

Estimating cases for COVID-19 in South Africa

Long-term national projections

Report Update: 6 May 2020

FOR PUBLIC RELEASE

Prepared by MASHA, HE²RO, and SACEMA

on behalf of the South African COVID-19 Modelling Consortium

Please address all queries and comments to: Harry Moultrie at HarryM@nicd.ac.za

The projections in this report are intended for planning purposes by the South African government.



Key Messages

COVID-19 is a new infectious disease. There is much still unknown about how the disease works, and how it will progress in the South African context. The South African COVID-19 Modelling Consortium was established to project the spread of the disease to support policy and planning in South Africa over the coming months.

Due to the rapidly changing nature of the outbreak globally and in South Africa, the projections are updated regularly as new data become available. As such, projections should be interpreted with caution. Changes in testing policy, contact tracing, and hospitalisation criteria will all impact the cases detected and treated as well as the required budget for the COVID-19 response in the next six months.

The model projects that by 1 June, under the optimistic scenario, detected cases are expected to rise to between 10,702 and 24,781 depending on availability of testing and the effectiveness of the post-lockdown. The cumulative number of deaths by 1 June is expected to be between 112 and 940.

The lockdown is anticipated to have flattened the curve and delayed the peak by 2 to 3 months, depending on the strength of the public's adherence to the lockdown and social distancing measures. In the coming weeks, we will be able to estimate more accurately what the effect has been.

South Africa is likely to see a peak demand for hospital and ICU beds between August and September. However, based on current resource levels, model projections indicate that the number of available hospital and ICU beds will likely be exhausted by July. The NDOH's COVID-19 budget will be between 10 and 15 billion rand and as such is affordable under the 20 billion rand budget allocation for the medical COVID-19 response.

Executive summary

The purpose of this report is to project estimated COVID-19 cases at national and provincial levels for the next six months. A mathematical model was used to simulate the transmission of local and imported COVID-19 cases based on data regarding laboratory confirmed infections until 30 April 2020 and using parameter estimates jointly agreed upon by the SA COVID-19 Modelling Consortium.

The model projects that by 1 June 2020, detected cases are expected to have risen to 15,817 (10,702, 24,781) in the optimistic scenario and 76,106 (44,955, 129,884) in the pessimistic scenario based on the availability of testing and effectiveness of the lockdown. The cumulative number of deaths by 1 June is expected to be between 112 and 940. The range of uncertainty grows with each month, with an estimated 3.4-3.7 million laboratory-confirmed cases by 1

November, with the number of deaths expected to be between 34,015 and 49,774. The required total budget for the national and provincial departments of health will be between 26 and 32 billion rand over the next 6 months, of which between 10 and 15 billion rand will accrue to the National Department of Health (NDOH). This budget covers personal protective equipment, the cost of additional ICU and hospital beds and staff, additional PHC staff, ventilators, drugs, isolation facilities, testing and surveillance and Port Health budgets. The NDOH portion of the budget is affordable under the 20 billion rand budget allocation for the medical COVID-19 response. **These projections are subject to considerable uncertainty and variability. Estimates will change and improve as the epidemic progresses and new data become available.** ICU and hospital bed numbers are to be interpreted with caution as severity of disease is yet to be contextualised to South Africa, and admission to ICU is likely to be subject to stricter criteria than globally. Nevertheless, model projections indicate that the number of available hospital and ICU beds will likely be exhausted by July, possibly increasing the death rate beyond what is projected here.

As updated testing and hospital data become available, the models can be calibrated to provide more robust predictions.

Due to the rapidly changing nature of the outbreak globally and in South Africa, the projections will need to be updated regularly and should be interpreted with caution. Changes in testing policy, contact tracing, and hospitalisation criteria will all impact the cases detected and treated in the next six months. The models have been developed using data that is subject to a high degree of uncertainty. Transmission has been modelled at national and provincial levels resulting in model predictions providing broad-stroke national/provincial guidance rather than informing strategy at a more granular level. All models are simplifications of reality that are designed to describe and predict system behaviour and are justified by the assumptions and data with which they are developed.

About the South African COVID-19 Modelling Consortium

The South African COVID-19 Modelling Consortium is a group of researchers from academic, non-profit, and government institutions across South Africa. The group is coordinated by the National Institute for Communicable Diseases, on behalf of the National Department of Health. The mandate of the group is to provide, assess and validate model projections to be used for planning purposes by the Government of South Africa. For more information, please contact Dr Harry Moultrie (harrym@nicd.ac.za).

Context for interpreting projections

The results presented below must be interpreted carefully and considering the following points of additional context:

Not all COVID-19 infections will be detected. Infected individuals who are asymptomatic are not likely to seek out a diagnostic test. Additionally, with laboratory and testing constraints, it is not always possible to test all individuals who seek laboratory confirmation. A meeting of epidemiologists was convened at the NICD to estimate the number of cases active in the population that were not being detected. The number of confirmed COVID-19 cases, evolution of patient under investigation criteria for COVID-19 testing, the number of contacts identified and proportion traced, and publications/reports on under-detection rates in other countries were reviewed. It was concluded that all hospitalised severe and critically ill cases would be detected while only 1 in 4 mildly ill cases would be detected. This inflation factor is applied in the model projections. The true value is unknown and is likely to vary through time. For example, it is likely that with a scale-up in testing and laboratory facilities this inflation factor will go down. The estimate may be revised for future projections. Serosurveillance studies are being planned to provide more robust estimates.

Projections at the population level do not capture local clustering of cases. The methods used in this report make simplifying assumptions regarding how contacts between infectious and uninfected people occur and assume that mixing is random at the provincial level. The models therefore cannot capture the differences in risk experienced by some members of society – e.g. health care workers or those living in close, confined quarters such as prisons – nor can it capture the effects of specific events – e.g. religious gatherings and funerals – on local transmission.

Models project total need for hospital and ICU beds. As currently formulated, the model assumes that hospital resources, including availability of general ward and ICU beds, staff, and ventilators, will be able to meet demand. This approach is intended to demonstrate the system-wide need for these resources. In reality, the demand for these resources is expected to exceed capacity. The effect, in particular on mortality, of not being able to meet ICU and ventilator demand is not taken into account in the model, nor are the effects of any rationing of these resources.

