *Diabetes* worden kleiner doordat mensen overlijden.

LaM

De interviewer legt uit dat recovery (de flow *Recovery from Undx PreD* of de flow *Recovery from Dx PreD*) staat voor het omkeren van mensen met diabetes type II, zodat T2DM patiënten weer normale bloedwaarden krijgen en dus gezond worden en dus weer instromen in de stock *Normoglycemic popn*. Hierop wordt gefocust binnen Grip on Health. De interviewer legt uit dat Levensstijl als Medicijn ingezet wordt om te kijken waar het programma het beste ingezet kan worden binnen het systeem.

Zorgverzekeringswet

De interviewer geeft aan dat aldus een collega expert er nu wordt ingezet op de populatie diabetes, omdat deze mensen een diagnose hebben en er daarom geld vrijkomt om LaM in te zetten. De expert in dit interview geeft aan het eigenlijk andersom is: wanneer iemand in het medische circuit zit, dan is er maar één weg en dat is doodgaan. Daar wordt aan verdiend, plus de verzekeraar vergoedt het ook niet wanneer het buiten het diagnosegebied valt. Concluderend dus dat het richten op prediabetes patiënten gemakkelijker is, omdat het buiten het medische systeem valt en men er zelf wat aan kan doen; men moet het zelf betalen maar het is niet gereguleerd. Wanneer iemand diabeet is, valt hij of zij binnen het systeem en is het moeilijker. LaM probeert een pijl te tekenen van de stock *Diabetes* naar de stock *Undx PreD popn*. De expert haalt ook de data verworven in naam van Vintura aan.

Stakeholders

De interviewer vraagt naar de stakeholders en noemt commerciële partijen als voorbeeld naast de werkgever en patiënt. De expert ziet graag dat het model laat zien wie er gaat verdienen aan de route *Diabetes onset from Undx Pred*; welke euro's worden verdiend (en dus niet welke nodig zijn) aan het gezond maken van mensen. Dit heet care vs. cure. De expert heeft dit proces aangegeven met de pijl en de getekende flow in het model in Figure 238. De pijl is deels weggevallen, omdat de naam van de expert van de afbeelding verwijderd is in verband met anonimiteit. Diabetes care: actoren verdienen eraan dat mensen niet gezond worden, bijvoorbeeld diagnoses, amputaties, insulinespuiten. Echter aldus de expert moeten we naar een gezondheidszorg met diabetes cure: mensen moeten eraan gaan verdienen om mensen wel gezond te laten worden, bijvoorbeeld door gezonde voeding, betere coaching, betere fitness, dus de diëtist is een voorbeeld van een stakeholder en niet de werkgever. Ook kan de overheid verdienen aan het LaM programma, omdat zij minder kosten zullen gaan hebben. Ziektekostenverzekeraars zullen geld gaan besparen, maar hier is de vraag: willen ze geld gaan besparen? Past dit wel bij hun businessmodel? Aldus de expert bestaat hun businessmodel uit het vroeg binnenhalen van geld (premies) en het laat uitgeven van datzelfde geld (zodat ze beleggingen kunnen doen). Ziekenhuizen kunnen ook tegenstand gaan bieden, omdat wanneer zij geen patiënten meer binnenkrijgen, er geen werk meer voor hen is en zij in het ergste geval een cardioloog bijvoorbeeld moeten laten gaan. In conclusie: in de sector care gaan mensen boos worden wanneer LaM wordt ingezet, dus de cure sector moet geld opleveren. Aldus de expert moet er een economie gaan ontstaan die geld verdiend en een andere economie uit de

markt drukt en dat is de reden waarom er gekozen wordt binnen het LaM programma om niet te starten in de pseudozorg (mensen met overgewicht en kwaaltjes), maar bij gediagnosticeerde diabetespatiënten/in de gezondheidszorg. Ter verduidelijk vraagt de interviewer of de zorgverzekeraar overtuigd moet worden dat het interessant is. De expert antwoordt hierop dat de overheid hierin een belangrijke speler is, want deze kan de zorgverzekeraars verplichten iets te vergoeden.

