# Implications of COVID-19 Data and Modelling a Pandemic

**Pandemics Task Force**

*Exposure Draft*
*11 March 2025*

# IAA Paper

# Data and Modeling a Pandemic

This paper was prepared by the Pandemics Task Force of the International Actuarial Association (IAA).

The IAA is the worldwide association of professional actuarial associations, with several special interest sections and working groups for individual actuaries. The IAA exists to encourage the development of a global profession, acknowledged as technically competent and professionally reliable, which will ensure that the public interest is served.

The role of the Pandemics Task Force is to deliver on the Statement of Intent for IAA Activities on Pandemics (SOI) as adopted by Council on 8 April 2022.

The paper was authored by a drafting group appointed by the Pandemics Task Force consisting of:

Marc Tardif (Lead) FSA, FCIA (Canada)

Chris Daykin MA Hon DSc FIA FSA (UK)

Dale Hall FSA (USA)

Kees Thiers MSc (Netherlands)

Kasun Amarasuriya FIAA (Australia)

Ash Bhalerao FIAA (Australia)

[This paper has been approved for IAA publication by the Pandemics Task Force in accordance with the IAA's Communications Policy.]

*This paper is published by the IAA solely to encourage understanding and debate of the issues raised therein. For the avoidance of any doubt, this is* ***not*** *an International Standard of Actuarial Practice (ISAP), nor does it set standards or requirements which any individual or organization is expected to consider or observe, or with which they are expected to comply. This is the case notwithstanding any language in the paper which, but for this clause, might suggest otherwise. This statement takes precedence over any such wording.*



International Actuarial Association
Association Actuarielle Internationale

**Tel:** +1-613-236-0886 **Fax:** +1-613-236-1386
**Email:** secretariat@actuaries.org
1203-99 Metcalfe, Ottawa ON K1P 6L7 Canada
www.actuaries.org

# Table of Contents

# Executive Summary

A pandemic, such as that caused by COVID-19, can result in a massive global health care crisis which requires significant analysis and quick decision-making in both the public and private sectors. This paper draws out lessons from COVID-19 in terms of data and modeling. In particular, it identifies issues that may need to be addressed to improve quality and quantity of data, allowing stakeholders to make quicker and better decisions. The paper also focusses on model features that could provide more accurate measures of risk. The intended audience for this paper includes actuaries and supervisors but should be of interest to other relevant stakeholders in the insurance industry, epidemiologists, public health experts and the medical profession.

Actuaries have many strengths in data and modeling, including an understanding of the development of suitable assumptions; an understanding of how to segregate data and develop reliable measures; and the development of sensitivities and scenarios. Actuaries also operate under a strong professional framework.

Whilst in a perfect world complete data on the impacts of the pandemic would be available, in practice, the complexity and fast-moving nature of a pandemic means that this is rarely the case. Therefore, key definitions and parameters ideally need to be agreed upon between jurisdictions. Where direct pandemic data is not available, other measures, such as excess deaths, can be used. In addition, indirect impacts such as impacts on deaths from other causes due to delayed diagnosis should be looked at.

Actuaries can assist in enhancing models of others. Actuaries can help develop simple models where extra features can be added later as more data becomes available. Actuaries can help to interpret model outcomes and can assist with the calculation and testing of the fundamental model parameters, as well as providing external independent review of models developed and run by others. A particular area where actuaries can play a role is in pointing out weaknesses in the models and the assumptions implicit in the models.

COVID-19 and the HIV/AIDS epidemic are two examples of where there was international cooperation between actuaries. Whilst there is scope for leveraging international sharing of data and models to a greater extent than happened in practice in these two pandemics, care needs to be taken in parameterising models to take fully into account the situation pertaining to the particular country being studied.

The experience with COVID-19 points strongly to actuaries developing information-sharing networks and active contribution to scientific research and pandemic model development, both at the national and international levels, at times when a real pandemic seems remote.

Finally, COVID-19 highlighted the need to undertake scenario analysis, particularly where there is uncertainty of ultimate outcomes. Actuarial work in scenario-building, probability-weighted outcomes, and sensitivity analysis are essential components of effective risk management. By carefully constructing scenarios, assigning probabilities, and testing key assumptions, actuaries provide valuable insights that enable organizations to navigate uncertain futures with greater confidence.

# 1. Introduction

The purpose of this paper is to draw out lessons from COVID-19 in terms of data and modeling. In particular, this paper identifies data issues that may need to be addressed to improve quality and quantity of data, allowing decision makers to make quicker and better decisions. The paper also focusses on model features that could provide more accurate measures of risk. In each of its sections, the paper identifies areas where actuaries can help to improve data collection and analysis and enhance model development, so that actuarial input could make a positive contribution in assisting public bodies and governments in their decision-making and cooperating with other professionals called upon to build models projecting the potential impact of future pandemics.

It is hoped that this paper will contribute to cooperation and coordination among stakeholders in data and modeling of pandemics. The intended audience for this paper includes actuaries and supervisors but should be of interest to other relevant stakeholders in the insurance industry, epidemiologists, public health experts and the medical profession.