Estimating mortality due to COVID-19. There is considerable uncertainty when projecting mortality due to COVID-19 using mathematical models. At this early stage of the epidemic, it is unclear what proportion of people who become infected will die as well as precisely how many people will become infected over the course of the epidemic. It is also unclear how risk factors such as HIV, TB, and non-communicable diseases will impact COVID-19 mortality in South Africa. In the model presented here, mortality has been projected using age-specific mortality from the Chinese epidemic adapted to the South African population.

It is particularly important to note that the projections over a six month period for South Africa cannot be compared to *current* mortality in other COVID-19 affected countries, as

mortality would have been observed for at most three months in those countries. All countries are currently in the early phase of their epidemics, with resurgence expected in the coming months. Current model projections track observed mortality in South Africa estimating 2 deaths per million population by 4 May 2020. This rate falls below countries such as Algeria (11 per million) and Egypt (4 per million) on the same date (<https://www.worldometers.info/coronavirus/>). The mortality and case projections are also determined on the assumption that social distancing will continue after the 5-week lockdown. New national and/or geographically targeted interventions will impact the expected deaths due to COVID-19.

Models do not account for population-wide behaviour changes in response to high levels of mortality. The projections provided in this document are based on an assumption that after the lifting of hard lockdown measures, level four restrictions are assumed to be in place for one month following which social distancing will continue at a moderate level, reducing transmission by 10-20%. No further responses to the epidemic are incorporated, either government-imposed measures such as lockdowns or natural behavioural changes induced by the severity of the epidemic. In recent epidemics of severe disease, including the Ebola epidemic in West Africa, the population's response to high local mortality has played an important role in reducing the rate of epidemic growth and the ultimate number of infections and deaths. Similar dynamics have likely contributed to the decline of severe COVID-19 epidemics in countries such as Spain and Italy. The extent to which population-wide behavioural changes may influence the spread of the epidemic in South Africa, or how these changes may vary across the population, are unknown and not taken into account in the projections provided in this report.

Projections will improve with new data. At the time of this report, very limited data are available beyond the number of new cases confirmed through time at the national and provincial level. Additional data, in particular health system utilization data such as numbers of hospitalizations occurring in different geographic areas and duration of stay for patients requiring different types of care, will be required to further refine the model and tune it to the South African context. The uncertainty range in the projections has been generated by varying a subset of model parameters. These ranges will be modified as local data becomes available.

Understanding of the virus's epidemiology is continually evolving, both locally and globally. Important parameters about which there remains substantial uncertainty in the scientific literature include the proportion of infections that are truly asymptomatic, the relative infectiousness of these asymptomatic individuals, and the relative duration of infectiousness for these individuals, as well as the severity profile of cases in different contexts. The Appendix presents a sensitivity analysis that examines the effect of varying these factors on the timing and magnitude of the expected epidemic peak.

Budgets had to be calculated before anything was known about the cost and resources needed for these interventions in a routine setting. The estimated budget is based on best available data regarding the likely type, quantity and price of inputs as well as baseline availability of resources such as hospital beds, ventilator equipment, staff and testing capacity and their ability to be re-purposed for the COVID1-9 response. The prices of a number of central resources are currently subject to strong market forces as many countries around the world are competing for the same set of materials. Additionally, the increase in lead times on deliveries resulting from manufacturing countries' travel and trade bans means that even if the budget is made available, supply might not be complete or in time.

Note on the long term and short term projections for COVID-19

Three companion reports have been produced by the National COVID-19 Modelling Consortium to project cases and deaths for the COVID-19 epidemic in South Africa.

1. Short Term Projections: May 2020
2. Long Term National Projections
3. Long Term Provincial Projections

There are a number of key differences in the assumptions used to generate projections in the short and long term.

In the long run, it is expected that biological characteristics of the disease, its progression, severity and mortality, will be similar across the nine provinces. In order to generate long term projections, all provinces were assumed to have the same basic reproductive number (R_0), though this number was allowed to vary stochastically.

However, in the early stages of the epidemic, the disease may have seeded differently in the provinces and in communities with varying contact behaviour. Stochastic events such as clusters of cases or sharp increases in deaths may occur that are divergent from the average pattern. Hence the differences in patterns of growth of the epidemic tend to be larger at the beginning of the epidemic, but reduce as the epidemic progresses. Thus, to provide short term projections reflective of the trends observed in reported deaths, different R_0 values were estimated for each of the provinces.

These stochastic fluctuations are not expected to continue in the long run and therefore the basic reproductive number is assumed to be the same for all provinces in the long term projections. For this reason, there is a lack of congruence between the short term projections for 29 May 2020 and the long term projections for 1 June 2020 in the national and provincial reports.

The short-term projections will be updated on a weekly basis. We are planning to update the long-term projections towards the end of May, taking into account two aspects:

- additional data on the development of cases and deaths after the end of lock-down, which will give us a better estimate of the impact of Level 4 restrictions;
- better consideration of the spatial aspects of the epidemic at lower geographical scales.

Findings: Projected cases in the next six months

We model two scenarios, as detailed in Table 1, to capture uncertainty in the potential effectiveness of lockdown and social distancing measures. The scenarios are modelled as a reduction in the daily contact rate of individuals. Fixed values regarding the size of these reductions were determined by the SA COVID-19 Modelling Consortium. The level of adherence by the population to lockdown and social distancing regulations will influence the effectiveness of these measures.

