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CONSIDERING THE NEED FOR ALTERNATIVE INTERVENTION STRATEGIES FOR THE MANAGEMENT OF DIABETIC POLICY FORMULATION IN SOUTH AFRICA

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ABSTRACT

The increasing prevalence of diabetes in South Africa, alongside other non-communicable diseases, places a heavy burden on the health care system; especially when faced with the significant difference in quality of care between private and public health care, and the increased burden of disease.

This paper analyses various diabetic policies already implemented in South Africa, and considers the need to investigate alternative policies and intervention strategies to manage diabetes in South Africa. Due to the complex nature and non-linear interactions which exist within the health care system, a system dynamics-based approach is suggested as a useful analysis tool to evaluate and understand the dominant factors that influence the effective management of diabetes to potentially inform more effective and efficient diabetic policy formulation.

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1. INTRODUCTION

The increasing prevalence of diabetes mellitus (commonly referred to as diabetes) in the world is a widespread concern [1]. According to predictions by the International Diabetes Federation, the prevalence of diabetes is expected to globally increase from 415 million in 2015 to 642 million in 2040 [2, 3]. While improvement has been made in the epidemiology and management of diabetes in the developed world [1], the same advances have not been made in sub-Saharan Africa. Sub-Saharan Africa, similarly to the rest of the world, is experiencing an increasing prevalence of diabetes alongside other non-communicable diseases [3]. In South Africa, this diabetic trend is still emergent in a region confronted with high rates of communicable diseases, such as HIV, as well as Tuberculosis [4].

Additionally, diabetes plays a significant role in contracting several other (often life threatening) diseases [4]. These diseases include both non-communicable diseases, such as cardiovascular disease and renal disease, and communicable diseases, such as pneumonia and tuberculosis, which have a considerable impact on morbidity and mortality in sub-Saharan Africa [4]. In addition, the prevention and treatment of diabetes is a significantly complex process, involving numerous role-players and stakeholders (i.e. government agencies, the healthcare system, communities and diabetic patients). It is, therefore, necessary to also consider diabetic health care in South Africa from a complex, system's perspective, with significant non-linear interactions. With the increasing burden of disease in South Africa, as well as limited resources and the complex, dynamic nature of the healthcare system, it is unsurprising that the prevalence for diabetes in South Africa continues to increase [1, 4].

In order to highlight the need to investigate alternative diabetic intervention and management strategies, this paper draws focus on (i) the South African health care system, (ii) diabetes in South Africa, (iii) policy and intervention strategies, and (iv) modelling techniques and approaches that could be utilised to model and subsequently evaluate complex systems. At the onset of the paper, an analysis of the South African health care system is presented to provide context for this paper, wherein the efficiency of the system, as well as the inequality between the public and private health care system and increased burden of disease, are discussed. The paper then focuses on specific aspects of diabetes in South Africa, such as the disease itself and the growing prevalence within the country, after which a discussion of the financial implications and management of the diabetes within South Africa highlights the need to address diabetes from the perspective of diabetic management intervention strategies.

The focus of this paper then shifts to a discussion of the approach used during policy analysis. An analysis of South African diabetic policy and intervention strategies is then presented, together with requirement specifications developed as an outcome of this analysis. These requirement specifications develop a need for a specific modelling technique, given the context, to analyse policy interventions. Thereafter, this paper introduces the concept of simulation modelling, where appropriate modelling approaches are discussed and evaluated so as to determine which approach most comprehensively meets the needs of the requirement specifications. Finally, this paper motivates the need to consider alternative intervention strategies for the management of diabetic policy formulation in South Africa by drawing on key points discussed throughout the paper.

2. SOUTH AFRICAN HEALTH CARE SYSTEM

During the past two decades, the South African government has aimed to improve the condition of the public health care system by outlining a clear model with a focus on primary health care (PHC) [5]. PHC, in the case of South Africa, refers to the first line of health care that a patient receives, at either a clinic, community health centre or district hospital, which may include the treatment of a disease, referral to more specialised care if required, and prevention through health education aimed at individuals, families, and communities [6]. The inadequacy of PHC available to the majority of the South African population during the apartheid era, however, led to a significant disproportionate excess of serious health problems and challenges, which was manifested in higher infant mortality rates, as well as lower life expectancies [5]. While the post-apartheid government has since developed a primary-centred health care model aimed at all South Africans, the quality of PHC in South Africa remains challenge-stricken [5].

In order to comprehend the current state of the South African health care system, it is necessary to investigate the efficiency of the system to provide health care for the South African public. Furthermore, the inequality between private and public health care, and the increased burden of disease experienced in South Africa, needs to be analysed to develop context for this paper, and is discussed in the sections below.

2.1 Efficiency of the health care system

In 2014, *The Economist* reported on a study that performed a 166-country health outcome report comparing the health care performance and spending patterns of various countries [7]. Figure 1 displays a plot that ranks the health outcomes of a country versus the ranking on healthcare spending for each country. The outcome measure was a combined function of (i) adult mortality in 2012, (ii) life expectancy at 60 years of age, (iii) disability-adjusted life years, and (iv) health-adjusted life expectancy. This study found that health outcomes were directly correlated with healthcare spending [7]. According to the study, a country with a high ranking for healthcare spending should be expected to have a high ranking for healthcare outcomes. It is, therefore, contradicting to this trend that while South Africa ranks high in terms of spending, it is ranked significantly low in terms of healthcare outcomes.

