

Modelling epidemics: HIV/AIDS and COVID-19

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ABSTRACT

The purpose of the paper is to describe a systemic approach to developing models, particularly for epidemics. The author reflects on his pioneering work modelling the HIV/AIDS pandemic in Southern Africa. The paper has been written, however, in the midst of the Covid-19 pandemic. The paper therefore also discusses and compares these two pandemics and some of the challenges to modelling epidemics in real time. Some insights are also provided on modelling based on the disciplines of actuarial science, data analytics and systemic thinking.

KEYWORDS

Actuarial models, modelling, systemic thinking, data analytics, epidemics, HIV, AIDS, Covid-19

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1. INTRODUCTION

1.1 People often ask about my experience developing the original HIV/AIDS model, which later became the genesis of the Actuarial Society of South Africa (ASSA) AIDS model. I usually find this hard to answer, because I had so many different experiences.

1.2 However, in late 2019, Lusani Mulaudzi, the current president of ASSA, pressed me into really thinking about how the HIV/AIDS model came about; and how those experiences could inform the thorny matter of the “public interest” role of actuaries.

1.3 This paper describes, using the experiences from developing the HIV/AIDS model, a systemic approach to modelling, as published by Doyle & Millar (1990).

1.4 Shortly after I started writing this paper, however, the calamity of Covid-19 appeared globally. In a few short months its health, social and economic impacts far exceeded that of the HIV/AIDS pandemic and the world had changed almost overnight. Writing this paper suddenly took on a different perspective and urgency. The focus changed to include thinking more about data analytics and the modelling of epidemics in real-time.

1.5 The greatest British actuary of the last century, Frank Redington, once published a book called *A Ramble Through the Actuarial Countryside* (1986), which I still highly recommend reading. To borrow freely from the title of that book, this is not intended to be a technical paper, but it is rather my ramble through the countryside of epidemic modelling. Nevertheless, I hope that some of my insights into actuarial modelling, data analytics and systemic thinking will be useful.

1.6 There are many possible disclaimers to this paper; but I shall mention just three:

- Firstly, this is written with the benefit of hindsight and therefore reliant on my both imperfect and selective memory. I apologise if this paper conveys any inaccurate or inflated views of the work we did. After all, it was no less than Churchill who is reputed to have said to Stalin “History will judge us kindly (in the history of the Second World War), because I shall write the history”, and it seems that I am doing that now.
- Secondly, very little of the modelling the HIV/AIDS epidemic was my work alone as it was always a highly collaborative undertaking and I have tried to give the credit to others where it is due. I would like to thank everyone whose path I came across and who shared their knowledge and time so generously with me; it would never have happened any other way. I apologise to anyone to whom I have not given sufficient credit in this note.
- Thirdly, although I have not developed my own model for Covid-19, I have closely observed and worked with others working on models, be they actuaries, epidemiologists or data scientists. Although it is also too soon to do any meaningful analysis of modelling of the Covid-19 epidemic as it still plays out around the world,

I make some observations on the already apparent similarities and the equally profound differences between the modelling of HIV/AIDS and that of Covid-19; and in particular the importance of systemic thinking.

2. THE OBJECTIVE OF THIS PAPER

The objective of this paper is to discuss a systemic approach to developing models, especially models of epidemics, using as a case study the development of the HIV/AIDS model. The paper will also discuss some of the challenges of modelling, also in the context of the current Covid-19 pandemic.

3. WHAT IS THE PURPOSE OF A MODEL?

Insight: All models are wrong; some are useful. George Box (1978)

3.1 We build models to make sense of a complex world, to answer our questions about the uncertainties ahead, and to guide policy decisions to manage risks and seek opportunities. So at the outset of modelling, it is important to ask the right question: what is the purpose of this model?

3.2 Both data analytics and modelling exist to solve problems, or at least to ask the right questions that lead ultimately to problem solving. The tool set I was equipped with as a young actuary always pointed in that direction.

3.3 It has been said that actuaries are the original data scientists. While I don't much care whether or not we actuaries were the original data scientists, the important truth is that actuaries are data scientists; and modelling is core part of the data science toolkit.

3.4 One of the common links of all the subjects that I studied in actuarial science is that they have both people and mathematics at their core, perhaps one of my favourite descriptions of an actuary.

3.5 I was also fortunate to study my actuarial subjects within the context of a business science degree at the University of Cape Town. Not only did I come across other subjects and fields of study, I also worked with people outside of the actuarial world, both academic staff and other business science and economics students. This was to prove very useful in my working career, including in business, economics, and actuarial science and ultimately mathematical and systems modelling.

3.6 In all my actuarial subjects the question of "data" always came up. There were always the same questions about the data. What data? Whose data? Biased data? Clean data? Grouped data? Useful data? Accurate data? Filtered data? Relevant data? As well as the dreaded ... NO data! This was in a time when there was comparatively little data of any

description available, compared to today's many terabytes of data available at the click of a button.

3.7 In spite of the vast amount of data we now have at our disposal, it still seems to me that not many people really understand how best to use and therefore derive real value from data.

3.8 Actuaries are perhaps uniquely equipped to derive value from data; not only to process the data, but also to understand incomplete data; or data over time, both historical data and future data and hopefully apply that data to the real world. Because of the powerful combination of probability and compound interest, actuaries can see the data continuum, almost over time and space and therefore the unique insights data provides into reality.

3.9 As one looks into the future through modelling, there is the wonderfully descriptive "expanding funnel of doubt" that confronts the actuary. Actuaries are one of the few professionals who can look into these funnels of doubt and interpret both the time and probability dimensions of what is being seen, as well as spontaneously thinking about the risk management and risk mitigation approaches that could help deal with all the uncertainties.

3.10 Finally, data and modelling are not reality; they only just reflect reality, and sometimes poorly at that. In our work on the HIV/AIDS model, we were forced from the beginning to confront the reality that the data represented the sickness and death of many people.

4. THE CONTEXT MATTERS

Insight: The context always matters.

4.1 It is easy to misunderstand history without the context. South Africa was a tense and divided country ... far more so than today.

4.2 We have lived through eventful times in the history of South Africa, including the demise of apartheid, which will continue to be analysed and debated well beyond my lifetime. However, the context always matters and so I would like to touch briefly on that context and how it influenced the HIV/AIDS epidemic itself and therefore the HIV/AIDS model.

4.3 The HIV/AIDS epidemic started during the last decades of apartheid in South Africa. This was a time characterised by social upheaval, both civil and border wars, sanctions, misinformation ("fake news" is definitely not a new phenomena), distrust, political change, fear and hope (albeit sometimes only a little hope) for the future.

4.4 Inevitably, the HIV/AIDS epidemic became rapidly politicised, far more so even than Covid-19 in South Africa today. Rumours abounded. The narratives were similar to some of the extreme stances we see with Covid-19 today and everybody used "statistics" to prove

their point. Neither did it help that HIV was primarily a sexually transmitted disease and so racial, sexual and religious stigmatisation was the order of the day.

4.5 One of the ways that we managed to navigate past these complex issues was to consult very widely and, later on, to present our findings very widely, both to the old establishment and to the incoming leaders of the new ANC government, to both organised labour and to business; and to civil society.