Table 1. Modelled scenarios of intervention effectiveness

Scenarios	Description
Optimistic Effectiveness	<p>Lockdown reduces transmissibility until 30 April ($0.4 \cdot R_0$; 60% reduction in transmission relative to baseline)</p> <p>Level four restrictions reduce transmissibility from 1 May to 31 May ($0.65 \cdot R_0$; 35% reduction in transmission relative to baseline)</p> <p>Social distancing (school closures, limited public gathering) reduces transmissibility - implemented after 31 May ($0.8 \cdot R_0$; 20% reduction in transmission relative to baseline)</p>
Pessimistic Effectiveness	<p>Lockdown reduces transmissibility until 30 April ($0.6 \cdot R_0$; 40% reduction in transmission relative to baseline)</p> <p>Level four restrictions reduce transmissibility from 1 May to 31 May ($0.75 \cdot R_0$; 25% reduction in transmission relative to baseline)</p> <p>Social distancing (school closures, limited public gathering) reduces transmissibility - implemented after 31 May ($0.9 \cdot R_0$; 10% reduction in transmission relative to baseline)</p>

Table 2 summarises the ranges of the number of cases, required hospital and ICU beds, and deaths estimated by the mathematical model. It is important to realise that not all active cases will require healthcare. A substantial proportion of cases (75% in this analysis) are assumed to be asymptomatic or very mildly ill such that they would not require an outpatient care visit and would be very unlikely to seek COVID testing. Approximately 95% of active symptomatic cases are predicted to be mildly ill, with only a fraction of those seeking outpatient care or

COVID testing. **Large case numbers do not necessarily present a large burden on the health system.** As has been the experience of many countries around the world, the vast majority of COVID-19 cases will show no or mild symptoms. Thus, the total case numbers projected by the model and shown in this document are substantially higher than would be reported.

Estimates on hospitalisation and death are based on international data. These will be regularly updated with admissions and case fatality data as these become available and the epidemic progresses. The wide variability in these projections suggests that there is much unknown about the disease. As such these estimates should be treated with caution.

The number of cases detected depends on patients feeling sick enough to seek testing/hospitalisation and being able to receive a test. Different criteria may exist in the public and private sector resulting in different testing and positivity rates. The detection factor takes this into account by adjusting the number of overall cases for those that would be detected. The detection factor is arbitrary in that it may relate only to one point in time. As public awareness and test seeking or contact tracing increases, and as tests are scaled up around the country, this factor will decrease.

