Abstract

This paper contains risk management modelling and discussion on the alternative COVID-19 herd immunity and elimination strategies for Western Australia. The paper discusses findings within the context of a risk management framework with conclusions provided, for the purpose of informing the public and democratic institutions so that they can further contribute to the public debate that is currently occurring regarding Western Australia's COVID-19 strategy. The modelling and discussions can easily be extrapolated to other Australian states and the whole of Australia.

The paper draws the following conclusions:

1. The herd immunity strategy is likely to result in 5 300 to 25 300 deaths in Western Australia that would largely be avoided under an elimination strategy.
2. The herd immunity strategy is likely to require 0.9 to 4.4 years of draconian public health measures that would largely be avoided under an elimination strategy.
3. Evidenced based on immune response to other coronaviruses indicates natural COVID-19 immunity will be short-term making it likely the natural herd immunity strategy will be unsuccessful long-term.
4. There was just 1 new case of COVID-19 spread from an unknown source in Western Australia over the week 12th to 19th April 2020. As of 19/04/2019 there had been a total of 14 case of unknown source or just 2.6% of cases. This provides anecdotal evidence that there are low rates of undetected asymptomatic COVID-19 infections in Western Australia, meaning the higher number of deaths (25 300), and the longer period of draconian health measures (4.4 years) are likely. Conversely it means there is currently a high chance of the elimination strategy being successful.
5. There are serious COVID-19 health risks other than death, such as long-term damage to the lungs and other organs of many who survive the disease.
6. The herd immunity strategy has significant health, economic, social, political, ethical and moral risks that are greatly reduced under the elimination strategy.
7. The requirement to deliberately increase COVID-19 infection and death rates, and greatly extend draconian health measures under the herd immunity strategy has not been clearly communicated to the Western Australian public and is likely to cause confusion if it is. An elimination strategy will allow the communication of a clear public health message to the Western Australian public.
8. There are currently many unknowns regarding COVID-19 (asymptomatic infection rates, immune response, effective treatments, ability to create a vaccine). The elimination strategy will allow time for the development of a greater understanding of COVID-19 leading to better informed strategies and likely better outcomes in the future. Continuing the herd immunity strategy at the current time negates these likely future improvements.
9. The Government of Western Australia should continue to build surge healthcare system capacity, just in case.
10. The Government of Western Australia should immediately adopt an elimination strategy and campaign for the same across the whole of Australia.

Introduction

As of 19/04/2020 the COVID-19 crisis has resulted in over 2.3 million confirmed COVID-19 cases and over 160 000 COVID-19 deaths globally (Johns Hopkins University, 2020). To control the outbreak governments around the world, including the Australian Federal Government and the Western Australia State Government have closed borders, restricted gatherings, encouraged working from home, and placed restrictions on many nonessential business and personal activities.

Greenbank (2020) reports how Australia's Deputy Chief Medical Officer describes two main schools of thought that can be used in combatting COVID-19. These are identified below:

1. **Flatten the curve to achieve herd immunity whilst avoiding overwhelming hospitals.** Greenbank (2020) indicates this will take 6- 12 months and is the strategy being followed by the Australian Federal Government. Duckett (2020) agree this option will require tight controls for as long as 12 months and identifies the strategy as "*the more deadly option*" whilst the "*impact on the economy would be severe and sustained*". Duckett (2020) states, *"Australia should explicitly reject a herd immunity strategy".*
2. **An eradication strategy as being implemented by New Zealand.** Greenbank (2020) describes how University of Melbourne epidemiologist Professor Tony Blakely believes whilst it's not guaranteed to work there is still a "50:50 shot" of achieving elimination should the government switch to this strategy. More recently and as Australia's curve has further flattened Duckett (2020) argues that,

   "The numbers of new locally transmitted cases is decreasing. We won't know for sure until testing is greatly expanded, but the number of cases in the community looks to be in control. Given this, state and territory governments should maintain harsh lockdown restrictions until new cases are effectively down to zero or close to it… …Some states – such as South Australia and Western Australia – could hit this threshold in a couple of weeks[1]. Then they could start to slowly lift their restriction".