# 2. What Data is Needed and How to Improve Quality

## 2.1 Methodology Options

The core requirement when preparing analysis for insights and data-driven decisions is the extent of data available. The availability of the quality, quantity and relevance of data will make a significant difference to the analysis prepared. Therefore, it is critical to establish the data requirements as early as possible. There are two potential approaches when analysing the impacts of a pandemic:

a) Use the counts of deaths, causes of death etc. to analyze the pandemic's impact; and
b) Use statistical techniques to analyze mortality and morbidity during the pandemic.

Both these approaches have advantages and disadvantages, which are discussed further below.

**The Best-Case Scenario – Data Availability**

In an ideal world, with available data complete and consistent, the impact of a pandemic on mortality and morbidity would be calculated using the count of deaths, c of death and other exposed-to-risk information such as population counts or completed tests. Additionally, when analysing the impact on mortality, the data would indicate whether the death was directly or indirectly caused by the pandemic. Similarly, when analysing the impact on morbidity, information such as the number of tests, the number of positive cases detected, and the proportion of the population's positive test outcomes would all be relevant.

Unfortunately, the complexity of a pandemic inherently makes it difficult to gather complete and comprehensive data, particularly during the early stages, when understanding of the pandemic is limited. For instance, during the first wave of the COVID-19 pandemic, testing was not as extensive and established as in later stages, as most countries had limited infrastructure and policies for conducting tests. Because of this, the COVID-19 casualties were understated, as some COVID-19 deaths were assigned as other causes of death. At later stages of the pandemic, vaccines became available and then people were tested less frequently, making measurement less representative.

In addition, data is rarely available in a complete and consistent format across provinces, districts, states, not to mention countries. Many jurisdictions reported significant issues in collecting data resulting in incomplete data. Each region often has its own definitions and methodologies for recording information. For example, within some jurisdictions, the definition of a pandemic-related death changed over the course of the COVID-19 pandemic. The change in definition resulted in a restatement of the number of COVID-19 related deaths in those jurisdictions.

**Making Data Sets Consistent**

Each pandemic will take a slightly different course and present unique challenges. However, setting a broad principles-based approach will improve global communication. Improving the data will require professional bodies and health authorities to work closely together and define a co-ordinated approach to develop a uniform framework for assessing pandemic-related mortality and morbidity. The uniform framework will enable the data to be aggregated across regions and countries more easily. The International Actuarial Association (IAA) is uniquely placed to coordinate discussions on a uniform approach, as it brings together professionals from many different jurisdictions.

To achieve such a goal, key parameters and definitions must be set. These will be fed into the analysis and decision-making process early on. This should include a definition of pandemic-related deaths, location of deaths to be included (e.g. whether care homes are included as well as hospitals) and the population being tested, against which positive tests can be measured. Another key consideration is to apply the learnings from the COVID-19 pandemic to any future pandemics. Consensus on the parameters and definitions early on will support ongoing analysis and improve comparability between regions and countries.

**Indirect Consequences of the Pandemic**

Analysing the impact of the pandemic solely based on counts of direct deaths or infections attributable to the pandemic fails to capture the full impact, as it overlooks some indirect impacts of the pandemic. For example, during the COVID-19 pandemic, many health care appointments or procedures were skipped because of the quarantine measures, leading to delays in treatment and hence potentially contributing to a risk of increased morbidity and mortality. In addition, several countries reported a surge in mental health issues related to the pandemic lockdowns, which may have contributed to deaths, as well as physical sickness. This means that some cases of mortality or morbidity were not considered to be pandemic-related even though they were a direct or indirect result of the pandemic. The instances of mortality or morbidity from delayed diagnosis, delayed treatment or mental health issues is of great importance for decision-makers who can work to minimise such instances in the future if there are sufficient data-driven insights available.

**Statistical Approaches**

Another approach adopted by several professional actuarial bodies across the world was to monitor the number of 'excess deaths' resulting from the pandemic. This approach benefits from not relying on a pre-defined definition for 'pandemic-related death' which, as stated earlier, could vary significantly. However, this approach requires mortality to be monitored for several years in order to get useful indications of a change in experience, so the investigation would need to be carried out over a period. The lag in obtaining insightful data would not be helpful to health authorities who need to make decisions rapidly during the pandemic. With this limitation in mind, the excess deaths approach is a powerful tool to support analysis around the implication of the pandemic over an extended period.

The approach will also support insights into how the pandemic evolved into a global catastrophe and to identify key drivers of the process so that future pandemics or similar events that have the same paralysing effects can be predicted and/or mitigated.

**Consideration for Comprehensiveness and Completeness of Data**

The 'excess deaths' approach requires that regions have an existing mechanism to regularly monitor mortality or morbidity experience in the given region. Having such monitoring mechanisms in place would ensure that the exposure to risk is calculated consistently between different regions. There are a number of jurisdictions which already have some form of 'continuous mortality investigation' which carries out research into mortality and morbidity experience on a regular basis. Similar to the co-operative and co-ordinated approach discussed above, supranational organizations can support entities to develop their infrastructure and to standardise definitions across regions.