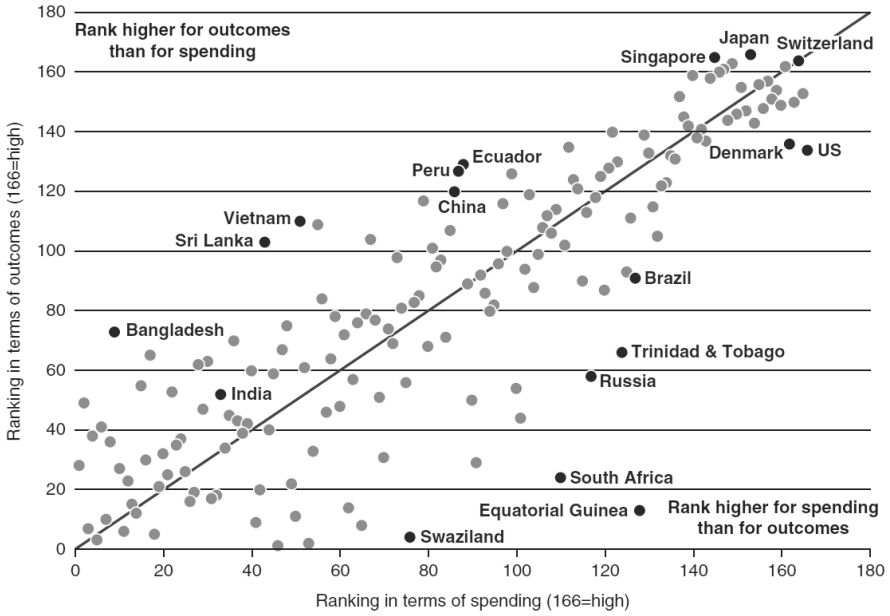

Figure 1: Health outcomes rank versus spending rank by country [7]

This result is echoed by the *Future Health Index* study, commissioned by Dutch technology company, Philips, which examined the current realities of how well the healthcare system of a country is set up for the future in order to quantify the readiness of health systems [7]. The results of the study ranked South Africa last among 19 nations in a global survey which measured healthcare system efficiency — the ability to deliver maximum results at the lowest possible cost. The study included countries such as China, France, the United States, Argentina, United Arab Emirates and Brazil, and whereas the group scored an average efficiency score of 10.5, South Africa achieved an efficiency score of 4.4 [7].

Maillacheruvu [5] argues that the quality of PHC in South Africa is challenged by two major issues: the inequality between private and public health care, and the increased burden of disease experienced in South Africa. Maillacheruvu [5] further argues that by addressing these issues, the health care outcomes of South Africa may be significantly improved. It is suggested that the inequality between public and private health care, as well as the increased burden of disease, is augmented by the historical struggles induced by the economic, political, and societal structure of the apartheid era [5]. These two issues are addressed in the respective sections to follow.

2.2 Inequality between private and public health care

Health care in South Africa varies from the most basic PHC offered by the state, to highly specialised health services available in the both public and private sector [8]. In 2015, the total health expenditure (THE) per capita was USD 570, where the THE formed 8.9% of the South African GDP [9]. According to the National Treasury's Fiscal Review [10], the South African GDP spent on health was split between the private health sector (48.5%) and the public sector (49.2%). The remaining 2.3% was donated and spent by NGOs. While the private and public sector both receive a similar share of the GDP for healthcare, the private healthcare sector only

services an estimated 16% of the population, while the remaining 84% of the population relies on public healthcare services [10, 9].

In addition to the disparate patient populations between private and public health care, the number of health care providers within each system is also disproportionate. The World Health Organization estimates that only 30% of all South African physicians work in the public sector, despite the public health care sector serving 80% of the population [11]. The relatively lower number of health care providers, along with the increased number of patients in the public health care system, results in an overburdened public care system, when compared to the private sector. It is also argued that public health care workers are, in turn, overworked and thus, making it challenging to provide the same level of personalised services when compared to the private sector [12]. This is clearly evident in a study conducted at Tafelsig Clinic by Maillacheruvu [5], where clinicians were often overworked, and were unable to provide the health care needed to serve all the patient present at the clinic [5].

In addition to the disproportionate number of health care workers in the public and private health care sectors, the economic divide between the rich and the poor, also contributes to the persisting inequality between the two health care sectors. To further illustrate the extent of the inequality, it was reported in 2007 that South Africa had the world's 10th highest Gini index at 0.578, which is a measure of income inequity among a nation's population [13]. The economic divide in South Africa has created a separation within the national health care system, and, as a result, has developed a considerable discrepancy between the resources used by public health care and the private sector.