Greenbank (2020) describes how, according to University of Melbourne epidemiologist Tony Blakely, many Australians don't realise the eradication strategy is not being followed in Australia, whilst Epidemiologist Professor Hassan Vally, from La Trobe University is reported as saying:

> "*Herd immunity was not straightforward, and warned it would be "reckless" to deliberately spread the virus through the community. "Letting the virus run through the population just doesn't make sense. We would be left with a lot of deaths".*

Hutchens (2020) describes how 250 economists have written an open letter to *"urge Government not to relax restrictions yet. The open letter — released on Monday* [20/04/2020] *— has more than 250 signatures and growing, including current Reserve Bank board member Ian Harper, former RBA board member Warwick McKibbin, former Treasury and RBA officials, and prominent academic economists."* Whilst, Rory Robertson, a former Reserve Bank economist *"has criticised the open letter from economists, saying… … …there have been almost no deaths of anyone under 60 years old"*.

Carmody (2020) describes on 1/4/20 how the Government of Western Australia's was committed to the, national flatten the curve to achieve herd immunity strategy.

In this paper models are developed that seek to answer the questions:

1. How long will it take to achieve herd immunity in Western Australia without overwhelming the health care capacity?
2. How many deaths are predicted under a herd immunity strategy in Western Australia?

The paper discusses findings within the context of a risk management framework with conclusions provided, for the purpose of informing the public and democratic institutions so that they can further contribute to the public debate that is currently occurring regarding Western Australia's COVID-19 strategy.

Findings from this paper can almost certainly be extrapolated nationally (with significant implications for Western Australia). For other countries with elimination potential, findings may also have international relevance.

[1] Epidemiologist should design the eradication program.

Flattening the Curve – Graphical Illustration

Figure 1 provides a schematic typically of recent media reports (Roberts, 2020). The two curves represent the number of cases against time with and without COVID-19 protective measures in place. In this typical media diagram it shows that without protective measures there is a small bump above the "healthcare system capacity" line whilst with the protective measures the curve is flattened below the "healthcare system capacity" line and so the most lives possible are saved whilst allowing herd immunity to develop.

Whilst **Figure 1** is useful for communicating the general principle to the public, it is fairly misleading in terms of how long the curve needs to be flattened for, so as to keep cases within the healthcare system capacity.

Figure 2 from a paper by the Imperial College COVID-19 Response Team provides a much more realistic representation of just how far the bump typically extends above the healthcare system capacity line (Ferguson et al., 2020) and is also fairly representative of Western Australia. To get this much larger bump in **Figure 2** down below the health care system capacity line will take a lot longer – by **Model 1** calculations developed in this paper it could take over 4 years.

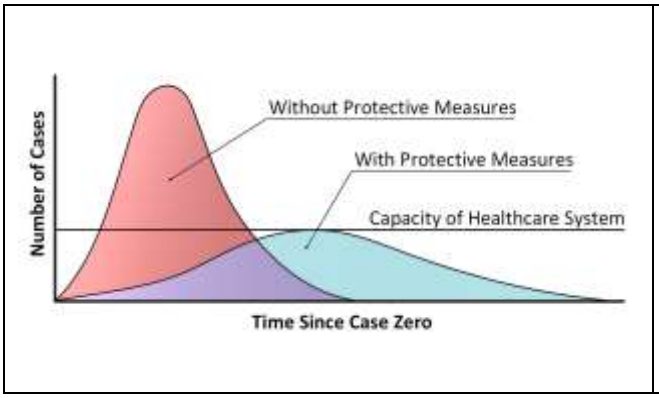


Figure 1: Typical media schematic showing "flattening the curve" adapted from Roberts (2020)