Figure 1. Projected National cases

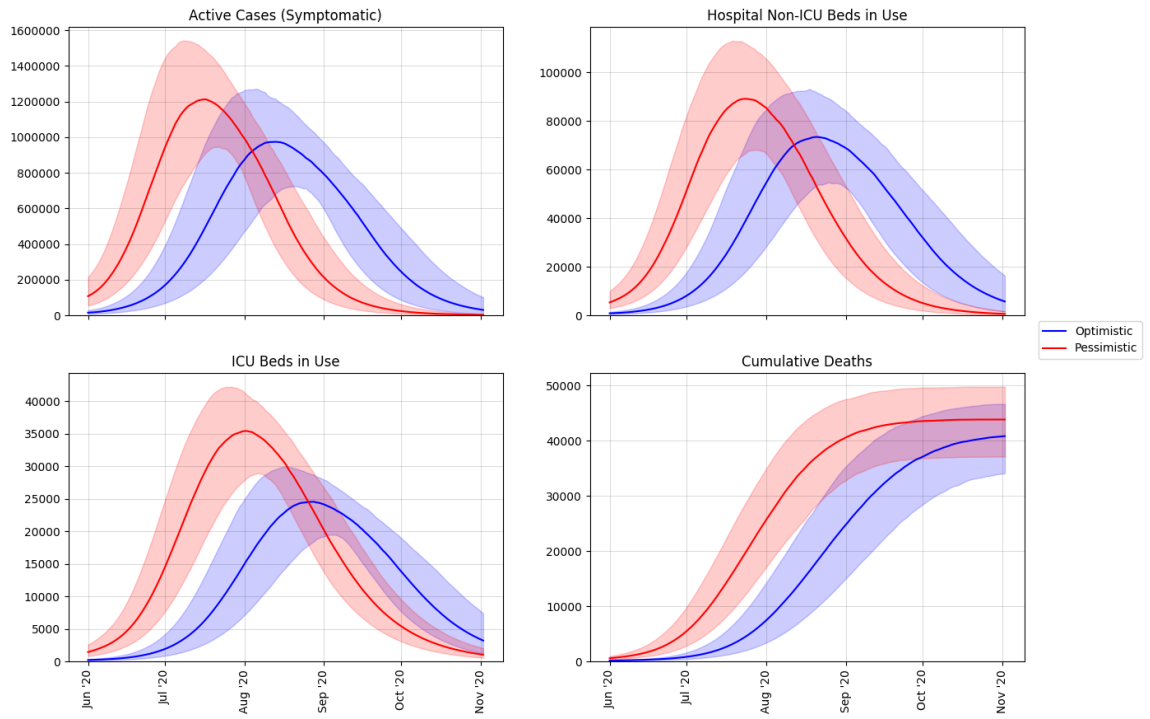


Table 2. Projected National cases

		Cumulative Incidence		Active Cases		Cumulative Detected Cases
		Total	Symptomatic	All	Symptomatic	
Optimistic	2020-06-01	382,366 (237,390 - 632,813)	71,541 (45,134 - 117,526)	82,298 (43,008 - 157,053)	14,763 (7,736 - 28,712)	15,817 (10,702 - 24,781)
	2020-07-01	3,661,393 (1,676,865 - 7,448,898)	598,489 (276,180 - 1,299,104)	966,647 (398,228 - 2,163,111)	169,318 (69,374 - 392,257)	112,997 (55,232 - 238,964)
	2020-08-01	21,686,098 (11,622,701 - 32,540,064)	4,270,362 (2,105,178 - 7,179,877)	4,696,334 (2,602,093 - 6,255,373)	874,156 (472,490 - 1,264,623)	910,318 (439,042 - 1,642,691)
	2020-09-01	41,487,628 (30,638,488 - 48,321,906)	9,524,163 (6,518,622 - 12,275,248)	4,063,347 (2,953,085 - 4,502,688)	791,638 (594,880 - 968,958)	2,416,136 (1,592,775 - 3,282,335)
	2020-10-01	47,781,735 (42,677,516 - 50,722,344)	11,744,679 (9,571,499 - 13,614,809)	1,171,259 (400,569 - 2,396,710)	244,925 (85,914 - 489,073)	3,245,104 (2,589,072 - 3,817,607)
	2020-11-01	48,658,190 (45,681,241 - 50,944,673)	12,153,147 (10,261,464 - 13,828,132)	141,168 (35,705 - 515,442)	32,146 (8,367 - 107,815)	3,450,932 (2,896,897 - 3,932,537)
Pessimistic	2020-06-01	2,306,459 (1,343,540 - 4,094,445)	394,780 (226,084 - 718,080)	598,761 (313,294 - 1,171,397)	107,255 (54,538 - 214,996)	76,106 (44,955 - 129,884)
	2020-07-01	20,139,796 (12,223,262 - 29,701,255)	3,761,577 (2,072,257 - 6,186,825)	5,058,676 (3,006,812 - 7,170,122)	942,500 (529,302 - 1,444,940)	743,689 (400,140 - 1,271,758)
	2020-08-01	44,867,939 (36,510,103 - 50,458,627)	10,327,075 (7,579,812 - 12,934,700)	5,011,909 (3,855,147 - 5,574,058)	991,907 (776,146 - 1,187,468)	2,586,688 (1,830,408 - 3,340,153)
	2020-09-01	50,929,041 (48,236,582 - 52,942,777)	12,651,032 (10,639,563 - 14,532,758)	960,210 (380,199 - 2,037,842)	212,102 (88,366 - 433,899)	3,532,779 (2,920,352 - 4,080,889)
	2020-10-01	51,444,712 (49,503,933 - 53,109,938)	12,926,888 (10,934,833 - 14,686,634)	87,694 (28,465 - 265,289)	23,404 (8,869 - 62,399)	3,670,117 (3,104,194 - 4,173,374)
	2020-11-01	51,474,905 (49,631,737 - 53,126,395)	12,941,100 (10,948,713 - 14,710,158)	7,199 (2,221 - 25,104)	2,579 (1,031 - 7,161)	3,685,249 (3,118,462 - 4,187,290)

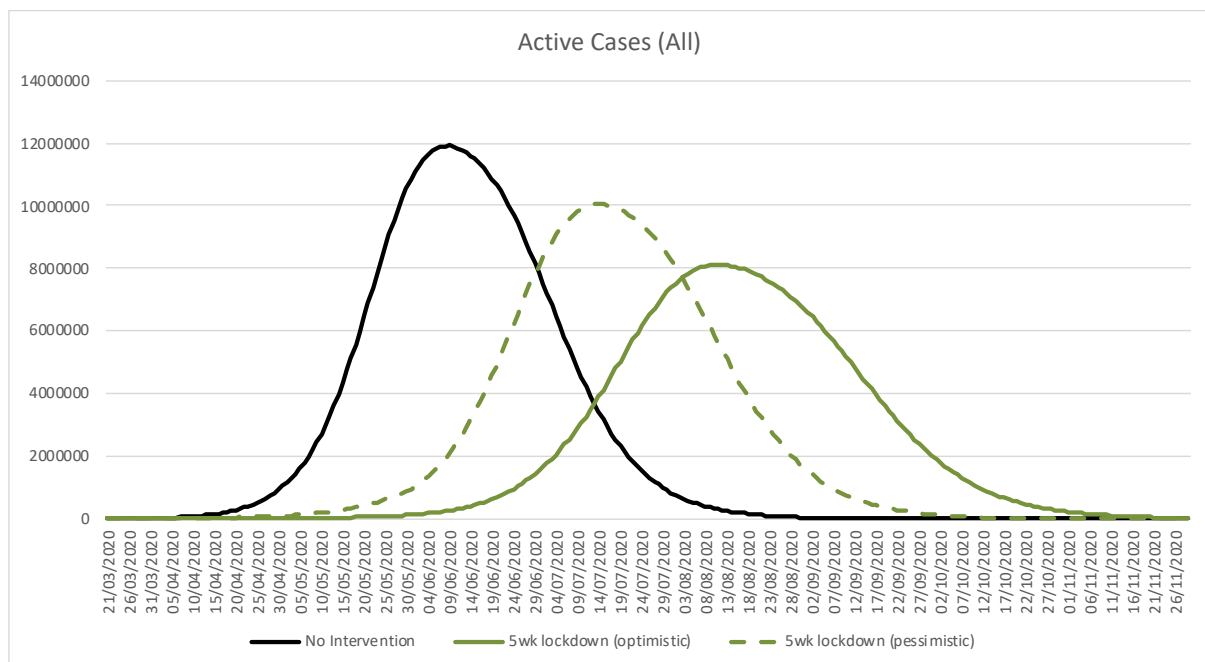
		Cumulative Admissions		Hospital Beds in Use		Cumulative Deaths
		Non-ICU	ICU	Non-ICU	ICU	
Optimistic	2020-06-01	2,256 (1,533 - 3,473)	729 (509 - 1,088)	797 (459 - 1,417)	206 (124 - 353)	151 (112 - 216)
	2020-07-01	15,559 (7,494 - 32,584)	4,563 (2,288 - 9,305)	8,079 (3,637 - 17,771)	1,904 (860 - 4,177)	822 (431 - 1,618)
	2020-08-01	120,685 (57,869 - 211,333)	38,392 (17,898 - 69,730)	54,543 (28,321 - 84,713)	14,973 (7,120 - 24,936)	7,430 (3,386 - 14,249)
	2020-09-01	295,663 (187,592 - 417,938)	106,621 (66,939 - 152,058)	68,893 (52,545 - 84,191)	24,113 (19,203 - 27,907)	24,750 (14,979 - 35,296)
	2020-10-01	382,637 (228,801 - 545,682)	146,208 (88,301 - 206,118)	31,924 (13,493 - 51,484)	13,829 (7,664 - 18,921)	37,090 (28,446 - 44,459)
	2020-11-01	398,642 (233,027 - 592,912)	154,810 (90,736 - 228,674)	6,034 (1,663 - 17,179)	3,372 (1,321 - 7,716)	40,784 (34,015 - 46,657)
Pessimistic	2020-06-01	10,491 (6,252 - 18,515)	3,134 (1,906 - 5,373)	5,295 (2,904 - 9,990)	1,427 (815 - 2,586)	571 (363 - 940)
	2020-07-01	100,141 (53,767 - 170,262)	30,273 (16,056 - 53,112)	51,450 (28,253 - 82,260)	14,483 (7,651 - 24,735)	5,486 (2,849 - 9,869)
	2020-08-01	317,464 (218,114 - 430,965)	113,133 (77,200 - 155,052)	85,462 (66,685 - 105,619)	35,380 (27,830 - 41,328)	25,647 (17,037 - 34,982)
	2020-09-01	414,516 (268,720 - 575,892)	158,892 (104,060 - 218,569)	31,851 (15,444 - 53,186)	20,121 (13,658 - 26,613)	40,565 (32,773 - 47,489)
	2020-10-01	425,360 (272,006 - 605,924)	165,134 (106,082 - 234,462)	5,024 (1,915 - 12,257)	5,410 (3,073 - 9,545)	43,543 (36,811 - 49,614)
	2020-11-01	426,207 (272,216 - 609,022)	165,634 (106,210 - 236,259)	606 (215 - 1,818)	1,078 (577 - 2,125)	43,831 (37,094 - 49,774)