The approach benefits from having unambiguous data since it is maintained consistently over time and the analysis focuses on how the actual experience has increased compared to previous periods not impacted by a pandemic. For example, the number of deaths taken into account does not depend on how cause of death is recorded in particular cases or on the specifics of testing policy and definitions. This approach also facilitates comparisons across jurisdictions.

An important consideration when comparing excess deaths is to focus on the increase in the *rate* of mortality rather than the absolute increase in the number of deaths. This approach will make comparisons across regions more meaningful.

## 3. Enhancing or Improving Existing Models and How Actuaries can Assist

Building an appropriate model requires a systematic approach. The following structure, developed from the paper 'Philosophy of Modelling'[1], could be an acceptable approach to separate out the different stages of the process:

- Model scoping: identification of the subset of the real world that the model aims to represent;
- Model specification and coding: Moving from model scoping to realized model, including data gathering and assumption-setting;
- Model running and Interpretation;
- Communication of results to stakeholders;
- Decision-making based on the results;
- The model 'loop': improvements based largely on experience using the model;
- Model review / independent validation;
- Review and updating of parameters;
- Sensitivity analysis; and
- Setting plausible alternative scenarios for stress-testing.

Actuaries may be involved in any or all of the above stages, both as modelers and in contributing to the development and application of other models in use. A broad classification of the ways in which actuaries can be involved in enhancing models might be categorized in terms of:

- Assisting with 'simplified models': strictly speaking almost any actuarial thought and logical analysis relates in some way to a model, if at times implicit, without necessarily having a formal mathematical model structure. There are useful contributions that might not be thought of as a 'model' with the formality of other pandemic models, such as the analysis and interpretation of excess deaths;
- Development of a new model;
- Assisting others (non-actuaries) with developing their existing and/or new models;
- Validation of models developed by others (including informal review or formal independent audit). Validation and audit are discussed further in Section 4 below;
- Review of results, including consideration of the plausibility of the results 'in isolation', i.e. not reviewing the underlying model; and
- How the results are interpreted and communicated, including model weaknesses / limitations and degree of uncertainty and how this has impacted on decision-making.

These two 'dimensions' of the question -- (1) different stages of the modeling process and (2) scope of involvement -- lead naturally to the following matrix of possible combinations, with rows for the stages and columns for the scope of involvement of actuaries. The letters allocated to each cell of the matrix are then discussed in the text below.

In principle each cell could be analyzed separately, but many cells raise similar questions to others, have obvious implications, or are perhaps naturally empty without forcing some involvement where little or no involvement might be a more realistic option. We set out below some thoughts on how actuaries can assist, based on this matrix structure.

***Table 1: Model Building - Matrix of Possible Combinations***

| | "Non-models" | Actuaries' new model | Help others - new model | Help others - existing model | Validation | Output |
|---|---|---|---|---|---|---|
| Model scoping | A | B | B | B | B | n/a |
| Specification /coding | A | C | C | C | E | n/a |
| Parameterization | A | D | D | D | E | n/a |
| Model running & interpretation | A | F | F | F | n/a | G |
| Communication | A | F | F | F | n/a | G |
| Other implications | A | H | H | H | H | H |
| Feedback loop | A | I | I | I | I | I |

*A: Regarding 'simplified models', or models which many would not think of as formal 'models'*

Actuaries can contribute substantially to scoping and specifying 'excess deaths' models and, subsequently, disaggregating the excess into key components. Problems experienced with some non-actuarial attempts to do this arose from reliance on numbers of deaths without adjusting for age-sex standardization. Another challenge in making this analysis successful and useful is setting the expected baseline, which itself is a non-trivial actuarial task. Overall, the analysis of excess deaths is an example of a useful 'simplified model' analysis using actuarial skills to provide insights into pandemic mortality. Similar work could also be done regarding morbidity, although we focus here on mortality aspects.

Extending the definition of a 'simplified model', some relatively simplistic approaches may also help understanding of the development of the pandemic, either as early quasi-models, or later 'back of the envelope' checks on full models. For instance, in March 2020 simply fitting curves to the recorded statistics of cases and mortality in European countries worked well to help in predicting cases and deaths (with timescales of weeks), as the early stages of transmission were not affected by numbers of infected-now-immune individuals (in effect, zero) or social controls (since there were none early on).

*B: Model scoping*

Although fundamental to the success of modeling exercises, insufficient attention is often given to defining the scope and purpose of the model and actuaries should be able to contribute substantially to this. There are three particularly relevant areas:

- Scope limitations: What elements would we want to model, but doing so is impractical for reasons of lack of suitable or sufficient data (this is particularly important early on in any emerging pandemic), limited understanding of the impact of possible interventions or potential model complexity?
- Future expansion: Given these constraints, how can we start to develop a model in a way that allows extra features to be added later as data and research emerge? How can we include results about impacts and interactions as data become available and there is more time to introduce extra model features, as part of the same continuing model, rather than creating a new model?

- Out of model adjustments: To what extent can we develop plausible parallel model or 'out of model' adjustments to reflect as usefully as possible the out-of-scope elements, even if these adjustments do not fit with standard academic approaches? In a pandemic context, the obvious example is measuring and incorporating the impact of significant non-pharmaceutical interventions (such as social distancing, travel restrictions and lockdowns) on the economy, on longer-term health via their economic and social impact, and on shorter-term health via indirect impacts such as deferral of primary care consultations, diagnostic tests and treatment, as well as the impact on people's mental health.