Aldus de expert is een voorbeeld van een stakeholder de Albert Heijn. De rol van Albert Heijn zou kunnen zijn om (persoonlijke) boxen aan te leveren aan diabetespatiënten om gezond te blijven. Vergelijkbaar bedrijf is Hello Fresh. Of bijvoorbeeld de rol van bedrijven is dat er alleen een pas voor de lift wordt afgegeven wanneer iemand minimaal op de vijfde verdieping werkt. Conclusie: er moet veel veranderen en het moet geld opleveren voor de veranderaars; een nieuw economisch gestel dat winstgevend is. Aldus de expert zijn er tientallen bedrijven bezig met het berekenen van gezond naar diabetespatiënt en profiteren daarvan. Dit is een vrij inherent systeem; het laat zich niet gemakkelijk veranderen. De expert ziet het liefst een model waarmee TNO langs fitnesscentra, startups etc. kan gaan en kan laten zien dat zij hieraan kunnen verdienen wanneer zij beter hun best doen.

LaM

Aldus de expert, is er dus een "LaM" systeem dat er loopt en ook redelijk loopt, maar het is niet goed genoeg. De LaM manier van werken: mensen worden gezond gemaakt en daarna gezond gehouden via diverse activiteiten. Verder heeft LaM aangetoond dat het goedkoper is om een LaM traject te volgen dan ziek te zijn, aldus de expert. De verschillen in kosten zijn ontzettend groot. De expert geeft aan dat hij de visionair aanjager is, die LaM bedacht heeft.

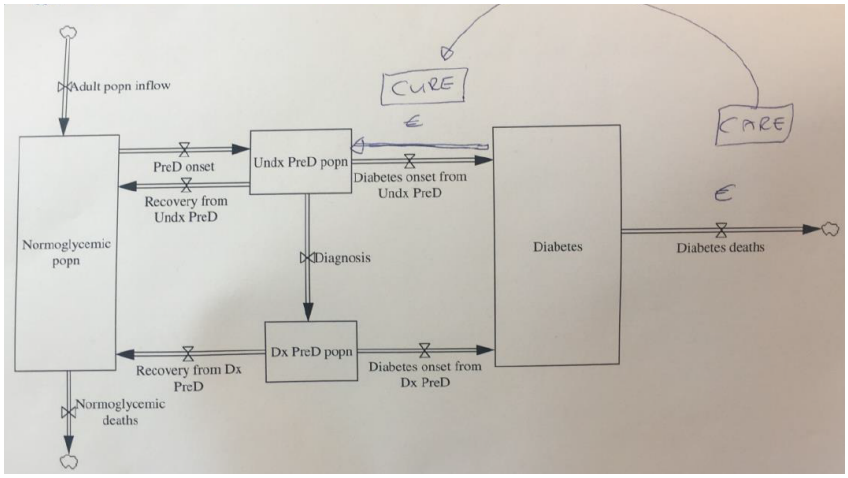


Figure 238 – Preliminary Model including Notes Expert C

Appendix 5.4 – Interview Guide: Expert D

Interviewer: L.V. Lokkers

Expert: Expert D

Achtergrond expert:

Economisch historicus. Werkzaam bij TNO sinds 2002 op de afdeling Worked Health en daarvoor bij Integrated Care. Die laatste bestaat niet meer als afdeling.

Afgenomen op: 8 maart 2017

Verwerkt op: 9 maart 2017

Tijd: 0.42.55 uur

Voor de start van het interview is er gevraagd voor toestemming om het interview op te nemen en benadrukt dat de data anoniem en vertrouwelijk behandeld zal worden.