4.6 Another significant problem at the time was sanctions. In the 1980s this was a real issue in South Africa and clearly one of the pressure points that forced change. It was difficult to travel to some parts of Africa on a South African passport. The southern African borders to our north were closed to most travellers, which itself had a complex impact on the spread of HIV infection in Southern Africa.

4.7 Even further afield one did not always feel welcome. The World Health Global Programme on AIDS did not come into South Africa until after 1994 and I had to travel to Zimbabwe and later to Switzerland to meet with their staff.

4.8 To balance all of the obstacles of the late 1980s, I was blessed to work in a remarkable company called Metropolitan Home Trust Life. Suffice it to say that Metropolitan was one of the most forward thinking and socio politically aware businesses in South Africa.

4.9 Metropolitan was, in many ways, a small ecosystem and perhaps prototype of the new emerging democratic South Africa, with courageous and visionary leaders. Although we did not always get transformation right, as neither does South Africa yet get it right, it was clear that we were (and still are) dealing with complex political and social changes.

4.10 However, our board members were not afraid to tackle these complexities head on. Some of those board members and executives have gone on to the most senior echelons of business and government in the new democratic South Africa.

4.11 One of Metropolitan's characteristics was that it truly engaged with its communities in which it did business; and if the HIV/AIDS epidemic was going to affect our clients, we wanted to know about it and do something about it. That full engagement later lead to a significant amount of Metropolitan's corporate social involvement and investment being focused on mitigating the impact of the HIV epidemic in southern Africa.

4.12 The industry body, the Life Offices Association (LOA) also had an AIDS committee, which I joined in the early days of my research. It was interesting, and I learned a lot, but its primary focus was on new business HIV testing and claims underwriting. The underwriting discussion was primarily about the wording of AIDS exclusion clauses.

4.13 Like many others at Metropolitan, I took exception to the use of exclusion clauses. They were discriminatory, difficult to enforce and failed the principle of fairness and equity. The financial consequences of misestimating our claims experience would also be devastating in the light of a possible HIV epidemic.

4.14 Many of our products were community rated and based on quick claims processing, often within 24 hours, which was essential for the families' financial security. AIDS deaths would almost certainly be under-reported, especially if the attending doctor knew that an associated insurance claim would be repudiated. Besides, most death certificates simply stated "natural causes" as the cause of death. Exclusion clauses were bound to fail and we were determined not to rely on them.

4.15 Much later on Metropolitan also pioneered several innovative products that managed the risks for both the clients and the company in the face of an HIV/AIDS epidemic, including one of the world's first products to provide life cover specifically for HIV-infected people.

4.16 The only previous epidemic from which we could draw insight was the 1918 Great Influenza epidemic. The company had had, at that time, queues of claimants standing around the block outside the head office. It was even reported that people in the queue collapsed themselves from the flu. In the face of this apparent onslaught, the board at the time nevertheless decided to honour and pay all claims.

4.17 This entire context provided the compelling business and actuarial reasons to develop an HIV/AIDS model and I proposed to our board that is what we needed to do. But I had made an undertaking that I had no idea how to fulfil.

4.18 The other really important implication of this context was the decision to build a model for the whole of society and not only for insured lives. This decision had a profound impact on the model design, the scenarios and the ultimate model applications.

5. OTHER MODELS

Insight: A challenge is a good starting point.

5.1 There were two distinct reasons why I wanted to model the HIV/AIDS epidemic. One was the business context described above. However, the other reason was a natural, scientific, actuarial curiosity.

5.2 I had become frustrated by the obviously speculative nonsense being published at the time about the HIV/AIDS epidemic, mostly pseudo-science and most of it sensationalist. Some of it was even based on "models". I could be writing about Covid-19 too, for that matter.

5.3 Then two authors, widely quoted at that time, forecast “doomsday” in Africa, predicting that HIV/AIDS would infect at least 50% of the entire African population. Their models used simple exponential doubling times of HIV infection, until it reached the 50% level. Knowing full well that nobody would believe a forecast of an infection rate of 100% in the following year, they conveniently stopped their models at 50%.

5.4 One author even went so far as to state categorically that 50% of the population in Africa would be “dead or dying by the year 2000”. A notorious TV documentary, from the BBC no less, suggested that Africa was becoming depopulated and showed aerial images of empty rural villages. Although never proven, these villages were probably empty as the result of war or famine, or both, but certainly not HIV/AIDS.

5.5 There were others, of course, particularly in the business sector, who said that the threat of an HIV/AIDS epidemic was being overstated, that it was even a myth that HIV caused AIDS; and so some of the seeds of the later disastrous AIDS denialism were being sown. I could again be writing about Covid-19 too, for that matter.

5.6 Working through these wild speculations was a serious challenge to a young actuary trying to understand how to manage the risk of an epidemic?

6. APPROACHING HIV/AIDS SYSTEMICALLY

Insight: The key decision in modelling a complex system is at which level of the system to anchor your model.

6.1 The first signs of an epidemic of AIDS cases in South Africa arose from imported HIV infections. This was years before a larger community-spread HIV epidemic took hold. This phenomenon is being echoed today with Covid-19. AIDS cases were also seen worldwide long before it was understood that this was a viral epidemic of HIV infection. Or before medical science even knew HIV existed, which happened only several years later.

6.2 There were many issues to be understood, even long after the HIV virus itself was discovered, including testing protocols, modality, causality, susceptibility, risk co-factors, definitions, etc. I spent many days getting to grips with the science of epidemiology itself, let alone the HIV epidemic. The amount of misinformation was huge, caused by a lack of knowledge, both worldwide and locally, but also due to the stigmatisation of HIV and AIDS.

6.3 Most published models, including some from actuaries in the UK and US, were based only on reported AIDS cases. Virtually all of them simply fitted an exponential s-curve to the reported AIDS cases. It became obvious to me that was a futile approach for South Africa, which posed just too many problems, not least due to the known under-reporting of AIDS cases. Those models clearly suffered from a data problem.

6.4 Firstly, it was well known that AIDS cases were significantly under-reported for a variety of reasons. Secondly, there was little data on when AIDS patients had become HIV-infected. What did the pattern of disease progression look like? The early AIDS cases gave no idea of the long tail of further possible AIDS cases from people already infected and still in the very long asymptomatic stages of the disease. Finally, there was little known about the likely morbidity and mortality of a cohort of HIV-infected people.

6.5 I therefore decided to approach the modelling of the spread of HIV infection systemically. I decided first and foremost to find and understand the data on the spread of HIV infection. This was probably the best decision I made about the model. The real epidemic was that of HIV infection, but nobody had tried to model that epidemic yet.

7. THE SCIENCE OF HIV INFECTION

Insight: Go deep into the science, even if, and especially if, it is in another field to your own.

7.1 The medical science of the HIV/AIDS epidemic was still in its infancy. New findings seem to be published every week. The tests used and the testing protocol for HIV was evolving. The exact mechanism that HIV used to impair the immune system was still being understood. The definitions used for an AIDS diagnosis changed. The modes of transmission, and, importantly, the co-factors of HIV infection were still being researched. New data was being published every week on levels of HIV infection and incidence. Sentinel studies of HIV infection were just being developed.

7.2 I made two very useful decisions at that time. One was to really understand the data and so I spent a significant amount of time talking to medical scientists and other medical professionals to understand HIV itself and HIV testing protocols. The second decision was to ignore almost completely the numbers and forecasts being quoted in the media at the time.