**Projections on hospital bed use assume unconstrained resources (testing, hospital beds, ICU beds)

The projected impact of lockdown

The scale-up in testing and data collected over the next few weeks will allow models to estimate the impact of lockdown. In the absence of such data, using the suggested optimistic and pessimistic effectiveness of lockdown, the model projected the epidemic curve for the scenarios of no intervention and the 35-day lockdown followed by Level 4 restrictions for one month and social distancing thereafter. The figure below is subject to wide uncertainty when estimating eight months into the future. The optimistic and pessimistic impacts of lockdown demonstrate considerable shifts in and flattening of the epidemic curve. The projected epidemic curves in Figure 2 show all active infections (asymptomatic and symptomatic), whether detected or not.

Figure 2. Projected epidemic curves (total active infections) under the 5-week lockdown scenario compared to a hypothetical scenario with no lockdown



Required budget

We projected the required budget for the first 6 months of the COVID-19 response (Apr-Sept 2020) under the pessimistic and optimistic scenarios, covering the incremental cost of personal protective equipment (PPE), additional ICU and hospital beds and staff, additional PHC staff, ventilators, oxygen, drugs at all levels of care, isolation facilities, testing and surveillance and Port Health budgets. Excluded are the costs of setting up and running field hospitals, oxygen delivery equipment, additional testing platforms beyond the currently planned ones (Xpert and Alinity), and additional NHLS staff. Stipends for additional community health workers to carry out screening activities are excluded as these are funded by a donor's budget; their PPE and other equipment is however covered. Based on this, the required total budget for the national and provincial departments of health will be between 26 and 32 billion rand over the next 6 months, of which between 10 and 15 billion rand will accrue to the National Department of Health (NDOH), in keeping with the additional 20 billion rand allocation for the medical aspect of the COVID-19 response announced by the President on 21 April 2020. (Note that while the details of the distribution of the budget items between the NDOH and provinces are still subject to discussion, this distribution assumes that the cost of testing, thermometers, drugs, and PHC staff will be borne by provinces).

Provincial variability

The epidemics in the provinces that had early seeding and growth of the epidemic (KwaZulu-Natal, Gauteng and Western Cape) are all expected to peak quickly. The peaks of other provinces are projected to occur later due in part to their population distribution and delayed seeding. Once public sector testing has increased substantially, the models will be recalibrated to better inform exact timing of each provincial peak and at which dates the hospital resources are expected to be exceeded. Figure 3 below shows this variation in timing of the epidemic peak between the provinces under the optimistic and pessimistic lockdown scenarios.

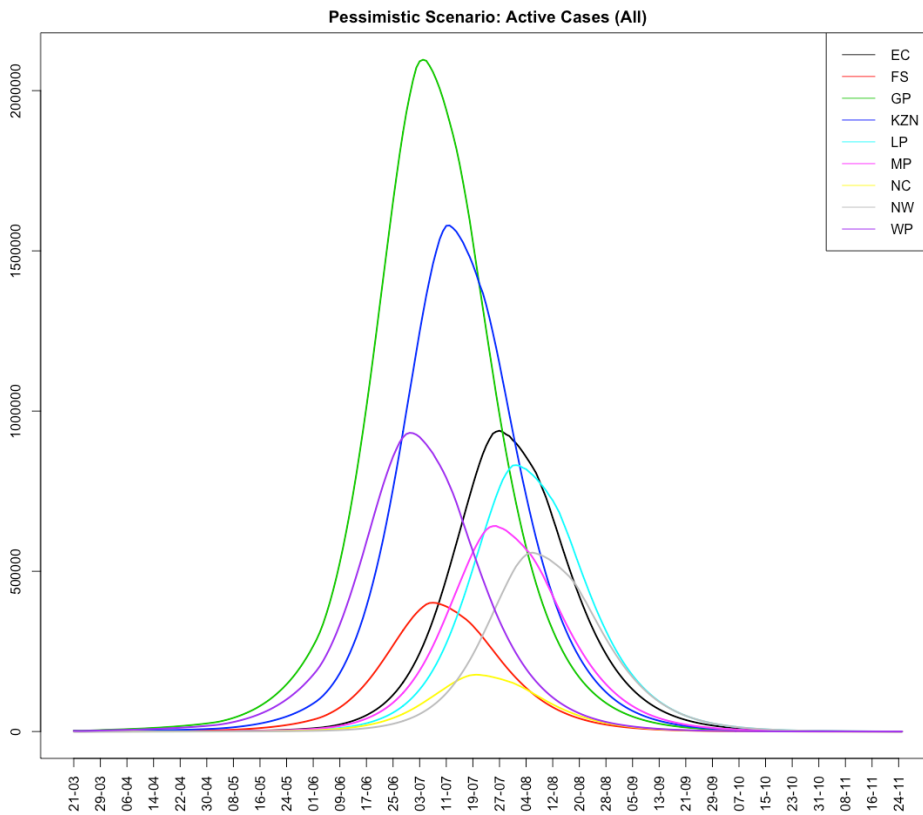
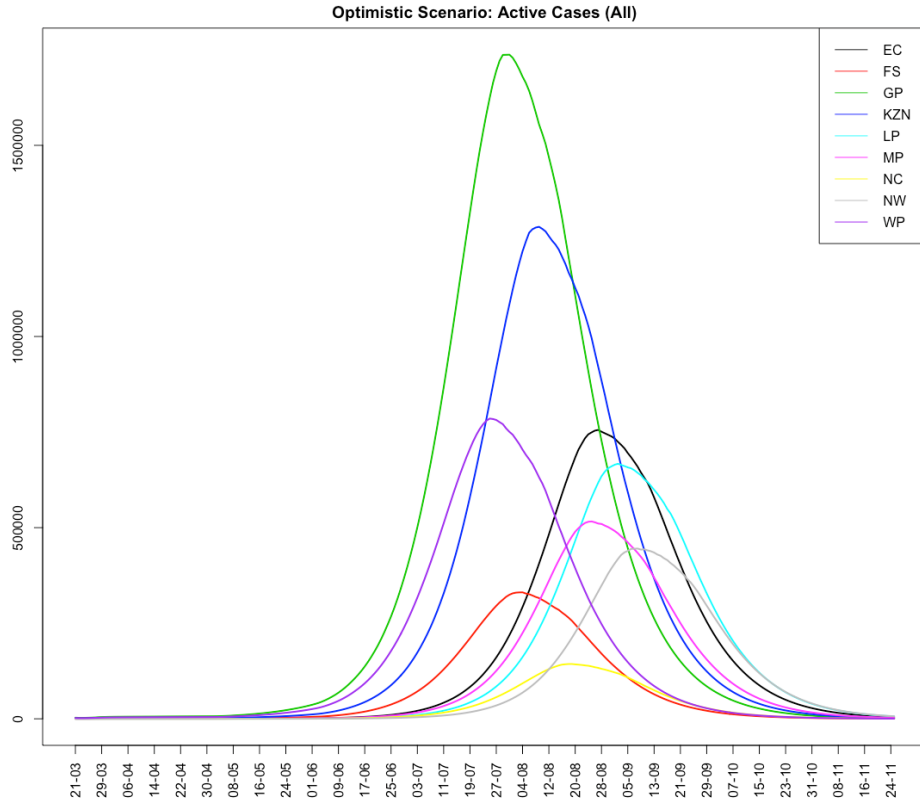