*C: Model specification and coding*

Although some actuaries may have strong technical expertise in developing code for models, there may be relatively little that actuaries can do in the details of model implementation that uniquely adds value, except perhaps in acting as an intermediary between coders and users.

*D: Parameterization*

Actuaries can assist, regarding both calculation and testing of the fundamental model parameters (or review of the calculations of others), and an awareness of where parameters may be 'conceptually' inappropriate, in particular:

- Basis risk (parameters from one population applied to a wider or different population);
- Lack of appropriate stratification (e.g. by socio-economic category, age distribution or ethnicity);
- Lack of awareness of sensitivity to other areas, such as social deprivation and housing (in particular if such areas are out-of-scope of the model).

Actuaries' experience of involvement in risk and capital analysis for insurers lends itself well to work on developing plausible scenarios and stresses, ideally appreciating wider aspects in scenario construction (where scenario design may help as first-order compensation for elements outside model scope, or perhaps to allow manually for known inadequacies in the risk aggregation elements of the model). This is explored further in Section 6 below.

*E: Validation:*

Actuaries can provide external independent review of models developed and run by others. In an emerging pandemic such review can usefully be carried out in stages – for instance, starting with definitions and scope, with reporting back as soon as possible, before moving on to specification and then to interpretation and presentation of results.

A particular aspect of model validation which has been found useful in other contexts is clarification of known model weaknesses and limitations, to feed into both framing communication of model results and the later model improvement (feedback) loop.

One other point to note is the nature of independence. Some aspects of the role of actuaries as independent reviewers are discussed in more detail in Section 4 below.

*F: Model runs, interpretation, communications*

Actuarial skills include appropriate interpretation of model results, in particular with regard to how much reliance should be placed on results, given the model weaknesses (which may relate largely to scope limitations, and parameter uncertainty in the light of sparse data and insufficiently understood impacts of interventions when there has been no time for any reliable research). Likewise, actuarial skills include effective communication of model results.

*G: Results Validation*

Validation of results is within the actuarial skill set, including:

- Reasonableness of results;
- Evidence of checks or 'internal validation' by the modelers;

- Awareness of model weaknesses and limitations and possible influence of those; and
- Interpretation of uncertainty in model results.

*H: Other Implications*

Wider implications include providing an overview of models using generic reasoning or common sense and making adjustments in respect of scope limitations or known model weaknesses. The conclusions here may perhaps be broad (perhaps even only indicating the 'direction' of the outcome, rather than being able to provide quantification), for instance: "The parameterization knowingly has little regard for heterogeneity owing to data limitations, and this is expected to make the model [overestimate] [underestimate] …"

*I: Feedback loop*

More developed models should have the capacity to take account of feed-back loops, whereby assumptions and model behavior in later periods are programmed to respond to developments in the earlier periods. This is a technique with which actuaries are very familiar from other applications, such as in modelling solvency of insurance companies.

*Conclusion*

The extent to which actuaries are operating in the areas of cooperation implied above depends not only on the theoretical 'fungibility' or usefulness of skills, but on the practical agreement and professional respect of Government, statistical services, academics, consultation mechanisms with experts and public health bodies (including supranationals). Optimum levels of cooperation may be difficult to establish from the outset, especially in the early stages of a pandemic, unless some preliminary frameworks have been established previously. This points strongly to actuaries developing information-sharing networks and active contribution to scientific research and pandemic model development, both at the national and international levels, at times when a real pandemic seems remote.

## 4. Provide Independent Audits of Projections by Others

The concept of independent audit or review of other people's projections has been touched on above. Actuaries are well-placed, particularly in the light of experience with Solvency II internal model development in Europe (and related regimes outside the European Union, such as the Insurance Capital Standard of the International Association of Insurance Supervisors), to provide independent model validation, looking at all components of the modeling process. Another example in a different context is where the UK Government Actuary's Department provides audit of models developed by other government entities, including the department responsible for social security.

Independent audit of pandemic modeling would likely need to be done in a much 'lighter touch' way than typically applied to formal model validation of insurers' internal models in a European Solvency 2 capital context, but the principles are the same. This is because of the tentative and exploratory nature of models being developed rapidly in the early stages of a pandemic, as well as the lack of firm information on key drivers, modes of infection and suitable parameter values.

The professionalism codes to which actuaries are subject provide a strong background for such work, differentiating the input of actuaries from modeling work carried out by others who are not subject to such professionalism requirements.

Independence is sometimes interpreted purely as independence of the validator from the model developer. However, another aspect of independence is diversity of thought and methodological and conceptual independence. This may be particularly useful in an emerging pandemic where there is no strict requirement for independence between teams or individuals, as is the case in insurers' capital modeling, but keeping an eye on alternative methodologies reflecting fundamentally different perspectives is important – and indeed essential – if group-think is to be avoided.