7.3 We need a brief digression into understanding HIV data. The initial tests for HIV were all antibody tests. It was only much later that PCR and other tests to identify the virus itself were introduced. This is exactly opposite to how tests have happened with Covid-19 where it is the science of antibody testing that is still lagging. It surprises me how little population surveillance testing has been done for Covid-19, with all the reliance being placed on PCR testing which is probably better used in a clinical setting. This is one of the key data problems that Covid-19 modellers face today.

7.4 In order to understand any HIV test results, the testing protocol mattered a great deal. Why the tests were being done? Who was being sampled? Who was doing the tests? Where were the tests being processed? Was the sampling anonymous or clinical? Was there pre-screening before the test samples? Was there bias in the selection? Which specific HIV test was being used? Was it a one-step or two-step Elisa test? Were there confirmatory Western

Blot tests? Were the results scientifically published? Was the data from a sentinel survey? Were the tests being repeated? Was the same testing protocol being used? Which specific strains of HIV were being tested? Did we know who produced and published the results? Was the publication peer reviewed? Every one of these questions mattered and this helped us to discern how to use the myriad of data that later came across our desks.

7.5 In many cases I travelled to meet the people conducting these tests. To recount all the meetings would be tedious, but I had many face-to-face meetings with doctors, scientists and laboratory technicians. I visited hospitals, AIDS clinics, medical schools, medical researchers, all the provincial and national blood transfusion services, the big mining groups and the Chamber of Mines (all of whom had both insight and much interesting data to share) and university academics.

7.6 Most of this happened before I designed the model. The most significant benefit was that I gained a deep understanding into the nature of HIV and HIV infection before I really gave serious thought to the model design. Furthermore, it allowed me to rapidly sift through the otherwise bewildering array of HIV data being published at the time. As a result, I used HIV data only if:

- It was scientifically published data or I personally knew who was doing the research and I could assess its scientific value myself (in the early years, my data was much more of the latter).
- The selection bias was clear to me (all data has a bias).
- The testing protocol was known and documented.

7.7 These decisions all proved very helpful in practice.

7.8 Finally, although my focus was South Africa, I also found useful data in Namibia, Botswana, Zimbabwe, Mozambique and Malawi. I travelled to Zimbabwe to meet with the head of the Global Programme on AIDS of the World Health Organisation (they were embargoed from visiting South Africa at that time). All this gathered data, together with the widely published Kenyan data, formed one of the cornerstones of our model design.

8. COLLABORATION AND MORE DATA

Insight: Seek first to understand the reality behind the data before developing a model that can be useful.

8.1 Other actuaries and several people from other disciplines had helped me to start thinking about a model.

8.2 One such actuary who I worked with closely, and who stands out as the first actuary to generate in me a real awareness of the public interest, was Paul Truysen. He had an

exceptionally good insight into the role of the actuary, the role of business and the public interest at large. In addition to being a broad thinker, Paul was also technically very strong and the one who would most often challenge my thinking in the early days of grappling with the AIDS epidemic.

8.3 Another actuary that helped me the most at that stage was Douglas Keir, the country head of Swiss Reinsurance in South Africa. Doug introduced me to a number of people, all outside of the actuarial profession, who were working in the medical and scientific field. We collaborated with many of these professionals for many years, particularly as later our modelling work started to become useful to them as well.

8.4 Several of the other large South African life insurers had large books of business in other Southern and East African countries, where the HIV epidemic was significantly ahead in time of that in South Africa. I initially proposed that we extend the ASSA's Continuous Mortality Investigation into a prospective model of data, using claims data from other neighbouring countries. We came very close to doing this, but eventually all of the other life offices declined to submit any of their data.

8.5 That was the point at which I took the idea back into Metropolitan to develop a "first principles" model of the epidemic. So I needed to understand the science first.

8.6 It is hard to imagine now, but when we were working on the HIV/AIDS model, there was no Internet, no Google, no laptops and no mobile phones. I relied primarily on faxed copies of articles in various medical journals, the print media, telephone conversations ... and many flights. Virtually all of my contact with people was face-to-face and I travelled to see most of them in their own offices or hospitals or laboratories; only later also at conferences and meetings.

8.7 Many of these were remarkable meetings, still etched in my memory. To recount all of these meetings would take many pages, but my learning curve became exponential at that point and I learned something, or many things, new from each meeting. Many of these people were at the forefront of the medical and scientific research in Southern Africa.

8.8 At every meeting I always asked the same three questions. Do you have any data that could be useful? (Most people said "yes" and I gained another vital piece of data). Who else should I talk to? (Most people gave me another link in the chain of knowledge). Is it possible to model the AIDS epidemic? (Everybody said "no"!).

8.9 A few of these meetings are worth recording because of the insights they brought to me.

8.10 Memorably, Doug and I met with Prof Reuben Sher who ran the South African Institute of Medical Research AIDS clinic in Hillbrow, Johannesburg. At one point we asked Prof Sher how many AIDS cases he knew about in South Africa at that time. He opened his desk drawer, took out his case files, and started counting them. In total he counted 24 cases; probably some of the first known AIDS cases in South Africa. He also knew about a few being treated in Cape Town. Doug asked Prof Sher about the demographics of those cases but, other than them all being male, he had no further information. Arising from that meeting and for several years Doug's office compiled the statistics and demographic reports of AIDS cases in South Africa on behalf of Prof Sher. This was the first data set I could work with.

8.11 I then obtained results from the first studies on HIV prevalence among antenatal women in South Africa, including one from King Edward Hospital in Durban where the HIV prevalence was just 0.2 %, doubling in eight months.

8.12 In Durban I met Drs Salim and Quarraisha Abdool Karim from the Medical Research Council (MRC). They were working on malaria research in rural Kwazulu-Natal, onto which they had added an HIV surveillance study (Abdool Karim et al., 1992). Their study was the first to identify and track differences in the urban and rural epidemics in South Africa. More importantly, they noticed that rural levels of infection were higher nearer to major transport routes, such as the N3 and the N2. Prof Salim Abdool Karim is now chairperson of South Africa's Covid-19 ministerial advisory committee and is dealing with yet another epidemic.

8.13 I noticed how dependent the spread of HIV was on transport routes, and the link from Durban to Richards Bay then through to sub-Saharan Africa became suddenly clear. That is why the epicentre of HIV infection was in Durban, not Johannesburg (something similar is happening with the Covid-19 epicentre being in the Western Cape, not Gauteng; this time due to the Cape being the tourist hub of South Africa. Thereafter the focus moves to Gauteng because of its population density).

8.14 After reading some of his papers (Schoub, 1988), I went to meet Prof Barry Schoub who was the head of the National Institute of Virology (now the NICD). It was through meeting him that I started to get a better grip on epidemiology and how epidemics actually spread and, in particular, how this was affected by social behaviour.

8.15 I visited researchers at the Baragwanath Hospital near Soweto and the General Hospital in Johannesburg. Furthermore much of the early HIV data in South Africa came from the provincial blood transfusion services and I visited every one of them in South Africa. Their initial data was excellent as they were screening blood donations for HIV infection. Their initial results were therefore closely representative of national data, with the country prevalence virtually zero, except for Kwazulu-Natal and Johannesburg; but later their data was no longer useful as they more aggressively screened out new donors.