Model

De interviewer introduceert zichzelf en haar rol binnen het Complexity program. Vervolgens wordt het basismodel gepresenteerd en uitgelegd. Het model inclusief aantekeningen van de expert zijn te zien in Figure 239. De uitleg van het model start bij de stock met mensen met normale bloedwaarden (*Normoglycemic popn*), die groter wordt doordat mensen geboren worden en kleiner wordt doordat mensen overlijden. Vervolgens krijgen mensen eerste symptomen van diabetes (de flow *PreD onset*). Deze mensen zijn nog ongediagnostiseerd, want ze zijn er dan nog niet mee naar huisarts gegaan en zijn weergegeven met de stock *Undx PreD popn*. Vervolgens hebben deze mensen twee keuzes: men gaat er niet mee naar de huisarts en wordt diabeet (de flow *Diabetes onset from Undx PreD* naar de stock *Diabetes*) of deze mensen gaan wel naar een huisarts en worden gediagnostiseerd (van stock *Undx PreD popn* naar *Dx PreD popn* via de flow *Diagnosis*) en gaan vervolgens ook naar de stock *Diabetes*. De stocks *Undx PreD popn*, *Dx PreD popn* en *Diabetes* worden kleiner doordat mensen overlijden.

Vervolgens is uitgelegd dat (de flow *Recovery from Undx PreD* of de flow *Recovery from Dx PreD*) staat voor het omkeren van mensen met diabetes type 2; dat zij weer normale bloedwaarden krijgen met als resultaat dat zij weer gezond worden en dus weer instromen in de stock *Normoglycemic popn*, waar ze mee bezig zijn bij Lifestyle as a Medicine. De expert vraagt of er hierbij vanuit gegaan wordt dat mensen naar de huisarts moeten gaan om te voorkomen dat zij diabeet worden. De interviewer legt uit dat zij in ieder geval naar de huisarts moeten voor een diagnose. Wanneer zij dit niet doen, worden de prediabeten sowieso diabeet.

Dat is de assumptie. De expert geeft aan te denken dat deze assumptie niet helemaal juist is: mensen die zich niet goed voelen en zonder huisartsadvies hun levensstijl aanpassen, kunnen ook weer gezond worden. De interviewer beaamt dit en legt uit dat dit de pijl "Recovery from Undx PreD" is. De expert geeft aan het te begrijpen en vertelt dat de leefstijlaspecten erg belangrijk zijn en dat een huisarts eigenlijk niet nodig is, mensen kunnen het zelf doen.

Interventie vs. Preventie

De interviewer geeft aan dat LaM zich voornamelijk focust op diabeten in plaats van prediabeten in verband met de Zorgverzekeringswet. De expert geeft aan dat het belangrijk is om de mensen terug te krijgen van prediabeet naar gezond in plaats van diabeet naar gezond, want bij deze laatste is alles veel complexer. Er is een disbalans. Daarnaast gaan veel mensen niet naar de huisarts, maar kunnen zij er wel zelf achter komen bijvoorbeeld door het internet en hun leefstijl te veranderen. Dit zou de ideale situatie zijn, omdat er dan helemaal geen kosten aan verbonden zijn (voor de staat) en dus zou de focus moeten liggen op preventie: het onderwijzen van prediabeten in plaats van diabeten. T2DM kan men zien aankomen, aldus de expert, bijvoorbeeld mensen met overgewicht, en daarom moet de preventie focussen op de populatie prediabeten zonder diagnose. Levensstijladvies zou hier al moeten worden gegeven om te voorkomen, dat mensen doorstromen richting diabeet zijn. Het liefst zonder de huisarts, want daar is de maatschappij het meeste bij gebaat omdat het dan geen kosten oplevert.

Rol van media

De expert geeft aan dat de huisarts vaak helemaal niet meer nodig is, omdat men dingen zelf kan vinden op het internet en met voorlichting en goede voorbeelden kan er veel bereikt worden. De expert geeft aan dat LaM zich ook daarop zou kunnen richten: het geven van bevolkingsinformatie of bevolkingsadvies.