Figure 3. Projected provincial epidemic curves under optimistic and pessimistic scenarios

Key Parameter values:

Table 4 below shows the values of key parameters used to inform the model. Parameter values have been selected for use by an expert panel of clinicians on the SA Covid-19 Modelling Consortium.

Table 4. Key model parameters

	Parameter	Value (range)	Sources
Infection severity**	Proportion of cases that are asymptomatic	75% (0.7, 0.8)	[1], [2], [3]
	Mild to moderate cases among the symptomatic	(95.64%, 96.78%)	[5]
	Severe cases among the symptomatic	(2.46%-3.64%)	
	Critical cases among the symptomatic	(1.16%-1.45%)	
	Proportion of cases that are fatal	(0.30%, 0.412%)	[4], [5]
Timeframes & treatment durations	Time from infection to onset of infectiousness	4 days (2.0-6.0)	[4], [6], [7], [8], [9], [10] with input from analysis of NICD data.
	Time from onset of infectiousness to onset of symptoms	2 days (1.0-3.0)	
	Duration of infectiousness from onset of symptoms	5 days (4.0, 6.0)	
	Time from onset of mild symptoms to testing	4 days (3.0-5.0)	
	Time from onset of symptoms to hospitalisation	5 days (4.0–6.0)	
	Time from onset of symptoms to ICU admission	9 days (7.0–11.0)	
	Duration of hospital stay	12 days (8.0–14.0)	
	Duration from ICU admission to discharge	18 days (14.0–18.0)	
	Duration from ICU admission to death	5 days (4.0-7.0)	

Data sources

The model has been informed by published and pre-print academic literature, global COVID-19 case information (specifically from the European CDC, World Health Organization and China CDC), South African population statistics from Stats SA's 2019 mid-year report, expert input from members of the SA COVID-19 Modelling Consortium, and national case details from the South African National Institute for Communicable Diseases and <https://sacoronavirus.co.za/category/press-releases-and-notices/>.