8.16 I met Prof Ron Ballard, the South African expert in sexually transmitted diseases (STDs) at the medical school of the University of the Witwatersrand. I learnt a lot from him. That meeting impressed on me that other sexually transmitted diseases were really important, both being correlated with the spread of HIV, but also causative in the sense that the presence of other STDs increased the likelihood of HIV being transmitted.

8.17 This knowledge was something of a breakthrough in thinking about the model and it had several consequences for our work. Firstly, I spent much more time studying the data for other STDs and began to see some parameters for the potential size of the HIV epidemic. Secondly, the group of people with STDs became a key risk group in the later development of the model.

8.18 I also went to see the Chamber of Mines and a few of the major mining groups. They were helpful with data sourced from the mines' own hospitals and STD clinics. They also initially published data on the HIV prevalence by country, as their mineworkers came from all over Southern Africa. That data later proved useful in calibrating some of our parameters.

8.19 Perhaps the most helpful source of both knowledge and data and on-going scientific collaboration was within the MRC. There were many excellent people I met at the MRC, such as Drs Malcolm Steinberg, Robert Schall, Olive Shishana, Debbie Bradshaw and others. Robert Schall did some initial modelling and he later published a theoretical model together with Dr Nicky Padayachee, the Johannesburg Director of Health, but by that time we were well into testing our scenarios.

8.20 Many other contacts proved immensely helpful in understanding the science and, increasingly, the social impact of HIV and AIDS. Importantly, every contact gave me better insight into the data of HIV infection.

9. DESIGNING THE MODEL

Insight: Accumulate and mull over the data. Draw the system. Build the model.

9.1 The most curious thing that happened was drawing out the final model design. I had spent over a year researching HIV/AIDS and I was nowhere near to producing an actual model, which I had promised to do.

9.2 A real breakthrough in my thinking had come from my meeting with Prof Schoub. That meeting was a "light bulb" moment for me in my understanding of epidemics, as Prof Schoub described how an epidemic proceeded through a population via the different susceptibility of risk groups. It then became more obvious to me how to approach the model, firstly when I saw the line of connection epidemiologically, but more importantly when I understood the connection to the data that I was gathering.

9.3 Not long after that, in early December when our offices were normally quiet, I closed my office door one morning and set out to design the HIV/AIDS model. Just pencil and paper. The first version did not fit onto an A4 page, so I took a card folder and opened it out to an A3 size, and in about two hours I drew out the model design. I acutely remember the process and being rather surprised at what I had put down on paper, which had not yet been fully formulated in my head before I started it off that morning. I still have a copy of that diagram (the original is in the offices of the ASSA). That specific creative process has happened a few times in my life and seems to work well for me.

9.4 That design process can best be summarised as: Learn ... Think ... Design ... Repeat.

9.5 Later I came to recognise this process as systemic modelling, more than mathematical modelling. Our original HIV model did not have a single differential equation or stochastic process in it, which is possibly why it proved so robust over the years.

9.6 The other insight that I gained then was that a model should not be too complex. It is, after all, a model, or simplification of the real, complex world. Making it too complex requires too much data and therefore too many assumptions. The secret is to have a model that explains the key features of the issue, but not too complex that it explains nothing at all.

10. KEY MODEL DECISIONS

Insight: Plan the model design systemically, before plunging into the mathematics.

10.1 A short technical digression into the mechanics of the model and some of the key design decisions and brief notes thereon may be useful.

10.2 Probably the key decision was to build an HIV infection model first and derive AIDS cases from those infections; this was not common practice at the time.

10.3 HIV prevalence data became my main source of information, whereas there were significant problems with reporting of AIDS cases. Only much later did better AIDS case reporting start to reflect the model results.

10.4 The core of the model was a basic population model using standard demographic factors such fertility, aging, mortality and other demographics.

10.5 HIV infection was modelled using four different groups at risk to HIV infection with different levels of susceptibility to infection, derived from known data, especially other sexually transmitted diseases. We also developed an algorithm for how these risk groups interacted, which proved very useful and became a key determinant in projecting susceptibility throughout the whole population.

10.6 Provincial and other sub-populations then could be aggregated to total populations. This feature was also used to examine urban, peri-urban and rural differences.

10.7 Imported (seeded) HIV infections. This was a major unknown factor and we vacillated over this for a long time, until we realised that the actual numbers did not really matter once local community spreading become dominant. All the imported infections did was give the starting point to epidemic spread and we had enough data to estimate when that was.

10.8 Deterministic assumptions were used throughout. This simply meant that we designed the model with parameters that could be verified in the field. Initially, while little was really known, as the epidemic and data progressed we could better validate and fine-tune our assumptions.

10.9 Given its deterministic nature, the focus then became fitting results to the observed data and more of a curve-fitting exercise. Note also that because of the risk groups we had chosen, we could apply almost any set of HIV prevalence data to improve the model fit.

10.10 Most of the initial data we used came from urban areas of other English-speaking sub-Saharan countries. Using primarily antenatal prevalence data, I estimated the time in years that other countries were ahead of the HIV infection curve compared to South Africa. We could then apply a time-lapse to the data, so that again any new data sets we obtained from these countries could be used to improve the model calibration. Some cities in Africa seemed to be up to seven years ahead of South African cities.

10.11 Every projection came with a set of scenarios, based on what would be known today as non-pharmaceutical interventions. In the initial scenarios we never anticipated the emergence of treatment and anti-retroviral therapy, which proved accurate until about 2004.

10.12 Finally, the method of working was to establish a possible range for each assumption based on research and then to calibrate the model and assumptions to most closely match our very limited data set.

11. ACTUARIAL AND ORGANISATIONAL SUPPORT

Insight: Little that is useful in life is achieved on your own.

11.1 Throughout this paper I refer to “we” and it is time to talk about this team approach.

11.2 Bear in mind that in the 1980s modelling did not really exist as an actuarial discipline, or at least it was not mainstream actuarial work. As a result a number of actuarial students and younger actuaries at Metropolitan were rotated through the job of supporting me in this modelling effort.

11.3 Eventually all this collaborative effort and public interest work led to the formation of a fulltime AIDS research unit at Metropolitan. A number of these great people, several of who were actuaries, worked in the AIDS unit over the years.

11.4 First and foremost I worked with Donald Millar, a young actuarial student at the time. After I designed the model I asked Donald to code it and turn it into a working model, which he did. We also co-authored the paper first describing the model and the first series of published scenarios.

11.5 As I was a general manager in the business at the time, I did not have a personal computer (PC). The only people with their own computers were valuation actuaries and the executive secretaries who used them for “word processing”, correspondence and report writing. Every piece of information came to me as a printed hardcopy, even valuation reports and management information.

11.6 Getting access to sufficient computing power was a real issue. Fortunately my excellent secretary, Janine Toerien, had a PC on her desk for her word-processing work. So Donald and I decided to run the model on Janine’s PC, both because I had access to it and it also had a 20MB hard drive! The problem was that one single run of the model, that is one scenario, took up to 4 hours for a 20-year scenario. Donald was able to grab some time during the day on an actuarial departmental PC to develop the code, but we could only run our scenarios on Janine’s PC at night.