Public Health vs. Curatieve gezondheid

De expert geeft aan dat het model op te delen valt in Public Health en Curatieve gezondheid. Normoglycemic population en een deel van de middelste stocks is public health en het andere deel van het model is curatieve gezondheid, zoals aangegeven in Figure 239. Public health bestaat uit de GGD, gemeentes, etc. die een rol zouden kunnen spelen in de voorlichting dat het krijgen van diabetes ernstige gevolgen heeft en bij de curatieve gezondheid is iemand al ziek en is vrij machteloos. Zij kunnen mensen wel terugkrijgen van diabeet naar gezond, maar

het gaat om het volhouden; een levensstijlaanpassing en die zit bij het zijn van prediabeet. De huisarts kan dit niet monitoren en daarom zou er een ander orgaan moeten komen die dit gaat doen. De expert geeft aan dat dit nu binnen LaM niet voorzien is. Een gedragsverandering moet plaatsvinden en die moet vervolgens volgehouden worden. Dit is onderdeel van public health: hoe ga je voorlichting organiseren en hoe zorg je ervoor dat mensen in de supermarkten niet verleid worden om snoepgoed te kopen.

Omgeving

De interviewer vraagt of de gedragsverandering en verantwoordelijkheid dus bij de patiënt zelf ligt. De expert beaamt dit en voegt hieraan aan toe dat het ook bij de omgeving ligt. De omgeving moet faciliteren dat de patiënt niet weer in oude gewoontes terugvalt. De expert geeft aan dat LaM daarin nog niet ontwikkeld is. LaM heeft bewezen dat het mogelijk is om met een bepaald programma weer gezond te worden, maar niet hoe iemand dit kan volhouden. Aldus de expert speelt de huisarts hier geen rol meer. De expert geeft wel aan dat er diabetesspreekuren zijn, maar dat deze van een ander niveau zijn dan het geven van leefstijladvies. Sterker nog, men wordt ontslagen wanneer de glucosewaarden weer normaal zijn en dan trekt de huisarts zijn of haar handen ervan af. Op dat moment is het weer stabiel. Daarnaast geeft de expert aan dat de huisarts hier te weinig tijd voor heeft en veel huisartsen hier geen opleiding voor hebben genoten. Het gaat dus om het gedrag van mensen en de expert geeft aan het gedragsaspect binnen LaM te missen. Deze gedragsverandering geldt voor zowel de gediagnosticeerde als ongediagnosticeerde prediabeten. Het gaat dus om de flow *Recovery from Undx PreD* en de flow *Recovery from Dx PreD*.

De expert geeft aan dat model-technisch gezien de diabetespatiënt loopt via normale glucosewaardes naar prediabeet naar diabeet. Wanneer mensen worden omgekeerd verloopt dit van diabeet naar normale glucosewaardes, want “pre” betekent de fase voor het krijgen van diabetes.

Stabiliseren

Aldus de expert hebben mensen met diabetes een voortdurend probleem met het vinden van de balans van de glucosewaardes. Deze moet gestabiliseerd worden door middel van goede voeding en voldoende verbranding. Verder geeft de expert aan dat wanneer iemand diabeet is er altijd medicijngebruik nodig is. Op het moment dat iemand genezen verklaard wordt, dan word je in de huidige Nederlandse gezondheidszorg ontslagen en niet meer behandeld en dus

moet de patiënt het zelf gaan doen en dit vasthouden. De expert geeft aan dat dit moeilijk is: “de preventieve geneeskunde verhoudt zich niet goed met de curatieve geneeskunde”. Huisartsen zijn gericht op diagnosen stellen en niet op het nog gezonder maken van mensen. De expert geeft aan dat hij niet verwacht dat huisartsen dit gaan oppakken en dat er daarom iets anders moet komen in de interventie.