Another consequence of the economic divide between public and private health care is the poor usage of the health care referral system [14]. Referrals between public clinics, community health care clinics and district hospitals are standard practice [15]. The referral system begins at PHC clinics as the first step in the provision of health care [7]. If the clinic cannot assist, the patient will be referred to a community health center, as the second step in the referral system. The third step in the provision of health care is the district hospital. Thereafter, patients may be referred to secondary, tertiary, or quaternary level of care [7]. It was, however, noted by Mojaki [14] during a study conducted at the Dr JS Moroka District Hospital in the Free State, that the majority of patients seen in the outpatient department and casualty had bypassed the referral system by means of self-referral. More than 50% of these patients could have been managed at PHC clinics or community health centers, which is similar to study findings of Rutkove [16] at King Edward VIII Hospital in Durban. Long waiting times (close to 6 hours) in the hospital may have been reduced if patients were managed at their nearest PHC facility.

Mojaki [14] found that the primary reason for patients bypassing PHC facilities was their perception of the superior care and resource availability at hospitals. This perception may be rooted in the inadequacy of PHC available to non-white South Africans during the apartheid era. Other cited reasons included dysfunctional community health centers and lack of education about the referral system among patients and health professionals. In addition, less than 2% of patients were educated on the referral system, and none had been charged the bypass fees, despite a provincial policy. Mojaki [14] argues that the tendency of patients to bypass PHC facilities disrupts hospital's core functions and is linked to the overcrowded outpatient department in these hospitals.

It may, therefore, be seen from the studies at Tafelsig clinic and Dr JS Moroka Hospital, together with the plethora of other health care facilities facing almost identical situations throughout South Africa, that the overburdened public health care facilities have an insufficient number of health care providers needed to fulfil the personal, community-based values of the PHC model outlined in the National Health Bill.

2.3 Increased burden of disease

Along with the economic divide investigated in the previous section, another defining characteristic of the public PHC system of South Africa is the considerable array of long-term diseases that providers must treat. This, in turn, minimises the available time allocated to other aspects of PHC, which includes counselling and prevention through education [5]. Communicable diseases, such as HIV/AIDS and Tuberculosis (TB) are widespread in South Africa, but non-communicable diseases, including hypertension and diabetes, are growing in prevalence [17]. With more chronically-ill patients, public PHC facilities are under significant strain to dedicate sufficient resources to assist all patients.

The most considerable health problem that South Africa faces is the combined HIV and TB infection rate [18]. In 2011, the prevalence of HIV among South Africans aged 15-49 years was 17.3%, which is among the highest in the world [18], and, in 2014, TB was the leading cause of death in South Africa [18]. Additionally, individuals affected by HIV/AIDS are more susceptible to other infections, such as TB, due to their compromised immune systems. In fact, individuals who are HIV positive are ten times more likely to develop TB [19]. Treatment methods for TB exist and are readily available, but require a strict treatment regimen that may last up to six months, and may necessitate multiple visits to a clinic per week [19]. The prolonged period required to treat TB increases the burden of communicable diseases on PHC facilities, and also decreases the likelihood that patients will complete their recommended course of treatment [18].

Statistics South Africa [20] recently released a report on the top ten leading causes of death in South Africa, based on all death notification forms maintained by the Department of Home Affairs. Although South Africa is afflicted with a high HIV and TB rate, the data, provided by Statistics South Africa, found that 55.5% of all deaths were attributed to non-communicable diseases and that diabetes was the second leading cause of death in 2015 after TB [8]. Furthermore, it has been reported that diabetes is the number one killer of women living in the Western Cape Province [21]. Potential associations between diabetes and TB, as well as HIV, may also further complicate the pattern of increasing diabetes prevalence in South Africa and the challenges posed on resource-constrained health systems. A recent meta-analysis of thirteen studies found that individuals with diabetes were associated with a three-time elevated risk of tuberculosis [22]. Furthermore, the high prevalence of HIV, as well as antiretroviral therapy treatment for HIV, may increase the prevalence of diabetes risk factors and, consequently, diabetes incidence [5].

Although once regarded predominantly as a disease related to the developed world, it is clear that diabetes now exerts a significant burden in South Africa, which is expected to increase [4]. Many diabetic patients face significant challenges accessing diagnosis and treatment, further contributing to the high mortality and prevalence of complications observed [1].

3. DIABETES IN SOUTH AFRICA

Global projections by the International Diabetes Federation (IDF) has shown that diabetes prevalence is expected to double from 285 million in 2010 to 592 million in 2035, with the sub-Saharan African region bearing the burden of this increase, and South Africa at the forefront [24]. Of the 14.7 million people living with diabetes in Africa [2, 3], approximately 11 million are found in sub-Saharan Africa, and 2.3 million in South Africa. Until recently, diabetes was considered uncommon in these regions, but due to demographic and lifestyle changes, diabetes is increasingly identified as a prevalent health problem [25].

This section firstly provides a brief overview of the diabetes disease. Thereafter, the prevalence of diabetes in South Africa will be explored. Consequently, the increasing financial implications of the disease is discussed. Finally, the section concludes with an analysis of the management of diabetes in South Africa.

3.1 The diabetes disease

Diabetes mellitus[4], or diabetes, is a chronic and lifelong condition which may affect the human body's ability to use the energy from ingested food. There are three major types of diabetes[5]: type 1 diabetes, type 2 diabetes, and gestational diabetes [3, 26].