11.7 Our ritual was that in the late afternoon Donald would load up any new code and programming improvements to the model, we agreed the parameters for the next scenario and hit “run”. Next morning first thing I would grab the printout and see what we had got. The worst of times was when there had been a glitch in the software and the run had “bombed out” during the night; so, we would have to redo it again the following night.

11.8 This is relevant because it made us very disciplined in our testing. We would put a lot of thought into the next run and set of parameters. Often we wanted to test the model’s sensitivity to a single parameter change and we needed to be sure that the order of magnitude change was reasonable and did calculations by hand before we set off the run. In the morning after scanning the results, either we felt we were on the right track or it was back to the drawing board. We had to be very thoughtful, however, because many of the results were counter-intuitive, while we were still trying to understand the model, let alone the epidemic.

11.9 A good example of this was the incubation period from HIV infection to AIDS sickness, which was probably the major unknown factor. Initially we expected that a much shorter incubation period in South Africa, because the comorbidities would lead to a more severe and quicker incubation period. Not so! Instead it became obvious that a more rapid

onset of AIDS sickness reduces the pool of HIV-infected lives more quickly and so leads to lower incidence of new HIV infections and a smaller overall epidemic. That was a counter-intuitive finding at the time. It would have been easy to discard that as a random result the first time we saw it, but the discipline of only daily runs force us to think through the logic every time and we learnt a lot in the process.

11.10 After we published the first scenarios, that programming work was taken over firstly by Tjaart Esterhuyse and then later by Thomas Muhr. They significantly improved the robustness and integrity of the computer model and allowed for greater parameterisation of the scenarios. We produced two further sets of scenarios also reflecting possible non-pharmaceutical interventions, especially behaviour change. Those scenarios later became our own most useful set of scenarios and produced credible results right through to 2005.

11.11 Stephen Kramer then did great work on expanding the application of the models as well as looking more widely at other factors such as TB and other comorbidity factors. Desiree Daniels and later Gillian Nur Samuels, experts in corporate social involvement, also led the AIDS research unit for several years and I learned a lot from them too.

11.12 Nathea Nicholay did extensive work with organised labour and business and the economic and employment issues. And finally Lee Sarkin extended the work into many other aspects of data collection, healthcare systems and other public interest issues.

12. THE ASSA AIDS SEMINAR AND AFTERMATH

Insight: A bold step needs both courage and humility.

12.1 The ASSA decided to host a special one-day seminar on the AIDS epidemic in October 1990. Donald Millar and I decided to publish our results of the modelling for the first time at this seminar. We agreed on publishing results from single scenario, numbered 53. That was literally our run count. Over the approximately 8 months of development, we had been able to do 53 runs of the model and every time we had scrutinized the parameters and output in detail.

12.2 Then began the work of documenting how the model worked and why we were confident of our results. One of the key problems was that several of the datasets against which we had calibrated the model were not yet published data; and we could definitely not publish that data, as it was not ours to publish. Nevertheless there was sufficient data in the public domain to make sense of our results.

12.3 After we wrote the first draft of our paper, I gave it to the most senior actuary I knew who was one of my mentors. His feedback was that, while the paper was interesting, we should rather not publish it “because the results may be wrong” and that would be a setback

to my career. However, we were already committed to the ASSA seminar, and so we decided to take our chances and publish it anyway.

12.4 As the time for the seminar approached, the event seemed to get bigger and bigger. It was a one-day seminar to be held the day after the ASSA annual convention. Many people outside the profession, including the media, were invited to attend the seminar. I felt dreadfully unprepared to go public with our work. In the end the presentation at the seminar went well, but it generated a storm of interest far beyond what we had expected.

12.5 The most positive responses were from others working in the field of HIV/AIDS. Our network of contacts grew significantly and as a result we ended up in many other fruitful debates and collaborations. New sources of data and other technical papers were brought to our attention. We had entered a much more intense phase, both technically and publicly that has carried on for years.

12.6 The more difficult responses were for the media, who were asking questions that we mostly could not answer with any level of certainty. Many journalists also wanted to know what we thought of the other projections in the public domain. All we could do was point to our research as being somewhat unique in its approach but based on real data.

12.7 One of the consequences of the publication of our scenarios was a “model stand-off”. At the time there were about seven groups publishing the results of their respective AIDS models, and the government and the media were getting frustrated about the wildly divergent results of these models. All seven of us were summonsed to Johannesburg to present our models in a public forum. This seems eerily similar to the current world of Covid-19 modelling!

12.8 Of the seven, two declined to present on the day although they were present at the meeting. Two presented their work but said that they were just theoretical exercises and did not plan to continue modelling. We presented and then the two others decided to throw their support behind our model and collaborate with us; and so for all practical purposes ours was the last model standing at the end of that day. No winner was declared, but nothing more came of any of the other models after that day.

12.9 I have no problem with competing modelling work; so long as it stands up to scrutiny and peer review, all scientific data analysis and modelling enhances the overall collective understanding of the epidemic. Models by definition deal with the unknown and so model results should be presented accordingly with the necessary caveats attached.

12.10 However, what is clearly different today, in the time of Covid-19, is the sheer volume of data and research. Many papers are also put into the media before scientific peer review, because of the apparent urgency of everything related to the epidemic; but some of this

urgency is clearly counter-productive, because scientific errors creep into the analysis, leading to false assumptions and poor decision-making.

13. A REBUKE AND AN AWARD

Insight: The value of criticism depends on how you deal with it; dealt with soberly, it can even be useful.

13.1 Every four years Metropolitan sent one of its actuaries to the International Congress of Actuaries (ICA) hosted by the International Actuarial Association (IAA). In 1992 the ICA was held in Montreal, Canada and I was selected to attend that year.

13.2 Since I was going anyway, I decided to submit our paper on the HIV model as a scientific paper at the ICA. Getting the paper together in the format set out for publication was difficult and a rush, because it had to be submitted so long beforehand to allow papers to be printed for the congress.

13.3 In between the time we submitted the paper and the congress, the first published studies of HIV infection among antenatal women came out in South Africa and I took along graphs of these results in case anybody was interested. This proved pivotal in what transpired later at the ICA.

13.4 Each day of the congress had a plenary session in the morning devoted to technical papers from one of the practice areas. I expected nothing much to come of our paper, as there were many other excellent papers in the Life section. I was wrong on all counts.

13.5 There were too many papers for presentation each day, so the practice was that the moderator of the plenary session would summarise one or two papers and then talk about the overall quality and trend of papers in the section. The day dawned for the Life section, which included our paper.

13.6 To my surprise, the moderator, in front of what seemed like several thousand actuaries, started off by discussing only our paper, but not in a way that I had hoped. He was highly critical of our paper as an example the sort of work actuaries should not be doing. He said there was not sufficient actuarial content. There was insufficient data. Modelling was also not a traditional field of actuarial practice. Actuaries should stick to Life and Pensions. Furthermore, actuaries in the US had already tried unsuccessfully to model the epidemic and it was therefore futile for actuaries in a third world country like South Africa to think they could do any better! I was shocked, to say the least.

13.7 After the moderator had his say, the conference routine was that a couple of authors were chosen seemingly at random to go up front at the plenary session to discuss their papers.