Omgeving 2

De expert geeft aan dat het gedrag zou kunnen worden beïnvloed door de overheid: winkels geen snoepgoed bij de kassa’s laten plaatsen en fitnesapparaten installeren in het park. Echter geeft de expert ook aan dat het ook verder gaat dan de overheid: bewegen op het werk, arbeidsomstandigheden en fietsstoelen om op te werken. Dit moet altijd in combinatie met eetpatroonverbetering. Het gaat om de gedragsverandering en hoe men die voor elkaar krijgt. LaM is een goede methode, maar er zou een preventieve kant bij moeten komen die een nadruk legt op de gedragsbeïnvloeding, aldus de expert. Dit is lastig om te meten; in tegenstelling tot het wel of niet hebben van diabetes waar bloedwaardes dit aangeven.

Stakeholders

Aldus de expert zijn stakeholders iedereen die het gedrag kan beïnvloeden. Dit zit in voeding, de winkel en supermarkt. De sociale omgeving, wanneer iedereen om de patiënt heen veel eet, gaat de patiënt ook veel meer eten. De expert benadrukt dat deze laatste een hele belangrijke factor is. Verder het faciliteren vanuit de overheid, bijvoorbeeld het goedkoper maken. Echter geeft de expert aan dat er nog weinig bewijs is voor de effectiviteit van financiële prikkels vanuit de overheid, bijvoorbeeld leidt een korting op sportschoolabonnementen tot meer sporten?

Sociale status

De interviewer geeft aan dat een collega expert aangeeft dat T2DM niet alleen voorkomt in lagere sociale klassen. De expert in dit interview geeft aan dat er data is dat er bepaalde wijken met veel mensen in lagere sociale klassen relatief meer diabetici wonen, maar hierbij moet rekening gehouden worden met vergrijzing en gerelateerde factoren. Een financiële prikkel zou niet ondenkbaar zijn, maar de expert geeft wederom aan dat er eerst meer onderzoek moet komen over de effectiviteit van financiële prikkels.

Interventies

Aldus de expert zijn interventies mogelijk: financiële interventies; mits daar meer onderzoek over wordt gedaan en omgevingsinterventies; zorg ervoor dat mensen betere voorbeelden in de omgeving zien. In deze laatste spelen scholen een belangrijkere rol. Wanneer kinderen geen vet eten krijgen op school of geen snoep, dan zou dit kunnen helpen in de bewustwording aldus de expert. Vereniging zijn een ander voorbeeld. Conclusie van de expert: alle plekken waar mensen bij elkaar komen.

Omgeving 3

Aldus de expert moet er meer onderzoek komen naar waar mensen zich door laten leiden. De supermarkt is een partij die invloed heeft in dit leiden, bijvoorbeeld door snoep bij de kassa's aan te bieden. Dit is hun verdienmodel. De supermarkt moet vervolgens overtuigd worden om op een andere manier te verdienen, bijvoorbeeld door er groente en fruit neer te leggen. Vervolgens geeft de expert aan dat kinderen vroeg in hun jeugd iets kunnen ontwikkelen, waar zij op latere leeftijd last van kunnen krijgen in de vorm van bijvoorbeeld diabetes. Daarom is voorlichting geven via consultatiebureaus belangrijk om ouders te beïnvloeden.

Obesitas vs. T2DM

Het is niet zo dat er altijd een directe link bestaat tussen obesitas en T2DM. Mensen kunnen ook T2DM ontwikkelen door andere factoren. De expert definieert deze niet.

Recovery

De expert geeft aan dat T2DM veranderd kan worden in tegenstelling tot T1DM. T1DM definieert de expert als dat het "in feite een handicap is". Echter, de expert geeft ook aan dat dit niet helemaal zijn vakgebied is en er niet het fijne van weet. Verder geeft de expert aan dat er een groep met T2DM is door een erfelijke aandoening en dat dat een groep blijft waarmee altijd rekening gehouden moet worden.