# 5. Sharing Learnings Across Time and Across Countries

To illustrate how the sharing of modeling methodology and learning across countries can play out effectively in a pandemic, we can go back to the late 1980s. At that time the development of models to project the future development of HIV infection and AIDS saw active cooperation between working groups established by different actuarial associations (see the Appendix for more details). The Institute of Actuaries AIDS Working Party used a model developed by Professor David Wilkie[2] to produce a number of Bulletins for the profession and wider dissemination. The Working Party also presented papers at professional meetings[3,4] and their projections were taken up and used in the national population projections of the UK. The model was an evolution of a model (which included the possibility of recovery) used by actuaries for Permanent Health Insurance. Other actuarial associations undertook similar initiatives.

The HIV/AIDS epidemic and the COVID-19 epidemic were very different in the way they played out. HIV/AIDS started slowly with transmission primarily between homosexuals with multiple partners and drug users. It was largely a sexually transmitted disease, with smaller categories of transmission from sharing needles and from infected blood products. The size of the 'at risk' population and the rate of transmission of the virus were the biggest uncertainties, although most evidence pointed to the rate of transmission being relatively low. Only in some countries, such as in South Africa, did the pandemic become primarily based on heterosexual transmission.

By contrast, when COVID-19 emerged it appeared to be highly transmissible, with the whole population potentially at risk. It soon became clear, however, that children were not much at risk of becoming seriously ill and that older people, and particularly those with underlying conditions, were much more at risk. Those becoming seriously ill could die quite quickly. It was not known at that time how the virus was transmitted, with some early theories that it could survive on surfaces and be transmitted by touch (and subsequent touching of the mouth or nose). More probably it is transmitted almost entirely by particles in the air, like other common viruses. Enhanced risk factors included: living in close proximity with someone infected, sitting or standing close to someone infected for a sustained period in an office, canteen or on public transport. Because of the rapidity with which scenarios unfolded, there was little time for international cooperation on research and publication and exchange of high-quality scientific information. Countries were largely on their own in modeling the potential impact of the spread of the virus and in deciding on policy responses, with the result that a wide range of approaches were seen, ranging from complete shut-down of the economy and schools to people just being advised to avoid unnecessary contact with others. It was also unclear how effectively to model the impact of different policy interventions.

There have been many more cases of COVID-19 than of HIV infection but far fewer deaths. Significant in accounting for the relatively low number of deaths from COVID-19 was the very rapid development and roll-out of vaccines, providing a high level of protection from serious disease and death in many countries. As a result of the accelerated pace at which COVID-19 developed to a first peak of infections, at which time a high proportion of the deaths also occurred, there was little time for research to be carried out and for scientific papers to be published in peer-reviewed journals. There are still many unanswered questions, which international research and collaboration may help to answer, but a bit late in the day for having any real positive impact on the epidemic, which has already long passed its peak.

Although there may not have been time to really benefit from international exchange of ideas for modeling COVID-19, a number of attempts were made to monitor comparisons of how the epidemic was progressing in other countries. This brought to light the hazards of making international comparisons (or even comparisons between regions within a country) without a proper understanding of whether there was consistency between the numbers compared. Firstly, many comparisons placed emphasis on the number of recorded cases of infection with COVID-19. This was not in practice a very useful statistic, as every country had its own approach to testing and, even within a country, the way in which testing was carried out – and the populations monitored – changed significantly over time. Growth in the recorded number of infections was often the result of more people being tested, instead of a more scientific approach using only prevalence statistics based on the *proportion* testing positive.

Secondly, there was considerable confusion about how to measure the impact of COVID-19 on mortality, with some countries adopting a definition of a COVID-19 death as being a death within a set period of having had a positive COVID-19 test. This resulted in a lot of deaths from entirely different causes, such as cancers, heart disease and chronic pulmonary conditions, being treated as COVID-19 deaths, since the patient had caught COVID-19 in hospital or whilst being treated for something else. Records of cause of death were also unreliable, as doctors would record both COVID-19 and some other condition as joint causes of death, or record only COVID-19 as the cause of death, when there was clearly some other significant contributing factor behind the death.

Probably the most reliable approach for monitoring the overall impact of the pandemic was to keep track of excess deaths, as discussed earlier in this paper.

Even ensuring proper comparability in analysing deaths from COVID-19 between countries was not easy. We have already mentioned differences in the definition of COVID-19 deaths, but there were also differences between countries because a) the pandemic started at different times in different countries and b) deaths in care homes and other non-hospital settings were not included in the published figures for deaths in some countries for certain periods. Much popular commentary was based on absolute numbers of deaths, with the all too obvious result that larger countries were reporting more deaths. From an actuarial perspective it clearly only makes sense to compare deaths relative to the size of the population, preferably in age-groups, rather than absolute numbers, and even this may not give a very reliable comparison because of differences in age distribution, and detailed figures of COVID-19 deaths by age were easy to obtain for many countries.

Differences in mortality by country were affected by a wide range of other factors, such as population density, incidence of poverty, attitudes to social distancing (whether normally or in response to such policies being promulgated), imposition of general lockdowns, extent of mask-wearing, and how older people in care homes were protected from the virus (or not). As time went on, the speed of roll-out of effective vaccines also became a significant factor.