[4]A variable disorder of carbohydrate metabolism caused by a combination of hereditary and environmental factors and is typically characterised by an insufficient secretion or utilisation of insulin, excessive urine production, significant amounts of sugar in the blood and urine, and by thirst, hunger, and loss of weight [3]. A number of medical risks are associated with diabetes, such as diabetic retinopathy, diabetic neuropathy, and diabetic nephropathy [26]. Furthermore, persons with diabetes have an increased risk of heart disease and stroke [26]. Treatment is required to maintain blood sugar levels within a target range, and includes taking several insulin injections every day or using an insulin pump, monitoring blood sugar levels and eating a healthy diet that spreads carbohydrate throughout the day [26].

[5] Type 1 diabetes is referred to as “insulin-dependent" diabetes and typically emerges during childhood. This variation of diabetes is an autoimmune condition, where the human body attacks its own pancreas with antibodies. After significant damage, the pancreas of a person with type 1 diabetes is be unable to produce insulin [4]. The most common form of diabetes is type 2 diabetes and accounts for 95% of diabetes cases in adults [3]. With the rise of obesity in children, however, type 2 diabetes is now being increasingly diagnosed in young people and teenagers [29]. In the case of type 2 diabetes, the pancreas is typically capable of producing some insulin. The insulin is, however, either insufficient for the needs of the body, or the cells of the body are resistant to the insulin. The final variation of diabetes is triggered by pregnancy, which is referred to as gestational diabetes, and occurs between 2% to 10% of pregnancies [26]. In contrast to type 1 and 2 diabetes, gestational diabetes typically resolves itself after pregnancy.

3.2 Diabetes prevalence in South Africa

Type 2 diabetes accounts for 90% of diabetes cases in sub-Saharan Africa, whilst type 1 diabetes and gestational diabetes constitute the remaining 10% [4]. The prevalence of type 2 diabetes has increased significantly from that recorded in pre-1985 surveys conducted within the region. These surveys found that the prevalence for diabetes in sub-Saharan Africa was typically below 1%, with the exception of studies in South Africa, where a 3.6% prevalence was observed [4].

Data from the IDF [2] estimates that, as of 2018, 7% of South Africans between the ages of 21 and 79 years have diabetes. Based on population estimates for South Africa, it is estimated that 2.29 million South Africans in the aforementioned age group have diabetes [6]. Of the 2.29 million people with diabetes, 1.4 million (61.1%) are undiagnosed [26]. Furthermore, it is estimated that an additional 5 million South Africans have pre-diabetes; a condition most likely caused by insulin resistance and results in blood glucose levels being higher than normal, but not significantly high enough to be classified as type 2 diabetes [3]. The highest prevalence of diabetes in South Africa is among the Indian population, with a prevalence of 11-13% [3]. This is followed by 8-10% in the coloured community, 5-8% among the black community, and 4% among the white community [3].

As diabetic symptoms may initially be extremely mild and develop gradually, combined with an ineffective PHC education intervention system in South Africa, many people fail to recognise symptoms as warning signs of diabetes [3]. In most cases, diabetic complications may have been avoided entirely by early diagnosis and proper treatment [3]. Due to the already considerable burden of disease in South Africa, however, the growing prevalence of diabetes may potentially be unavoidable and lead to increased strain on the already stressed health care system, as well as economic ramifications for South Africa.

3.3 Economic implications of diabetes in South Africa

In 2010, the cost per person with diabetes in South Africa per annum was approximated by the Centre for Diabetes and Endocrinology (CDE) as USD 405.52 [28]. The Society for Endocrinology, Metabolism and Diabetes of South Africa (SEMDSA) estimated that the cost per person with diabetes in South Africa per annum in 2015 increased to USD 918.9 [28]. This is consistent with the observed increased prevalence of diabetes in South Africa. As discussed in section 2.2, the healthcare spending per capita was equivalent to USD 570, which is significantly lower than the cost per person with diabetes in South Africa estimated by SEMDSA.

Furthermore, the estimated cost per diabetic person in South Africa is likely to be significantly lower than the actual cost, due to factors such as undiagnoses, the cost for diabetes prevention programs, over-the-counter medications required for diabetes-related eye and dental problems, and the cost of reduced quality of life, pain and suffering which cannot be measured directly [29]. The economic implications further extend to the public health care system, which may continue to be over burded by the potencial increase of diabetcis to treat. With the increasing impact of diabetes that is expected to occur, future health care spending for diabetes is likely to increase.

3.4 Management of diabetes in South Africa

In order to address the increasing financial and economic strain of diabetes in South Africa, the management of the disease needs to be considered. In South Africa, there are a number of private and public agencies, with a wide spectrum of strategies, in attempt to manage diabetes.