We had been given strict instructions to watch the screen, as the names of speakers chosen to speak next would be put up on the screen. As the moderator finished lambasting our paper, I received a further shock to see my name up on screen as the first author to speak. Armed only with my overhead slides of the recent antenatal data and a few graphs, I marched up to the podium and I think gave a relatively calm and credible response to the chairman's criticisms.

13.8 This was one of my important formative professional learning experiences; if nothing else, it taught me how to deal with criticism. It also had the added benefit of giving prominence to our paper and several other actuaries came up to talk to me afterwards and seemed genuinely interested in our work. Welcome to the world of the international actuary!

13.9 Ironically I was President of ASSA in 2010 when South Africa hosted its first ICA in Cape Town. During his opening address, Yves Gérard, the Secretary General of the IAA said:¹

Over the past few decades, the Society experienced a number of interesting developments and challenges. One of these was modeling the AIDS pandemic. At the Montreal International Congress in 1992, a South African actuary presented a paper on an actuarial model applicable to the HIV pandemic in South Africa. This model saw a number of revisions and improvements, and the current version is known as the ASSA 2003 AIDS and Demographic Model. And, for those who did not know, the young South African actuary who presented the paper in Montreal is the current President of the Actuarial Society of South Africa. I was personally Chair of the Scientific Committee for the Montreal Congress and I can remember the interest that paper generated.

13.10 Yves Gérard was not the moderator of the plenary session I referred to earlier and I later went on to collaborate with Yves and many other excellent people within the IAA for many years.

13.11 Finally, the later award of the Murray Medal from ASSA in recognition of my work in the implications of the HIV/AIDS pandemic more than made up for my experiences at the ICA in Montreal.

14. THE ASSA AIDS MODEL

Insight: There comes a time to pass on the baton.

14.1 After publishing the HIV/AIDS model I served as the convenor of the ASSA HIV/AIDS committee for several years. The pressure on our modelling and public interest work grew, while the needs of actuaries to access the model also grew beyond what we could deliver.

1 Personal communication from Christian Levac at the IAA: christian.levac@actuaries.org.

14.2 I am therefore eternally grateful to Professor Rob Dorrington who finally persuaded us to make an open source version of the model available to the profession.² Starting in 1996, ASSA, under the leadership of Prof Dorrington, took AIDS modelling and the value of the model far beyond what we were probably capable of doing or could be discussed here.

14.3 Suffice it to say that ASSA also entered the fray just as the era of the South African government AIDS “denialism” was about to burst onto the scene in full force. A fuller analysis of the history of HIV/AIDS modelling in South Africa and how some of the early forecasts turned out, is beyond the scope of this paper. Furthermore the period of “AIDS denialism” by the South African government deserves analysis in its own right and is also beyond the scope of this current paper. However, see the excellent paper by Geffen & Welte (2018), which explores these important themes.

14.4 Other than recording that in early years after 2000 I had some robust engagements with the Minister of Health and her advisors at that time, as well as a meeting with the Cabinet’s AIDS Council, chaired by the then Deputy President, the brunt of the engagement with the government in the first decade after 2000 was borne primarily by Prof Dorrington and others.

14.5 Prof Dorrington also received ASSA’s Murray Medal in 2003, partly in recognition of his work on HIV/AIDS.

15. THINKING SYSTEMICALLY

Insight: Thinking systemically can reveal much more than numbers can; but numbers can illustrate the systemic thinking.

15.1 I would like to revert to the matter of systems thinking. Although actuaries are at heart systemic thinkers, it was only later in my actuarial career that I discovered the formal discipline of systems thinking.

15.2 I was first introduced to systems thinking by an Israeli scientist, Eliyahu Goldratt, who wrote a book called the *Theory of Constraints* (1998). We engaged Eliyahu to run a strategic project at Metropolitan, which included training on his theory. His approach was essentially the application of systems thinking to solve complex problems, which, of course, resonated with me as an actuary.

15.3 In fact, the vision statement of the International Actuarial Association (IAA) confirms this resonance when it states “Our vision as actuaries is to be the foremost profession in the

² Dorrington RE (2000). The ASSA2000 suite of models. Actuarial Society of South Africa Convention, 2000. Somerset West, South Africa. Available: www.assa.org.za/default.asp?id=1000000086.

management of complex problems and their associated risks and opportunities. Actuaries apply unique skills and a professional approach to solving complex problems, advising on future risks, opportunities and options, across diverse fields and industries”.

15.4 Systems thinking appealed to me as it synthesised a number of lines of thought and also helped to integrate many of the subjects I had studied. I now think that actuaries adopt a systems thinking approach intuitively in much of their work.

15.5 A modern example is the concept of the Own Risk and Solvency Assessment (ORSA) that actuaries apply in insurance companies today. An ORSA is simply a systemic view of the business and its capital requirements now and in the many possible futures.

15.6 Similarly, many actuarial models first start with a systemic understanding of the problem, before it gets reduced to some set of formulae. Unfortunately, real understanding can be lost in that translation to mathematics. A systems thinker, on the other hand, seeks not to reduce the problems to numbers, but to expand thinking about problems to gain understanding. The result could be scenarios and options, supported by the mathematics.

15.7 Epidemics are clearly systemic problems and should be first thought about systemically before being modelled mathematically. If I think back to our modelling of HIV/AIDS, I sometimes wonder what modern toolset would have been more helpful at the time: A bigger, faster computer or a whiteboard and erasable pens? I would pick the whiteboard every time.

15.8 I have since studied systems thinking more formally and there are many excellent resources. I will just point to one book, *Thinking in Systems* by Donella H Meadows (2008) in which she says that:

Everything we think we know about the world is a model. Our models do have a strong congruence with the world. Our models fall far short of representing the real world fully.

16. THINKING SYSTEMICALLY ABOUT HIV/AIDS & COVID-19

Insight: Epidemics are essentially systemic problems.

16.1 The global impact of Covid-19 is clearly a systemic issue. Covid-19 has impacted on health, real economics, investments, politics, globalisation, climate and societies at large. The systemic impact has been without parallel. And yet one wonders why? As at the date of writing, there have been fewer than 700 000 reported Covid-19 deaths worldwide, although admittedly this number is probably under-stated. On current trajectories of the spread of infection, particularly in a few larger countries such as Russia, Brazil, India and parts of the USA, we may well see up to one million deaths reported in 2020.

16.2 However, the World Health Organisation also estimates that there will be approximately one million HIV/AIDS deaths in 2020, as there were in 2019 and in excess of that in each of the 15 years before that, peaking previously at nearly two million deaths from HIV/AIDS worldwide in 2005. This is in spite of significant advances in the treatment of HIV and AIDS. And the WHO estimates that there continues to be nearly two million new HIV infections each year.

16.3 The obvious question is why did the HIV/AIDS epidemic not bring the world systems to a halt in any of the last 15 years, as Covid-19 has done in 2020? Some systemic thoughts come to mind:

- **Fear:** Covid-19 has instilled fear because medical science has not been able to cure this disease, in spite of science's promises to cure all ills.
- **Global:** Covid-19 appeared in every country in the world within a few short months; hotly pursued by the media.
- **Time:** The incubation period for Covid-19 is very short and sharp; so that the infection and the resultant illness are directly correlated.
- **Personal:** The effect of Covid-19 is being driven by the fear that anybody can get infected, today; even those doing the modelling or their families.
- **Response:** The success or otherwise of Covid-19 responses have been driven primarily by the inter-locking effects of medical science, data analytics including modelling, and the effectiveness, or otherwise, of leadership.