At the time cumulative COVID-19 deaths were frequently reported without showing the ratio of deaths to the size of the population. The IFoA's COVID-19 Actuaries Response Group published comparisons showing deaths from COVID-19 per million of population and deaths based on scaling the relevant populations to the size of the population of the UK, so as to make the figures more comparable.

This section (and the Appendix) has aimed to give a flavour of international cooperation between actuaries in the two most recent global epidemics, HIV/AIDS in the 1980s and 1990s and COVID-19 in 2020-22. There is obviously scope for leveraging international sharing of data and models to a significantly greater extent than happened in practice in either of these two pandemics. Some pandemic models could be quite transferable between different countries, although the experience of South Africa with the HIV/AIDS epidemic is illustrative of how a pandemic can take an entirely different course in some countries to others. Care needs to be taken in parameterising models to take fully into account the situation pertaining to the country being studied, as many aspects of the risk factors of the underlying population, the rate of transmission of the virus, definitions, reliability and consistency of available data, the approach to testing, treatment and vaccination may all differ markedly from one country to another.

## 6. Scenario Building

**Actuarial Experience in Scenario Building**

Actuaries play a crucial role in assessing and managing risk for insurance companies, pension funds, and other financial institutions. A key aspect of this role involves building scenarios that illustrate variability in potential outcomes. This process is essential for understanding the range of possibilities without giving undue prominence to extreme outcomes.

In scenario building, actuaries draw upon historical data, statistical models, and expert judgement to create a spectrum of possible future events. This includes considering various economic conditions, market trends, and demographic factors that could impact the organization's financial health. Once scenarios have been constructed, actuaries assign probabilities to each outcome based on their likelihood of occurrence. These probabilities are derived from rigorous analysis and are crucial for understanding the weighted average or expected outcome. Probability-weighted outcomes provide a more nuanced view of risk, allowing organizations to prepare for a range of possibilities.

As part of their risk management system, insurance companies regularly run scenarios. For example, for every European insurance company reporting under Solvency II this is a mandatory part of their own risk and solvency assessment (ORSA). In the period before COVID-19, several insurance companies reported a pandemic scenario as one of the total set of scenarios in which their solvency position would be negatively affected. When COVID-19 broke out, and the first results became visible, many insurers started to execute an additional out-of-sequence ORSA, in which the pandemic scenario included in the scenario set was replaced by the COVID-19 scenario.

### Sensitivity to Key Assumptions

Actuaries are also tasked with illustrating sensitivity to key assumptions. This involves testing how changes in certain variables or parameters impact the overall outcomes. By varying these assumptions, actuaries can assess the robustness of their models and understand which factors have the most significant influence on the results.

Sensitivity analysis helps organizations make informed decisions by identifying which assumptions are critical and where there is potential for uncertainty. Actuaries may present sensitivity analysis through tornado diagrams or scenario stress-testing, showing how variations in inputs affect the outputs.

In times of crisis, and therefore also during COVID-19, it is crucial for insurance companies to undertake sensitivity and scenario analysis in order to gain sufficient insight into how the crisis could proceed and how quickly the crisis could end.

### Conclusion

In conclusion, actuarial work in scenario building, probability-weighted outcomes, and sensitivity analysis are essential components of effective risk management. By carefully constructing scenarios, assigning probabilities, and testing key assumptions, actuaries provide valuable insights that enable organizations to navigate uncertain futures with greater confidence. This expertise was essential in assisting companies navigate through the pandemic, helping companies look at their capital resilience, for example, to different scenarios.

## 7. Conclusions

### Data and Models Interactions

Data is critical in decision-making. In a crisis such as a pandemic, existing models projecting potential outcomes will be refreshed and new models will be built to adapt to the circumstances of the pandemic. To feed all of these models, data needs to be collected, aggregated and adapted to fit the needs of the models.

In the insurance world, actuaries are often tasked in analyzing data and determining how to use it in models projecting potential future developments. The outputs provide decision-makers with pertinent information to make key decisions. The models that are used for many insurance products are multi-state stochastic processes in which the probability of what happens next depends on the attained state and not on the route taken to get there.  These models can be adapted to modeling the future of a pandemic and they are very much the same family of models that are used by epidemiologists, for example, in their work on forecasting the impact of disease.

In examining and analyzing data, it is critical to understand

- how to segregate the data,
- which measures to use that are likely to be robust for modeling purposes
- how to compute more reliable measures.
- how to identify the exposed to risk for a particular outcome; and
- ensuring that the measure of the outcome is correctly aligned with the exposure.

As the impact of COVID-19 unfolded and was disclosed to the public, some absolute numbers which were regularly quoted, such as infection case numbers and number of deaths per country, may sometimes have provided a misleading picture. Population numbers and numbers of tests, as measures of exposure, could have been useful to calibrate the results.

In projecting outcomes, there is significant uncertainty about interpretation of the data relating to what has occurred and even more uncertainty about how the future may unfold. This necessitates strong application of statistical inference in relation to the data and use of scenarios and stochastic variables in models of future development. In presenting model results, the users would benefit from a good understanding of the sensitivity of projections, identification of key drivers and the weight to be placed on different potential outcomes. More comprehensive models could also take into account feed-back loops, with adjustment of assumptions in future periods in response to more extreme outcomes which would inevitably trigger further policy developments.