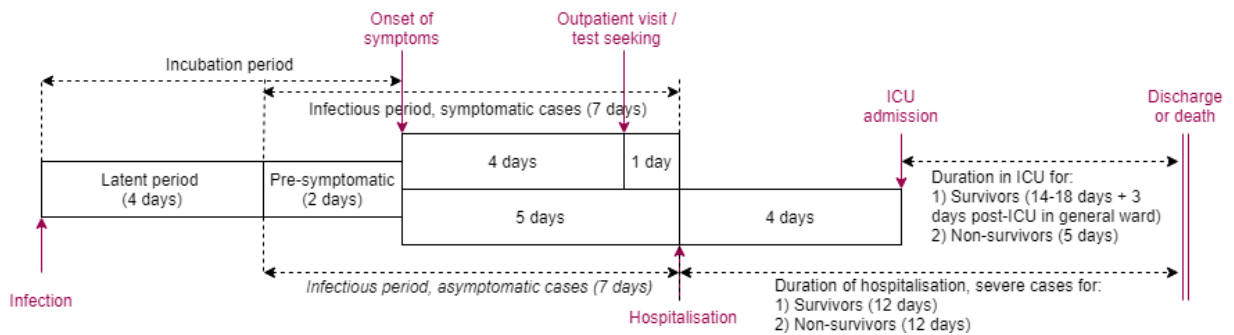
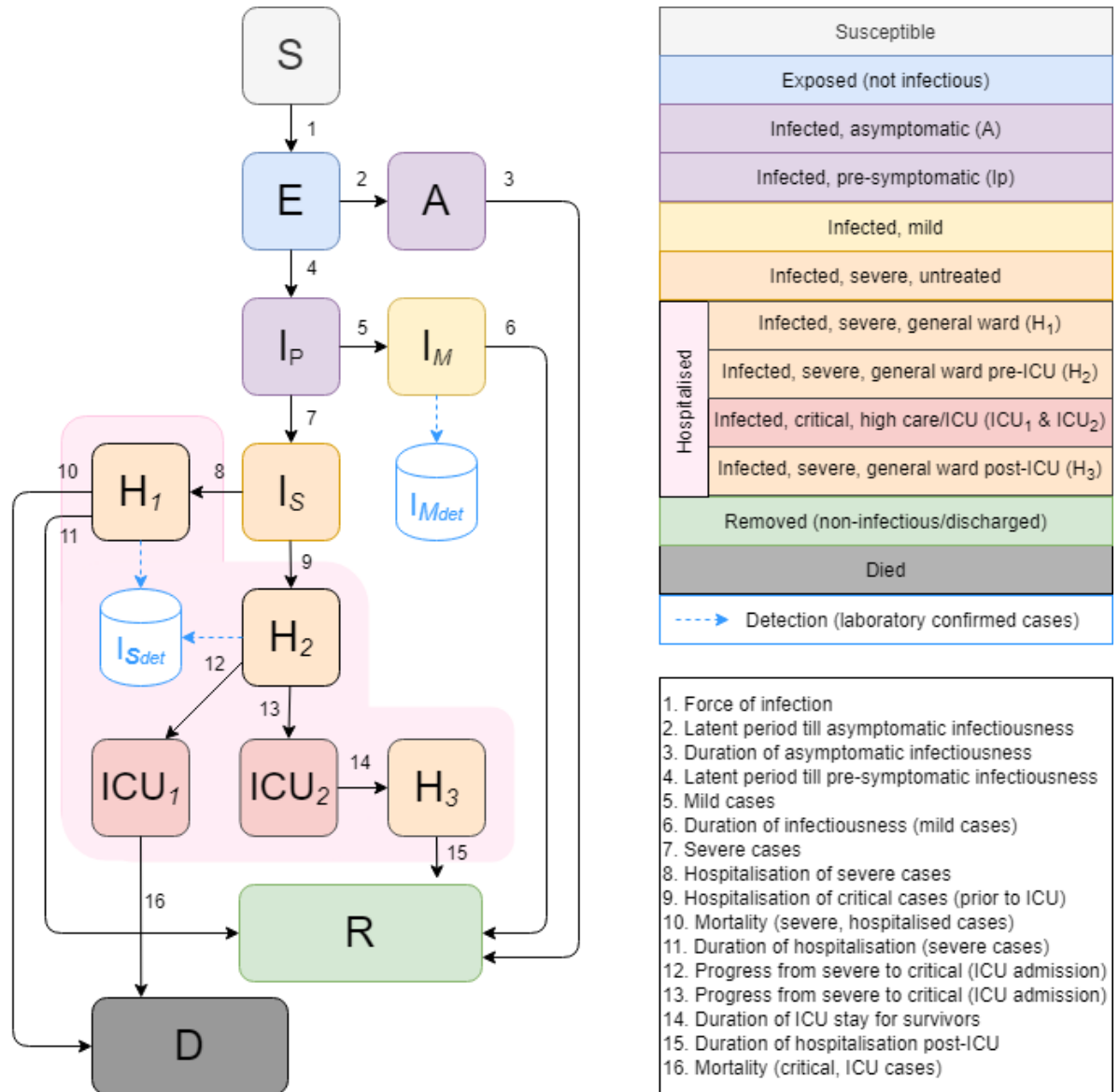
About the National COVID-19 Epi Model

The National COVID-19 Epi Model (NCEM) is a stochastic compartmental transmission model to estimate the total and reported incidence of COVID-19 in the nine provinces of South Africa. The outputs of the model may be used to inform resource requirements and predict where gaps could arise based on the available resources within the South African health system. The model follows a generalised Susceptible-Exposed-Infectious-Recovered (SEIR) structure accounting for disease severity (asymptomatic, mild, severe and critical cases) and the treatment pathway (outpatients, non-ICU and ICU beds) as shown in Figure 4. Contributors to the NCEM include Sheetal Silal, Rachel Hounsell, Jared Norman, Juliet Pulliam, Roxanne Beauclair, Jeremy Bingham, Jonathan Dushoff, Reshma Kassanjee, Michael Li, Cari van Schalkwyk, Alex Welte, Lise Jamieson, Brooke Nichols and Gesine Meyer-Rath. For more information please contact Dr Sheetal Silal (sheetal.silal@uct.ac.za).

About the National COVID-19 Cost Model

The National COVID-19 Cost Model (NCCM) was developed using inputs from a range of health economists in South Africa contributing data from existing sources that were adapted to represent the type, number, and prices of ingredients required in the country's COVID-19 response. The model produces the COVID-19 response budget for the National and provincial departments of health, incremental to existing resources such as hospital beds and staff contingents. Contributors to the NCCM include Gesine Meyer-Rath, Kerensa Govender, and Jacqui Miot from the Health Economics and Epidemiology Research Office (HE2RO) at Wits, Nikhil Khanna and colleagues at the Clinton Health Access Initiative (CHAI) South Africa, Ijeoma Edeka and colleagues at PRICELESS at Wits, Donnela Besada and Emmanuelle Daviaud at the Medical Research Council (MRC), Steve Cohen at Genesis, and David Crewe-Brown from SCTA. For more information please contact Dr Gesine Meyer-Rath (gesine@bu.edu).