16.4 Whereas:

- The medical narrative is that HIV/AIDS is now a treatable, albeit endemic, disease.
- HIV/AIDS still hides itself behind several other comorbid diseases.
- The asymptomatic incubation period for HIV/AIDS is many years; so the initial infection and subsequent illness are separated by time and place.
- HIV/AIDS is now mostly prevalent in sub-Saharan Africa and, to a lesser extent, in parts of South America. Few people in the more developed countries give HIV/AIDS much thought in their daily lives.

16.5 Covid-19 has confounded many people as it has spread through the world. This novel coronavirus appears to spread like the influenza virus, but the resulting illness is definitely not like the flu. The result of infection can range in the individual from completely asymptomatic, to very mild symptoms, to sickness, hospitalisation, through to severe sickness requiring intensive care, and incubation and in some cases resulting in death.

16.6 Another perspective is that the world is significantly more complex and interconnected now, with both trade and travel, and more highly specialised in all our supply chains. This complexity, while initially building some risk mitigation into the system, has developed to the point of bringing fragility back into the system, of which the 2008 global financial crisis

was just a foretaste. It is not the virus that has wreaked havoc, so much as the global response to the virus.

16.7 Furthermore, while HIV/AIDS became politicised during the decade after 2000, this Covid-19 pandemic has been highly politicised from the first moment the virus became known. In many countries every government policy decision has been highly scrutinised, politicised and even opposed. It is striking that the countries that seem to have responded best to Covid-19, and had the best outcomes to date, are those countries with the most harmonious or compliant responses to government policy.

17. MODELLING COVID-19

Insight: Covid-19 is a novel virus that requires novel scientific approaches.

17.1 Those actuaries and other data analysts working on Covid-19 now have my greatest admiration, because they are working in a far more pressurised environment than I ever did, both in terms of the intensity of the epidemic as well as the scrutiny and transparency of the modern world. To balance that, we also have more data ... much more data!

17.2 I was surprised to hear that some of the Covid-19 models, using three high-powered virtual machines, can take up to eight hours to run a scenario. I thought it would be only a few minutes today. My only conclusion is that the mathematics and simulations are far more complex now, and I hope that there has been a commensurate improvement in the value and accuracy of these models?

17.3 While I have not developed a mathematical model of Covid-19, I have nevertheless followed the data and modelling very closely and have developed a few systemic views of the epidemic. However, in the following paragraphs I set out a few approaches to modelling Covid-19 and, for that matter, any other novel virus pandemic, that I would recommend using.

17.4 Develop and keep adapting a systemic model of the pandemic. This can be just a simple whiteboard exercise. There is great value in doing this, because not only does it focus the mind on where the most effort is needed, but also once the model is reduced to mathematics and code, it is easy to miss or ignore significant new insights that the systemic view can bring.

17.5 Clearly establish the purpose of the model, as this affects many aspects of the modelling process further down the line; for example, the choice of model assumptions and scenario testing.

17.6 Be very disciplined about what information to read; but at the same time read very widely. Some people have described Covid-19 having a parallel “infodemic”, even more

so than for HIV/AIDS. This “infodemic” consists of misinformation, disinformation and excessive information which requires critical thinking and a discerning mind.

17.7 Develop a unique model or at least adapt the traditional SEIR (Susceptible – Exposed – Infected – Recovered) model, as opposed to trying to fit Covid-19 into an existing model template because the Covid-19 is a novel pathogen.

17.8 Choose the optimal geographic or community level at which to model the epidemic based on where there is sufficient data. It appears that provincial level data is the best fit for South Africa.

17.9 Model the observed differences using known demographic data, time since onset and develop a few of the modifiers suggested below, reproducing the observed spread of infection, sickness and deaths.

17.10 Engage with other professionals respectively even if, and especially if, there are different points of view that you can learn from; we are all still learning and, after all, that is the purpose of modelling.

17.11 Study the key co-factors of infection and, after understanding the data, do not necessarily build this into the model at a micro level, but rather understand the possible systemic impacts and then use approximate modifiers that can adapted and explained in the model over time. The infection co-factors for Covid-19 would include for example:

- **Proximity behaviour:** This includes many of the non-pharmaceutical interventions (NPIs) such as hand-washing, hygiene, wearing masks, social distancing and personal and family bubbles. This is after all how infection happens.
- **Mobility:** This includes actual movement and modes of travel and interconnection with other social bubbles. This is after all how infection spreads.
- **Workspace and living densities:** This is after all where infection mostly happens.
- **Heterogeneity infection susceptibility:** This may be a duplication of the three factors mentioned above; but there may also be other more important physiological factors at play here that we do not understand yet. The most interesting research is still going to come from infected but asymptomatic people and their immune system responses.

17.12 Study the unique pathology of Covid-19 and the key co-factors of medical outcomes and, after understanding the data, do not build all this detail into the model, but rather understand the possible systemic impacts and then use approximate modifiers that can be adapted in the model over time. For example:

- **Pathology:** What does the virus actually do in the individual and how does the disease present, including all the emerging knowledge about demography and comorbidity.

- **Treatment protocols:** These are emerging and changing over time.
- **Healthcare capacity:** This includes both physical capacity and professional capability.

17.13 Country comparisons – there is already an astonishing amount of data available on this epidemic globally. Infections in South Africa (SA) initially lagged most other countries, simply by virtue of when the virus first took hold. It therefore had a small window of opportunity to calibrate model results not only against emerging South African data, but also against other country data. However, as the global experience has been anything but uniform, this begs the question: which countries should we have compared to? At a very high level, we observe several different patterns of infection emerging:

- **Far East and some isolated countries:** Fast initial growth in infections and then a strong suppression of new infections – no comparison.
- **Europe:** Very steep growth in infections and very high rates of mortality and a gradual decline in new infections, with a few small “second waves” of infection – no comparison.
- **USA:** Very steep growth in infections, high rates of mortality and then waves of new infections across the individual states – Some comparison, although individual states may be more interesting comparisons to South Africa.
- **South American countries, Brazil, Chile, Peru, Argentina and some other “BRIC-type” countries including Mexico and India:** Comparable start to the epidemic, flat as early NPIs had an effect and then steeply rising infections, moderate rates of mortality generally except where healthcare systems seemed overwhelmed – similar to South Africa?

17.14 So the current list of comparative countries that appear similar to SA include Brazil, Chile, Peru, Argentina, Mexico, India and perhaps some individual states in the USA; note that one of the commonalities between these countries are the complex socio-economic conditions that prohibit their governments holding to a strict lockdown that could significantly reduce new infections. Those same socio-economic factors are, in all probability, also exacerbating co-factors for the further spread of Covid-19 infections.

17.15 We could hold up continental Europe as an example of what we could strive to achieve in terms of reducing infections, through interventions, but we could expect better overall mortality outcomes in SA because of a younger age demographic.