In the private sector diabetes landscape, there exists the CDE - a diabetes management solutions enterprise in South Africa [28]. Their mandate is to improve the health and lives of diabetics by means of various formal diabetes management programmes, partnerships with medical aid schemes, and the education and accreditation of healthcare professionals in diabetes care principles [28]. Additionally, a non-profit organisation, Diabetes South Africa (DSA), which was founded to be a support and advocate for all people living with diabetes in South Africa [30]. The DSA primarily acts as an advocate for diabetics in South Africa by lobbying for better facilities, cheaper medication and better health care services, as well as promoting prevention through public awareness of diabetes, and its symptoms and risks [30].

While a plethora of private agencies play a role in the management of diabetes in South Africa, the most prominent is agency is SEMDSA – a scientific society that aims to further the clinical practice, as well as promote both clinical and scientific research and publication, into all branches of endocrinology, metabolism and diabetes [26]. This society strives to promote acceptable standards for training and the professional practice of endocrinology, metabolism and diabetes as well as to provide advice, where necessary, regarding the academic standard of individuals and training units [26]. SEMDSA also aims to promote access to the provision of health care services and adequate treatment for all affected diseases related to endocrinology, metabolism and

diabetes, with particular focus on the poor and needy [26]. In 2017, SEMSDA released the *SEMDSA 2017 Guidelines for the Management of Type 2 diabetes mellitus* diabetic guideline to inform general patterns of care, to enhance diabetes prevention efforts and to reduce the burden of diabetes complications in people living with this disease, which is based on international best-practice [26]. The guideline addresses diabetes diagnosis, screening, diabetic lifestyle interventions, glucose management, comorbidities and complications, as well as focusing on special diabetic populations, such as children, adolescents, older persons, pregnant women [26]. It is, however, noted that this guideline only pertains to the care of adults with type 2 diabetes at primary care level [26].

In 2014, SEMDSA collaborated with the South African Department of Health (DoH) to produce the updated *Management of type 2 diabetes in adults at primary care level* policy guideline to manage diabetes from a public healthcare sector perspective [31]. The aim of implementing the updated guideline was to reduce diabetic complications, as well as to reduce premature mortality from diabetes. This formed an integral part of the Diabetes Implementation Strategy for South Africa, which was developed in response to the African Diabetes Declaration and Strategy of 2006 [31]. In this policy guideline, diabetes diagnosis, screening, glucose management, comorbidities and complications are addressed [31]. The policy, however, fails to address the treatment of diabetes at a level higher than PHC, or diabetic treatment for children.

In the 2013 *Strategic Plan for the Prevention and Control of Non-Communicable Diseases 2013 – 2017*, a listing of all the health care policies published by the DoH since 1998 are presented [32]. Prior to the 2014 *Management of type 2 diabetes in adults at primary care level* policy, only two other diabetic guidelines are listed – the 2005 *Management of diabetes type 1 and type 2 in adults at hospital level* and the 2008 *Guidelines for the management of type 1 diabetes in children* [32]. These two guidelines are, however, not publicly available. Kleinert [33] suggests that the content of South African health policy, as well as the poor documentation and availability thereof, is hampered by ineffective leadership, inexperienced and unaccountable managers, and a weak health system. In addition, both the 2005 *Management of diabetes type 1 and type 2 in adults at hospital level* and the 2008 *Guidelines for the management of type 1 diabetes in children* are only implemented as guidelines, as opposed to policy [32]. The 2014 *Management of type 2 diabetes in adults at primary care level* policy is, therefore, the most recent, publicly available diabetic policy implemented by the DoH at a national level and will be useful when considering the need to investigate alternative policies and intervention strategies to manage diabetes in South Africa. In addition, the *SEMDSA 2017 Guidelines for the Management of Type 2 diabetes mellitus,* while not published by the DoH, may prove to be useful in understanding the management of diabetes, as it is the most recently published diabetic guideline in South Africa [26].

In order to manage diabetes effectively in South Africa, the public health system should ensure that implemented intervention strategies and policies address the needs of diabetics at *all* levels of health care. This paper, therefore, argues that there is substantial need to investigate alternative policy and intervention strategies to inform diabetic policy formulation in South Africa.

4. POLICY AND INTERVENTION STATEGIES

According to Walt [34, 35], policy analysis is a multi-disciplinary approach to public policy, which aims to explain the interaction between the interests and ideas of the various stakeholders in the policy process, and may be useful a useful tool in understanding past policy failures and successes and planning future policy implementation.

As discussed in Section 3.4, it is crucial that policy and intervention strategies are developed, evaluated and implemented that ensures effective management of diabetic health care in South Africa. To further highlight this need, the methods of health policy analysis, as well as a brief overview of South African diabetic policy and intervention strategies, are discussed in the sections to follow.

4.1 Policy analysis approach

Walt [35] argues that health policy analysis typically focuses on the content of policy reform and neglects the actors involved in the reform, the processes required to develop and implement change, and the context within which the policy is developed. When a disproportionate amount of focus is placed on the content of a policy, attention is typically diverted away from understanding the processes, which substantiates why desired policy outcomes may fail to emerge [35]. Reich [36] argues that policy reform is generally a political process, which affects the inception, formulation and implementation of policy. Furthermore, policy-makers, whether politicians or bureaucrats, are acutely aware that reforms are often unpopular and may cause significant social instability [35].