**Calling Upon Actuaries in Data and Models**

Actuaries are experienced in data analysis and in using data to develop appropriate assumptions, in particular where there is great uncertainty surrounding the data and about how the future might be expected to differ from the past. This includes sensitivity to understanding of bias in data and the influence of selection effects, as well as identification of key drivers which should be taken into account in possible future outcomes. Actuarial models normally take into account the need to analyze modeling separately by age and gender, as well as by many other potential characteristics, in order not to conflate different influences which could lead to spurious projections of heterogeneous groups. A key skill in this sort of modeling is deciding what degree of homogeneity to accept as a plausible model representation of massive real-life heterogeneity.

Actuaries operate within a strong code of professional conduct which focuses on serving society as well as the immediate client – and the need for effective communication of results. The nature of actuarial work is to focus on the impact of the results of the models on different groups and to take into account the broader context in which the work is carried out.

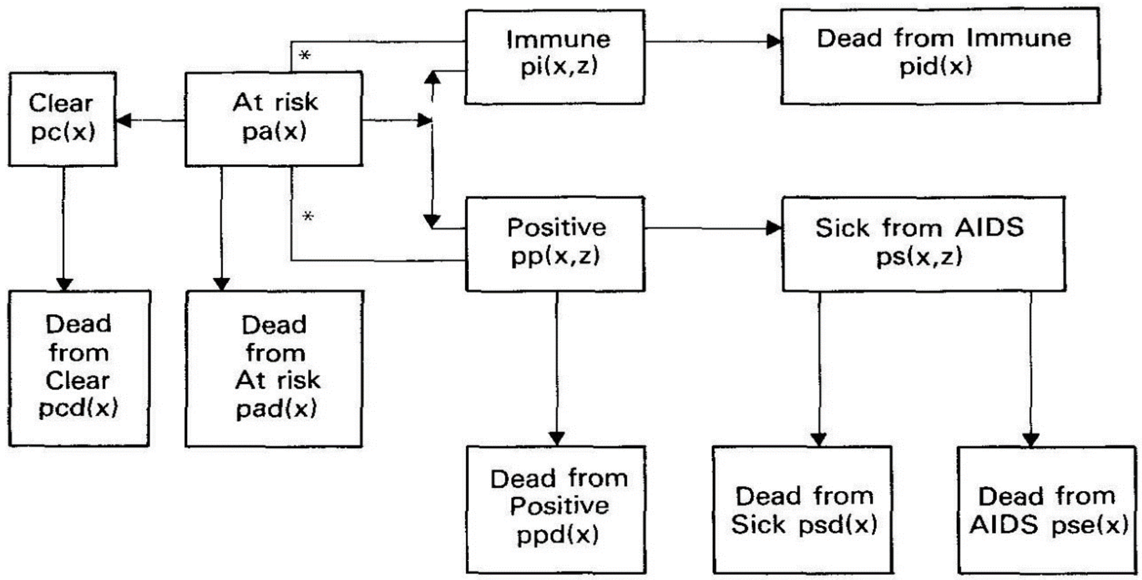
Actuaries are used to working in multi-disciplinary teams, both within insurance companies and even more so in new areas of practice such as risk management, climate risk and biodiversity. In modeling an epidemic there will usually be considerable value in bringing together the expertise of epidemiologists, public health experts, medical professionals and actuaries. In relation to COVID-19 a range of other expertise was needed, such as economics, social science and behavioral science, in order to evaluate the likely responses to different policy proposals and come to an overview of the impact on society and the economy. Making the cooperation as broad as possible will ensure greater diversity of thought and reduce the potential for group-think and bring all the advantages that diversity of background brings to decision-making. Actuaries should build contacts and networks with other professionals which will facilitate cooperation and mutual respect in a future pandemic.

# APPENDIX

**Actuarial Involvement and International Cooperation During the HIV/AIDS Pandemic**

In the late 1980s, the development of models to project the future development of HIV infection and AIDS saw significant cooperation between the working groups established by different actuarial associations, such as the Institute and Faculty of Actuaries (IFoA) in the United Kingdom, the Society of Actuaries (SOA) in North America[5], the Canadian Institute of Actuaries (CIA)[6], the Institute of Actuaries of Australia[7] (IAAust) and the Actuarial Society of South Africa (ASSA)[8]. The IFoA AIDS Working Party utilised a model developed by Professor David Wilkie[9], which was a Markov stochastic process, applicable to a large population, with time-varying transition intensities between states. It was mathematically similar to models used by leading epidemiologists[10] but, unlike most of the models being used by other forecasters at the time, it allowed fully for the age distribution, with transition intensities and survival factors able to be varied by age, and hence was able to produce results by age.

***Figure 2: AIDS Model – States and Transitions***




*denotes possible infection.

*Source: Wilkie A D (1988) An actuarial model for AIDS. Journal of the Institute of Actuaries 115, 839-853*

Although there was some valuable exchange of mutual knowledge between the different AIDS Working Parties, the context in each country was different, leading to different parametrization of models and often also to a difference in emphasis in what was the focus of study and the outputs that were presented to the profession or more widely in the public arena. Unlike the recent COVID-19 epidemic, the actuarial work was mostly focused on supporting the insurance industry with information about the evolution of mortality rates and the consequent impact on underwriting, pricing and reserving, although, in the UK at least, and later in South Africa, the actuarial work was held in high regard by policymakers and influenced important aspects of national policy.