Model

De expert geeft verder aan dat een model bouwen met betrekking tot preventies lastig is, omdat iets voorkomen moet worden. De interviewer geeft aan dat het daarom ook een model onder andere gebaseerd op assumpties zal worden.

Shared savings

Aldus de expert betalen meerdere partijen eraan mee en zien zij hun investeringen ofwel direct of indirect terug. Volgens de expert zijn voorbeelden van deze partijen de zorgverzekeraar, de werkgever, de overheid, etc. De overheid betaalt maar ziet er weinig van terug, want wanneer iemand gezond wordt gaat dit geld naar de zorgverzekeraar. Voor de supermarkt is het gezonder worden van mensen ook niet per se voordelig, want het kost hen omzet plus de mensen die beter worden doen nog steeds boodschappen bij hen dus daar zit geen prikkel om mensen gezond te maken. Verder is het lastig om bepaalde partijen vanuit de overheid erbij te betrekken, bijvoorbeeld supermarkt A wel en supermarkt B niet. De expert voegt hieraan toe dat de programma's daarom gepersonaliseerd moeten worden; de verantwoordelijkheid ligt bij de patiënt zelf. Bijvoorbeeld wanneer de patiënt naar fitnesscentrum met een bepaalde certificering gaat krijgt hij of zij korting. Zorgverzekeraars doen dit door bepaalde behandelingen in te kopen bij bepaalde organisaties. Dit is niet mogelijk voor een supermarkt, want dan is het marktvervuiling.

Gedragscomponent

Verder geeft de expert aan dat op dik zijn een taboe ligt en daarom is de gedragscomponent zo belangrijk. Daarnaast is het bij sommige mensen niet mogelijk om het gedrag te veranderen, doordat zij een eetverslaving hebben ontwikkeld.

Samenwerking tussen Public Health en Curatieve gezondheidszorg

Het succes van curatieve gezondheid is afhankelijk van de public health, doordat de curatieve gezondheid geprotocolleerd is en de public health maatwerk is. Conclusie van de expert: er moeten meer gedragswetenschappers betrokken worden bij LaM, bijvoorbeeld psychologen en economen om het effect van financiële prikkels te onderzoeken.

Verder geeft de expert aan dat er twee vormen van gedragsveranderingen zijn: het ofwel zelf doen ofwel met de hulp van specialisten om het voedingsgebruik aan te passen en bewegingsgewoonten te veranderen. Aldus de expert moeten deze voortvloeien uit beide stocks prediabeten.

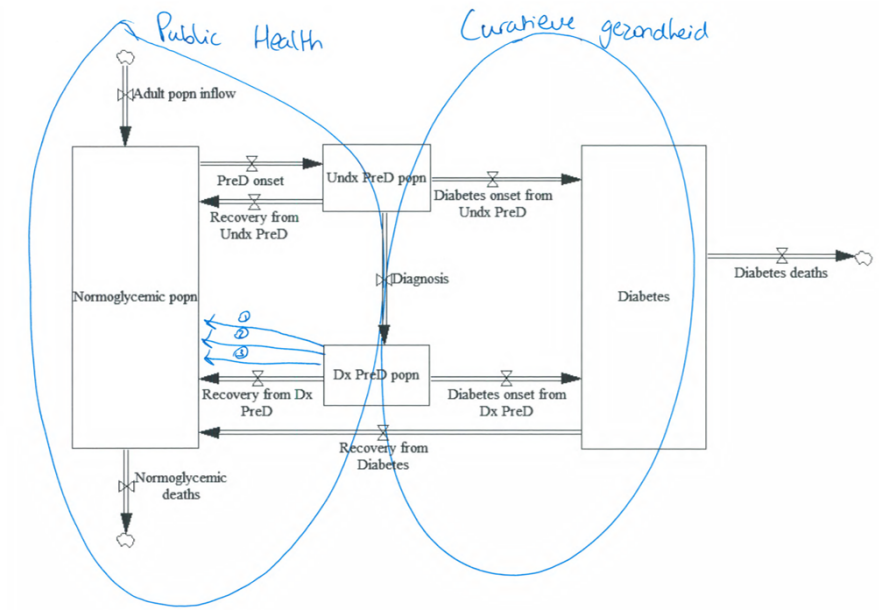


Figure 239 – Preliminary Model including Notes Expert D

Appendix 5.5 – Interview Guide: Expert E

Interviewer: L.V. Lokkers

Expert: Expert E

Achtergrond expert:

Senior scientist, gepromoveerd in de Medische wetenschappen op erfelijke stofwikkelingsziektes.

Afgenomen op: 11 maart 2017

Verwerkt op: 11 maart 2017

Tijd: 0.45.35 uur

NB: De opname bevatten veel stiltes omdat er naar data wordt gezocht.

Voor de start van het interview is er gevraagd voor toestemming om het interview op te nemen en benadrukt dat de data anoniem en vertrouwelijk behandeld zal worden.

Het model

De interviewer introduceert zichzelf en haar rol binnen het Complexity program. Vervolgens wordt het basismodel gepresenteerd en uitgelegd. De expert heeft geen aantekeningen gemaakt in het model, zoals te zien in Figure 240. De uitleg van het model start bij de stock met mensen met normale bloedwaarden (*Normoglycemic popn*), die groter wordt doordat mensen geboren worden en kleiner wordt doordat mensen overlijden. Vervolgens krijgen mensen eerste symptomen van diabetes (de flow *PreD onset*). Deze mensen zijn nog ongediagnostiseerd, want ze zijn er dan nog niet mee naar huisarts gegaan en zijn weergegeven met de stock *Undx PreD popn.* Vervolgens hebben deze mensen twee keuzes: men gaat er niet mee naar de huisarts en wordt diabeet (de flow *Diabetes onset from Undx PreD* naar de stock *Diabetes*) of deze mensen gaan wel naar een huisarts en worden gediagnostiseerd (van stock *Undx PreD popn* naar *Dx PreD popn* via de flow *Diagnosis*) en gaan vervolgens ook naar de stock *Diabetes*. De stocks *Undx PreD popn*, *Dx PreD popn* en *Diabetes* worden kleiner doordat mensen overlijden.

De expert geeft hierbij aan dat de flow *Diagnose* niet helemaal correct is, omdat de huisarts pas gaat acteren wanneer iemand diabeet is. Er wordt vaak zelfs pas laat ontdekt dat iemand diabeet is en dan wordt dus de hele fase van gediagnosticeerde prediabetes overgeslagen. De reden hiervoor is dat huisartsen pas iemand gaan behandelen wanneer iemand patiënt is en willen dan ook niet medicaliseren door een gezond iemand al een stempel “je bent ziek” mee te geven, bijvoorbeeld prediabetes. Huisartsen doen niet aan preventie. Momenteel

ligt de bal om mensen zich ervan bewust te maken bij niemand. Vervolgens is uitgelegd dat (de flow *Recovery from Undx PreD* of de flow *Recovery from Dx PreD*) staat voor het omkeren van mensen met diabetes type II dat zij weer normale bloedwaarden krijgen met als resultaat dat zij weer gezond worden en dus weer instromen in de stock *Normoglycemic popn*, waar ze mee bezig zijn bij Lifestyle as Medicine.

Omkeren

De expert geeft vervolgens aan dat het moeilijker is om een diabeet om te keren dan een prediabeet om te keren. Ook als zorgaanbieder kan er veel meer worden betekent in het begin van het proces (prediabetes) dan achterin het proces (diabetes).

Beleid

De expert beaamt dat er momenteel geen beleid is.