From a policy-domain characterised primarily by consensus, health policy is increasingly subject to conflict and uncertainty. This encouraged Walt [35] to generate alternative ways of analysing policy. Walt argues that policy analysis from a systems perspective offers a more comprehensive framework for thinking about health reform, than approaches which concentrate on the technical features of the content of reform. Walt, therefore, suggests the use a simple analytical model, as shown in Figure 2, to conduct policy analysis. This model, commonly referred to as the policy analysis triangle, incorporates the concepts of context, process, content, and actors to allow policy-makers and researchers to understand the process of health policy reform better, and to plan for a more effective implementation.

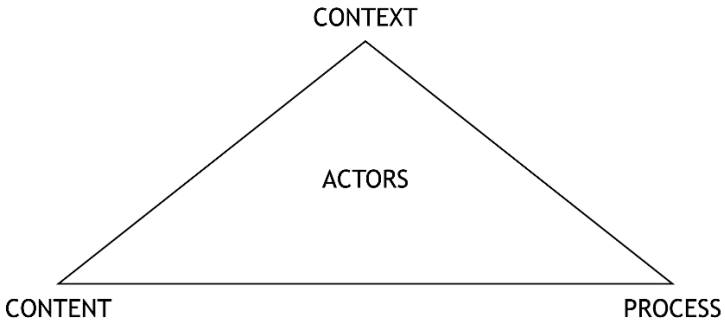

Figure 2: Policy analysis triangle [35]

The policy analysis triangle is a simplified model of a complex set of interrelationships. This model also considers the system as a whole, as opposed to each entity separately. This rationale may be observed as follows: *actors*, as individuals, members of interest groups, or professional associations, are influenced by the *context* within which they live and work. Context may be affected by many factors, such as instability or uncertainty created by changes in political regime, the economic standpoint of a country, social inequalities, historical experiences, or culture. The *process* of policy-making is in turn affected by actors, their position in power structures, their own values, and expectations of the policy. The *content* of policy may, therefore, reflect some or all of the above dimensions.

The traditional analysis focus on the content of policy, but neglects the other dimensions of process, actors and context, which may significantly affect the successful implementation of a policy [35]. In adopting the model, this paper argues that policy is not developed free of bias, but is rather the outcome of complex social, political and economic interactions, as well as non-interactions.

4.2 Analysis of South African diabetic policy and intervention strategies

As discussed in Section 3.4, two South African policy guidelines were identified to be in most prominant in managing diabetes in South Africa. The first of which is the *SEMDSA 2017 Guidelines for the Management of Type 2 diabetes mellitus* diabetic guideline — published by SEMDSA, a private organisation. The second is the 2014 *Management of type 2 diabetes in adults at primary care level* policy guideline — published by the South African Department of Health (DoH), a government entity. In order to understand these policy guidelines, a policy analysis is simultaneously conducted on both policies using the policy analysis triangle introduced in Section 4.1.

The policy analysis begins by considering the *actors* involved in both policies. In the context of the public policy of South Africa, it is observed that the policy was developed by the South African DoH with advice and direction provided by the SEMDSA Steering Committee and the Advisory Committee [26]. It is, however, noted that while these *actors* (the DoH and subject-matter experts) were acknowledged for their contribution to the policy, the consultation of diabetic patients, PHC clinicians, and community health workers were not mentioned. Public policy is, however, typically created in an open environment with free debate is subject to the force of law, whereas private organisations may develop their own policy based on the rules and regulations of their organisation without public accountability. This characteristic of private policy should to be considered when analysing the SEMDSA policy. While the *content* of the SEMDSA is based on international best-practice and the *actors* involved include the guideline committee (consisting of an extensive number of subject-matter experts), the public was not acknowledged as *actors* in this policy. Since there were, however, a significant number of subject-matter experts involved in the creation of both policies, as well as an external moderation process, the *content* of both policies may, therefore, be considered of a significantly high quality that meets international

best-practice. It is, however, viewed that the *content* of both policies is directed at adults with type 2 diabetes at primary care level, and do not address higher levels of health care, or other types of diabetes.

While analysing the *actors* involved, it is seen that diabetic patients, PHC clinicians, or community health workers were not actively involved in the policy-making process. The knowledge of the involvement of actors is vital when the *context* of a policy is considered. As described in Section 2.2 and 2.3, there is a large inequality between the private and public sector, and an increased burden of disease in South Africa, respectively. This has placed a significant stress on the PHC clinicians and community health workers, and, therefore, increases the difficulty of diabetics assessing sufficient health care. In addition, the poor usage of the referral system in South Africa, as discussed in Section 2.3, is extensively relied on in the public policy. Although the *content* of both policies should equip PHC clinicians to treat diabetics effectively, the *context* of the current South African health care system prevents PHC clinicians from providing sufficient health care to diabetics. Finally, the *process* aspect of the policy analysis is considered. While the South African DoH released and implemented the *Management of type 2 diabetes in adults at primary care level* policy guideline in 2014 to manage diabetes in South Africa, the prevalence of the disease has significantly increased, as discussed in Section 3.2. This may be similarly found for the policy released by SEMDSA.