Relatively soon it emerged that the context in South Africa was different from some other countries. Although HIV infection started to develop a little later than in North America and the UK, it soon became evident that heterosexual spread was going to be the major consideration and there were great differences in rates of transmission between different parts of the population. This necessitated a new approach to modeling the epidemic and led to the development of the ASSA AIDS Model by Peter Doyle and collaborators[11,12]. This model came about after extensive consultation with experts in the medical profession and led to the development of a sophisticated model that was used over a number of years, when the South African epidemic (and that in other countries in Africa) grew in significance, whilst the number of cases in the UK and North America became less concerning and treatments for those with HIV infection and those with AIDS substantially increased the expectation of life of those who became infected. The ASSA model was further developed by Professor Rob Dorrington and colleagues at the University of Cape Town[13,14,15] and became recognized as a major source of information for public policy. Peter Doyle has more recently looked back at the development of the ASSA AIDS model and compared it with the response to COVID-19[16].

In practice the publication of scary projections of how the numbers infected and dying from AIDS would grow resulted in strong public policy measures being taken to warn those most at risk of the dangers – and as a result transmission fell steeply, although heterosexual transmission became more material, and children were also infected from their mothers. Treatments were developed which slowed the progression to developing AIDS and substantially extended the lifespan of those with AIDS. As a result, the outcome on all measures was very much below the early projections. This was true in most industrialised countries, but the epidemic continued to grow elsewhere, for example in sub-Saharan Africa.

The HIV/AIDS epidemic is not over, although its impact has declined. WHO estimates[17] that worldwide 1.3 million people acquired HIV in 2022, including 130,000 children. Since 2010, the number of people acquiring HIV has been reduced by 38%, from 2.1 million. HIV continues to be a major global public health issue, claiming some 40 million lives so far. In 2022, an estimated 630 000 people (including 84,000 children) died from HIV-related causes globally, although since 2010 HIV-related deaths have been reduced by 51%, from an estimated 1.3 million. The global HIV epidemic claimed 69% fewer lives in 2022 compared to the peak in 2004. An estimated 39.0 million people were living with HIV worldwide at the end of 2022, including 1.5 million children (0-14 years old), with 25.6 million of them in Africa. Since the beginning of the epidemic an estimated 85.6 million people have been infected with HIV and 40.4 million people have died of HIV.

# References


1. Philosophy of Modelling (2012), Edwards M and Hoosain Z, Staple Inn Actuarial Society
2. Wilkie A D (1988) An actuarial model for AIDS. OARD40. *Journal of the Institute of Actuaries 115, 839-853*
3. Daykin C D (1989) AIDS: Some issues for the Profession, *Journal of the Institute of Actuaries 116, 193-214*
4. Daykin C D et al (1990) Projecting the spread of AIDS in the United Kingdom: a sensitivity analysis. *JIA 117, 95-133*
5. Society of Actuaries (1988). The impact of AIDS on life and health assurance companies: a guide for practicing actuaries. (Report of the Task Force on AIDS)
6. Canadian Institute of Actuaries Task Force on AIDS (1988). First report of Subcommittee on Modelling. (Report to C.I.A. meeting in Montreal, November 1988)
7. Institute of Actuaries of Australia AIDS Working Party (1988). Bulletins Nos 1, 2 and 3.
8. Keir D B et al (1988). HIV infection and AIDS–some issues of concern to valuators. (Presented to Annual Convention of Actuarial Society of South Africa, October 1988)
9. Wilkie A D (1988) An actuarial model for AIDS. OARD40. *Journal of the Institute of Actuaries 115, 839-853.*
10. Anderson R M et al (1986) A preliminary study of the transmission dynamics of the Human Immunodeficiency Virus (HIV) the causative agent of AIDS. *I.M.A. Journal of Mathematics Applied in Medicine & Biology*, 3, 229-263.
11. Doyle PR and Millar DB (1990). A general description of an actuarial model applicable to the HIV epidemic in South Africa. *Transactions of the Actuarial Society of South Africa*. VIII(II):561–593.
12. Doyle PR and Millar DB (1992). A general description of an actuarial model applicable to the HIV epidemic in South Africa. *24th International Congress of Actuaries (TICA)* (1992) 3: 93-107.
13. Dorrington R E (1998) ASSA 600. An AIDS model of the third kind? *Transactions of the Actuarial Society of South Africa*. 13(1) 99-153.
14. Dorrington R E (2000) The demographic impact of HIV/AIDS in South Africa. XIII$^{th}$ International AIDS Conference, Durban, South Africa. [Poster MoPpD1040]
15. Dorrington R, Bourne D et al (2001) The impact of HIV/AIDS on adult mortality in South Africa. MRC.
16. Doyle PR (2020) Modelling epidemics: HIV/AIDS and COVID-19. Paper presented to the Actuarial Society of South Africa's 2020 Virtual Convention 6–8 October 2020.
17. Global HIV Programme (who.int)