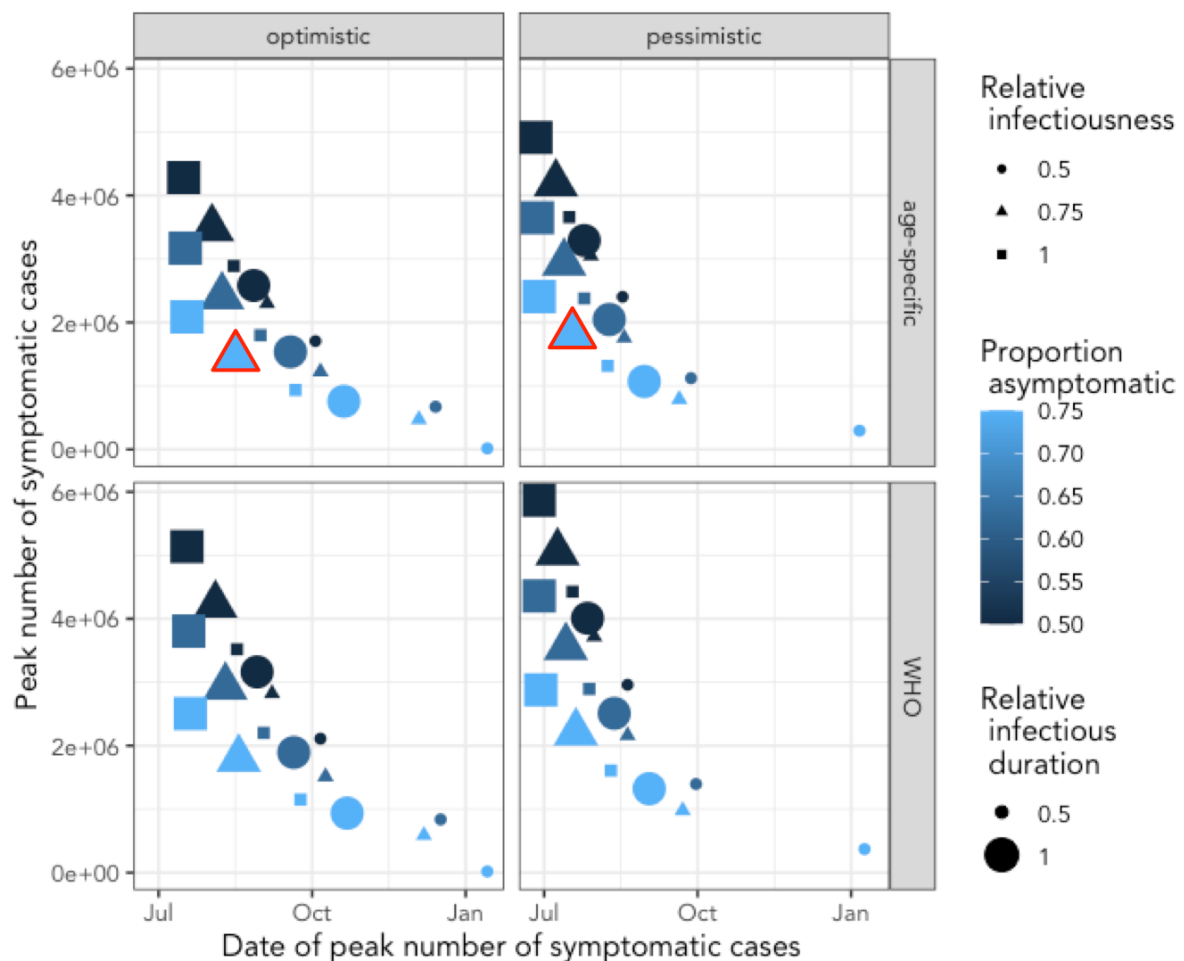
Figure 4. Generalised SEIR Model Structure (Disease and Treatment Pathway)



Appendix

Sensitivity analysis examines the effect of varying certain parameters on the timing and magnitude of the expected epidemic peak. The points representing the parameters used in the main analyses are outlined in red. The following parameters were explored:

- Proportion of infectious that are asymptomatic throughout the course of infection (values considered in sensitivity analysis: 0.5, 0.625, 0.75; value used in main analysis: 0.75).
- Relative infectiousness of asymptomatic infections to symptomatic ones (values considered in sensitivity analysis: 0.5, 0.75, 1; value used in main analysis: 0.75).
- Infectious duration of asymptomatic infections relative to mild infections (values considered in sensitivity analysis: 0.5, 1; value used in main analysis: 1).
- Distribution of mild, severe, and critical cases (levels considered were the values as presented in the WHO-China mission report and values derived from adjusting the China age-specific severity values to the South African population; the adjusted, age-specific values were used in the main analysis).
- Scenario regarding effectiveness of interventions (optimistic and pessimistic, as described above; both are presented in main analysis).



References:

1. Inui S, Fujikawa A, Jitsu M, Kunishima N, Watanabe S, Suzuki Y, et al. Chest CT Findings in Cases from the Cruise Ship “Diamond Princess” with Coronavirus Disease 2019 (COVID-19). *Radiol Cardiothorac Imaging* [Internet]. 2020 Apr 1 [cited 2020 Mar 23];2(2):e200110. Available from: <http://pubs.rsna.org/doi/10.1148/ryct.2020200110>
2. Sutton, D., Fuchs, K., D’Alton, M. and Goffman, D., 2020. Universal screening for SARS-CoV-2 in women admitted for delivery. *New England Journal of Medicine*.
3. Day, M., 2020. Covid-19: four fifths of cases are asymptomatic, China figures indicate.
4. World Health Organization. Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19) [Internet]. 2020 [cited 2020 Mar 14]. Available from: <https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf>
5. Verity R, Okell LC, Dorigatti I, Winskill P, Whittaker C, Imai N, et al. Estimates of the severity of COVID-19 disease. *medRxiv*. 2020 Mar 13;2020.03.09.20033357.
6. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *www.thelancet.com* [Internet]. 2020 [cited 2020 Mar 14];395:497. Available from: <https://isaric.tghn.org/protocols/>
7. Gaythorpe K, Imai N, Cuomo-Dannenburg G, Baguelin M, Bhatia S, Boonyasiri A, et al. Report 8: Symptom progression of COVID-19 [Internet]. 2020 Mar [cited 2020 Mar 18]. Available from: <https://doi.org/10.25561/77344>
8. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet* [Internet]. 2020 Mar [cited 2020 Mar 14];0(0). Available from: <https://linkinghub.elsevier.com/retrieve/pii/S0140673620305663>
9. Tindale L, Coombe M, Stockdale JE, Garlock E, Lau WYV, Saraswat M, et al. Transmission interval estimates suggest pre-symptomatic spread of COVID-19. *medRxiv*. 2020 Mar 6;2020.03.03.20029983.
10. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical Characteristics of 138 Hospitalized Patients with 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. *JAMA - J Am Med Assoc*. 2020 Mar 17;323(11):1061–9.
11. StatsSA. Mid-year population estimates 2019. Statistical release P0302. 2019.