From the above policy analysis, the following requirement specifications may be developed to investigate alternative intervention strategies for the management of diabetic policy formulation in South Africa by means of a modelling approach:

i. **Problem identification**: Does the modelling technique assist the developer in identifying the intervention strategies and actors within the entire system?
ii. **Non-linear and dynamic intereactions**: Does the modelling technique accurately investigate the effect of intervention strategies on the healh care system?
iii. **Flexibility**: Does the model adapt well to varied input data and changes to interrelationships?
iv. **Outcome accuracy**: Do the results of the model justify the computational intensity?
v. **Indication of effect over time**: Does the model provide the expected outcome of the system over a time period specified in order to model future predictions?

These requirement specifications may, therefore, be utilised in identifying an appropriate modelling approach to investigate alternative intervention strategies for the management of diabetic policy formulation in South Africa.

5. THEORETICAL MODELLING OF DIABETIC INTERVENTION STRATEGIES IN THE SOUTH AFRICAN HEALTH CARE SYSTEM

Complex, dynamic systems typically presents multiple non-linear interactions, and may, therefore, also act as barriers to solving problems by means of analytical approaches. In order to address the issues that arise in complex systems, Banks [37] recommend that a mathematical computational method, based on iterative algorithms, should be employed, and identified simulation as the most appropriate method to analyse and understand such systems. Additionally, Banks [37], as well as Borshchev [38], noted that the use of simulation allows for the behaviour of a system to be evaluated and predicted beyond that of the available data for time or space. According to Banks and Borshchev, simulation is the only practical means to test complex system models, and suggest that without simulation, even the best conceptual models may only be tested and improved by relaying on the learning feedback through the real-world. This real-world feedback is, however, slow and often rendered ineffective by dynamic complexity, time delay, inadequate or ambiguous feedback, poor reasoning skills, or the cost of experimentation [37, 38]. In these circumstances, simulation becomes the only reliable way to test hypotheses and evaluate the likely effects of interventions, such as policy.

In the section to follow, simulation modelling approaches will be introduced and discussed. Thereafter, the simulation modelling methods will each be evaluted, based on their ability to meet the requirement specification developed in Section 4.2, in order to identify an appropriate modelling approach to investigate alternative intervention strategies for the management of diabetic policy formulation in South Africa.

5.1 Simulation modelling approaches

According to Borschev [38], the three most commonly used simulation modelling approaches are system dynamics modelling, agent-based modelling, and discrete-event modelling.

System dynamics is a simulation method, which was first developed in the 1950s by MIT Professor, Jay Forrester, to examine and characterise the dynamics of economic, as well as social structures [38, 39]. It is suggested by Borshchev [38], that when using a system dynamics approach, that the most important notion is to maintain a point of view from within the system, and that it should, therefore, be viewed as endogenous. This view is achieved by modelling the system as a casually closed structure which, in turn, defines the system's behaviour [38, 40]. The next step is to identify the various feedback loops. Feedback loops can be thought of as circular causality in that they essentially continually recalibrate the system based on the state of other parts within the structure [38]. Feedback loops are considered the crux of systems dynamics. It is suggested that all the concepts in the real system should be defined as continuous quantities, interconnected in loops of information feedback and circular causality. Furthermore, the system dynamics approach involves identifying the different accumulations, or stocks within the system, as well as the flows that affect them [38].

Agent-based modelling is a modelling approach developed in the early 2000s as a result of the rapid growth of available CPU power and memory. This is in the light of the fact that agent-based models are more computationally demanding of both when compared to system dynamics and discrete event models [37, 38]. In agent-based modelling, a system is modelled as a collection of independent decision-making entities, called agents [38]. In this modelling method, each individual agent assesses its situation and executes various decisions or actions based on a set of established rules [38]. Borshchev [38] suggests that agent-based modelling is ideal when the simulation developer possesses insight into how the objects in the system behave individually, rather than knowing how the system behaves as a whole. The model may, therefore, be constructed using the bottom-up modelling approach, commencing by identifying objects or agents and defining their behaviours. This modelling method differs from the systems dynamics approach, which develops a model through means of a top-down modelling approach [38].

Discrete-event systems are systems where specific state changes or events occur at discrete instances in time and that no state change takes place in the system between these events. Systems that are defined by occurrences discrete events may be modelled using discrete event modelling [38]. According to Borshchev [38], the level of abstraction suggested for discrete event modelling is significantly lower than that of system dynamics modelling. Abstraction refers to the complexity by which a system is observed [38], and is an important consideration depending on the type of problem at hand. The highest level of abstraction considers the entire system in low detail, whereas the lower levels of abstraction normally investigate smaller system components in a higher level of detail. In discrete event modelling, each object in the system is represented by an entity or a resource unit at a low level of abstraction, whereas the individual objects in a system dynamic model are aggregated, and are therefore modelled as a high abstraction [38].

5.2 Evaluation of simulation modelling approaches

When considering which simulation modelling method is most appropriate to understand the influencing factors of various diabetic intervention strategies for the management of diabetic policy formulation in South Africa, the decision is primarily based on the type of system being modelled and the purpose of this system [38]. Borshchev [38], however, also notes that the selection of a modelling approach is often largely influenced by the skill set or background of the simulation developer. Another consideration when selecting the modelling approach may be the level of *abstraction*.