Leefstijl als Medicijn

De interviewer geeft aan gestuit te zijn op het programma Voeding Leeft. De expert geeft aan dat Voeding Leeft geen concurrent is van LaM, omdat LaM ervoor zorgt dat mensen, verenigingen, bedrijven, etc., mensen met hetzelfde doel hun krachten gaan bundelen om het voor elkaar te krijgen. Men is dan niet per se elkaars concurrent, maar versterkt elkaar en dat er een soort van stichting komt die ervoor zorgt dat de kwaliteit goed is waarin iedereen zijn of haar eigen rol/niche in kan aannemen. Het idee daarachter is dat het meer persoonlijk wordt. De ene persoon heeft baat bij meer coaching, de ander bij een ander dieet (bijvoorbeeld Voeding Leeft) en een derde bij beweging bijvoorbeeld. Bij LaM doen verschillende partijen mee op hun eigen voorwaarde met een aanbod van levensstijl als medicijn. Hierdoor zit er geen vaste periode aan het traject van bijvoorbeeld 2 jaar.

De interviewer geeft aan vernomen te hebben van collega experts dat voor de geloofwaardigheid een samenwerking moet zijn tussen de huisarts en LaM. De expert geeft aan dat er wellicht een vorm van medisch bewijs nodig om LaM op de kaart te krijgen wanneer het aangeboden gaat worden als behandeling of medicijn om mensen ervan te overtuigen. Daarom moet er gedacht worden aan het betrekken van artsen. Ook kan er op die manier geïnnoveerd worden en programma's aangepast worden om ze persoonlijker te maken, aldus de experts.

De expert noemt ook een ander project, waarin een samenwerking tussen huisartsen, diëtisten en fysiotherapeuten, waarbij mensen zijn gediagnosticeerd en ingedeeld in subgroepen. Op basis van de subgroep hebben zij een interventie aangeboden gekregen. Mensen met insuline resistentie in de lever moesten afvallen (FGT), mensen met insuline resistentie in de spieren (IGT) kregen een ander dieet en een combinatie kregen een combinatie-interventie aangeboden.

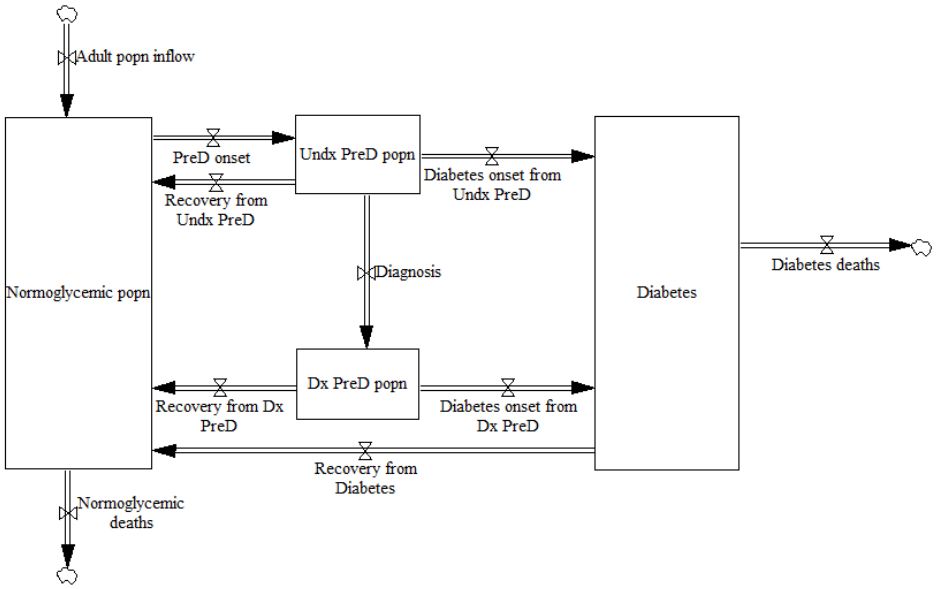


Figure 240 – Preliminary Model presented to Expert E