17.16 If South Africa fails to halt the wide spread of Covid-19, we run the risk of it becoming endemic in the same way that has happened with HIV/AIDS. We must do everything possible not to let that happen. This will not only have disastrous health outcomes for our people, it could also continue to hold back our economy for years, as the rest of the world unlocks travel and trade selectively based on “equivalence of infection”, in which SA will compare poorly.

17.17 An issue that is not yet getting sufficient attention is post-infection morbidity and long-term disease. Covid-19 may have both an early peak in mortality as well as a long-term effect on the mortality of the survivors of the initial infection. The range of debilitating conditions found in survivors is very wide, even in some people that had apparently mild symptoms while infected.

17.18 The other issue where there is much still to understand is that of immunity post infection, either via antibodies or activated T-cells and memory B-cells. The emerging studies also seem to show some level of historic immunity, perhaps from previous coronavirus infections. The focus is rapidly moving to the development and distribution of vaccines; but the systemic challenges of, firstly developing a successful vaccine and, secondly administering vaccines globally, are immense.

17.19 One of the key new data sets emerging in South Africa is the weekly excess mortality report being produced by the South Africa MRC. There is now sufficient data to triangulate that with the provincial death reporting data and modelling results to get a better calibration of the models.

17.20 One of the most exciting recent developments as I finalised this paper was the release of the updated version of the ASSA Covid-19 model. This model is a traditional SEIR model, suitably modified for the complexities of Covid-19. One of its key features is allowing more explicitly for heterogeneity of infection as well as possible non-susceptibility within a population. The challenge is that there is currently little empirical data to validate these assumptions and the important work now required is to produce scenarios that can calibrate to the data, especially the MRC data excess mortality data mentioned above. A full appreciation of the ASSA model is, unfortunately, beyond the scope of this paper, but this will no doubt be done by others in due course.

17.21 Finally, it seems helpful to always keep in mind a big picture view of the pandemic, in all its facets, asking the big questions about what is happening. Then one is able to better evaluate the significance of new emerging data and their effect on key assumptions; otherwise one will be swamped by both the data and the opinions.

18. THE PUBLIC INTEREST

Insight: Actuaries have a unique contribution to make to the public interest.

18.1 Turning now to the specific question of actuaries and the public interest. The ASSA Code of Professional Conduct says “the Society also serves the public interest by engaging the regulators and in public debate”. Furthermore, “members are encouraged to consider the public interest when rendering actuarial services”.

18.2 While I initially started working on the HIV/AIDS issue for purely commercial actuarial reasons, the implications of the unfolding human tragedy immediately plunged me into the question of the public good. This awareness was profoundly affected by my contact with so many people outside of the actuarial profession. We started to build bridges between the actuarial profession and other professions, disciplines and the community itself. The many benefits of this public interest role only became apparent later as the epidemic unfolded and affected the community more widely.

18.3 My public interest orientation was also encouraged by the genuine public interest and community engagement of my employer. Metropolitan was already fully engaged with the community through a variety of channels. One of my most important mentors in this regard was our non-executive director, Prof Willie Esterhuysen. He opened my eyes to the world beyond business and actuarial science, and, importantly, the role that both we can and should play in society.

18.4 A major benefit of publishing our paper in 1990 was the engagement and collaboration that came about with many others already involved in the field. The list of people and organisations is extensive, but I will just mention a few.

18.5 Dr Malcolm Steinberg, an epidemiologist at the MRC, and Dr Jonny Broomberg, who was the first health economist I had met, approached me to collaborate on a series of papers on the potential socio-economic impact of the HIV/AIDS epidemic (Broomberg et al., 1993). Their subsequent paper is still one of the best analyses produced on these potential impacts and addressed issues not dissimilar to those faced in the current Covid-19 climate.

18.6 A pattern had been set, where we produced demographic and epidemiological forecasts and collaborated with other professionals and researchers to apply those scenarios to a wide range of socio-economic factors. We did such collaborative work on economics, orphans, dependency ratios, mortality, sickness, healthcare, education, communication, training and prevention and many more.

18.7 A very fruitful working relationship was formed with Prof Alan Whiteside from the HEARD centre at the University of Natal. The significant work that we did with Prof Whiteside is worth a paper on its own; suffice it to say that he was one of the bastions of understanding and mitigating the impact of the HIV and AIDS epidemic in Southern Africa (Cross & Whiteside, 1993).

18.8 Dr Horst Kustner, head of the Department of Health's Epidemiological Directorate was another very fruitful relationship. I learned a lot more about epidemics from him and especially the use and interpretation of health data. He edited a regular publication called *Epidemiological Comment* and his reporting on HIV/AIDS became a standard feature of

that publication, especially tracking the national and provincial HIV prevalence. In due course Dr Kustner started to include our forecast to validate their data and we did a lot of collaborative analysis together.

18.9 We also worked extensively with the Department of Health and their AIDS Unit. At one time Dr Quarraisha Abdool Karim was the head of the AIDS Unit and we were able to work together again for several years on the problems facing the country from HIV/AIDS and how to mitigate them.

18.10 As mentioned previously, one thing that stood out to me is that our training as actuaries equips us almost uniquely to deal with complex issues; and many, if not most, public interest issues are complex issues. We are also trained to work across multi-disciplinary groups; and most public interest issues span many disciplines.

18.11 One of the difficulties of communicating actuarial work to the wider public is the uncertainty inherent in much of what we do. However, it is that very element of uncertainty that often creates the complexity for decision-makers. Nevertheless, to the extent that we can wrap our minds around uncertainty within the so-called “expanding funnel of doubt”, which expands over the dimension of time, it behoves us to find ways to communicate to decision-makers what can be understood and inferred from our data and modelling; and therefore leading to better policy options and choices.

18.12 At the very least, we actuaries should be able to communicate the difference between the uncertainties presented by the data, the choice of model design, the critical assumptions, any future actions and then the uncertainty of the unknowable. We should therefore also be able to entertain and debate alternative points of view.

18.13 One of the other complexities in doing public interest work is that of actual and perceived bias of people involved. That includes us! We would be naive to presume that actuaries are not biased, but at least our professional discipline pushes us towards considering the views of all stakeholders objectively.

18.14 One of the benefits of working on the issue of HIV/AIDS for so many years was that I managed to build up many personal relationships in which perceptions were gradually replaced with mutual trust and respect.

18.15 Finally, it is clear to me that, just because a matter is complex, doing nothing and or saying nothing about it is not an option. Covid-19 is the classic “wicked problem” and actuaries have a contribution to make in managing its outcomes.

19. CONCLUSION

19.1 I hope that you enjoyed this ramble through the interesting countryside of actuaries, data, models and epidemics; and thinking systemically about things along the way. The conclusion from our Doyle & Millar (1990) paper is worth repeating here:

Modelling at times can be very down-heartening and sometimes one wonders whether it is not just a guessing game. The major benefit of modelling, however, is that with an alert mind you can explain things that may be obvious but not noted before and it therefore enriches your understanding of the subject. Furthermore it develops a framework for evaluating alternative strategies.

19.2 Stated much more eloquently by GK Chesterton as quoted in the book by Donella Meadows (2008):

The real trouble with this world of ours is not that it is an unreasonable world, nor even that it is a reasonable one. The commonest kind of trouble is that it is nearly reasonable, but not quite. Life is not an illogicality; yet it is a trap for logicians. It looks just a little more mathematical and regular than it is.

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