In order to select the most appropriate modelling approach, discrete-event modelling, system dynamics modelling, and agent-based modelling will each be evaluated based on the ability of the approach to meet the requirement specifications developed in Section 4.2. As the selection of a modelling approach is often largely influenced by the skill set or background of the simulation developer, 'ease of creation' is added as an additional requirement specification. Table 1 contains a summarised description of the three modelling approaches and their capacity to meet the requirement specifications.

Table 1: Summary of simulation modelling techniques [37, 38, 39, 40]

Attributes	Modelling approaches		
	Discrete-event	System dynamics	Agent-based
Problem identification	Very poor	Excellent	Poor
Non-linear and dynamic intereactions	Very good	Very good	Excellent

Flexibility	Very good	Very good	Very good
Outcome accuracy	Poor	Excellent	Good
Indication of effect over time	Very good	Very good	Very good
Ease of creation	Poor	Good	Very poor

Discrete-event modelling is found to be an inadequate approach for the intended modelling purposes, as this approach is better suited to model queuing systems and supply chains [38], whereas the intervention strategies for a diabetic health care system may be viewed as a continuous flow of resources and information. Furthermore, the discrete-event approach is typically focused on the on the details of a system rather than from a holistic system perspective [38], and may, therefore, be unable to identify the effects of the various intervention strategies on the system. This may not be ideal in the context of national health care, as the problem is almost always viewed at a high-level perspective. An additional shortfall of the discrete-event approach is that ease of model creation is poor [38].

System dynamics modelling, and agent-based modeling are identified the most appropriate modelling techniques to understand the effects of various intervention strategies to manage diabetic policy formulation given the requirement specifications, as summarised in Table 1. Agent-based modelling is, however, rejected for the purposes of this study, as this approach is better suited to model a system at a low level of abstraction [37, 38]. Consequently, in the case of agent-based modelling, the 'Problem identification' aspect is scored 'poor'. Although agent-based modelling is excellent at incorporating non-linearity in a system, it is significantly criticised for its poor ease of creation [37].

System dynamics modelling is, therefore, selected as the appropriate modelling approach based on the identified requirement specifications. As the South African healthcare system consists of a multitude of stakeholders, the effects of diabetic policy interventions would be more effectively modelled from a systems perspective [39, 40], therefore, scoring 'excellent' for the 'problem identification' aspect, as well as 'very good' for the 'non-linear and dynamic interactions' category. Furthermore, the system dynamics approach adapts well to varied input data and changes to interrelations, and also has the capabilities to provide the expected outcome of the system over a time period specified in order to model future predictions [39, 40]. In conclusion, system dynamics modelling will also provide a more holistic solution to understand the influencing factors of various diabetic intervention strategies in the South African healthcare context for the management of policy formulation.

6. CONCLUSION

The increasing prevalence of diabetes in the world is a widespread concern. While improvements have been made in the epidemiology and management of diabetes in the developed world, the same advances have not been made in South Africa. In addition, it was noted by The Economist that while South Africa ranks high in terms of health care spending, it is ranked significantly low in terms of health care outcomes.

The ability of the South African health care system to provide sufficient PHC has been constrained by several factors, such as the increased stress on the public health system, caused by the inequality between public and private health care, and the increased burden of disease in South Africa. Communicable diseases, such as HIV/AIDS and TB are widespread in South Africa, but non-communicable diseases, such as diabetes, are growing in prevalence. In fact, about 7% of South Africans have diabetes, and, according to the IDF, this percentage is only expected to increase. While public and private policies have been developed to address the growing prevalence of the disease, this paper argues the importance of implementing policy and intervention strategies which address the needs of diabetics, at all levels of health care, to effectively management diabetic health care in South Africa.

When a disproportionate amount of focus is placed on the content of a policy, attention is typically diverted away from understanding the processes, context, and actors of a policy, which explains why desired policy outcomes may fail to emerge. This paper argues that policy-making should not only focus on policy content, but also policy context, processes and actors, achieved in the triangle policy analysis. By applying this analysis tool to existing South African diabetic policies, requirement specifications were developed to identify a modelling approch to investigate alternative intervention strategies for the management of diabetic policy formulation in

South Africa. These requirement specifications include (i) problem identification, (ii) non-linear and dynamic interations, (iii) flexibility, (iv) outcome accuracty, and (v) indication of effect over time.

This paper argues that the South African health care system, together with diabetic policy, is a complex system, with non-linear and dynamic interactions, and the approach to analysing such a system should take the form of a simulation model. In order to select the most appropriate simulation modelling approach, three of the most commonly used simulation modelling approaches were evaluated based on their ability to meet the developed requirement specifications. System dynamics modelling was deemed the most appropriate modeling tool to provide the holistic approach to investigate the influencing factors of various diabetic intervention strategies in the South African health care context for the purpose of informing policy formulation.

In conclusion, this paper argues that there is justified need to investigate alternative intervention strategies for the management of diabetic policy formulation in South Africa, and that the most appropiate tool for investigation would be by means of a system dynmics modelling approach.

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