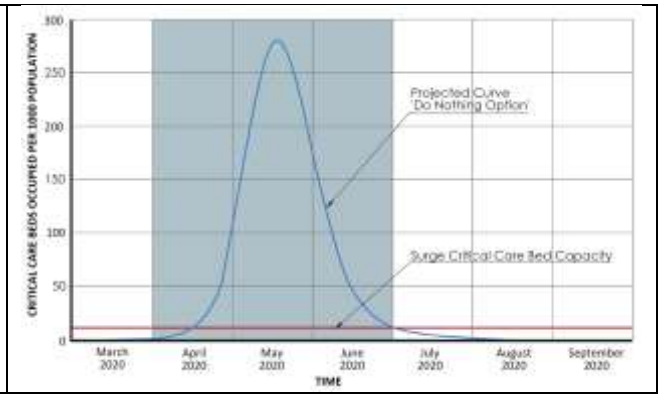


Figure 2: More realistic schematic showing "extent of curve above Healthcare system capacity line adapted from Ferguson et al. (2020)

Modelling

Appendix 1: provides models, variables and variable values used in modelling in this paper.

Model Results

Using **Model 1** and based on variables and variable values in **Appendix 1** it is calculated that the time required to reach herd immunity in WA without overwhelming the healthcare system for the three different rates of asymptomatic infection modelled are as given in **Table** 1 following.

Table 1: Model 1 Results

Rate of Asymptomatic Infection	Years Required to Achieve Herd Immunity in WA
5 % (Low Range)	4.4 years (1.d.p.)
50 % (Mid-Range)	2.3 years (1.d.p.)
80 % (High Range)	0.9 years (1.d.p.)

Using **Model 2** and based on variables and variable values in **Appendix 1** it is calculated that the excess deaths that are likely to occur in Western Australia under a herd immunity strategy that may be avoided under an alternative elimination strategy for the three different rates of asymptomatic infection modelled are as given in **Table 2** following.

Table 2: Model 2 Results

Rate of Asymptomatic Infection	Excess Deaths in Western Australia
5 % (Low Range)	**25 300 deaths** (3.s.f.)
50 % (Mid-Range)	**13 300 deaths** (3.s.f)
80 % (High Range)	**5 300 deaths** (2.s.f.)

Discussion

The 5 300 to 25 300 potential deaths (or planned deaths under the herd immunity strategy) represents a significant human cost and associated personal tragedy for many Western Australians. 0.9 to 4.4 years of draconian shutdown of the Western Australian economy and way of life seems an unacceptable and quite likely unnecessary public burden compared to those under the alternative elimination strategy that could most likely still be implemented.

There was just 1 new case of COVID-19 spread from an unknown source in Western Australia over the week 12th to 19th April 2020. As of 19/04/2019 there had been a total of 14 case of unknown source or just 2.6% of cases. This provides anecdotal evidence that there are low rates of undetected asymptomatic COVID-19 infections in Western Australia, meaning the higher number of deaths, and the longer period of draconian health measures identified above are likely. If this was borne out by randomised Western Australia COVID-19 immune response testing studies, then it would indicate the herd immunity strategy is likely to be closer to 4.4 years, with a planned 25 300 lives lost.

Conversely this anecdotal evidence indicates that an elimination strategy has a high likelihood of being successful and being achieved quickly. This will minimise the length of draconian social distancing measures required and the associated social and economic impact. Western Australia's internal economy can be fully opened up once elimination is achieved. With careful controls, major Western Australian export industries (mining, gas, agriculture and tertiary education) could be maintained. Western Australia's tourism industry can be supported in catering to domestic rather than international demand.

Models assumes that the curve can be flattened to a perfectly flat line along the healthcare system capacity line over the full time that is required to achieve herd immunity. In practice this will be next to impossible to achieve as it can be expected there will be bumps and troughs above and below the healthcare system capacity line. Either there will be excess deaths during bumps above the healthcare system capacity line or a safety factor will need to be introduced such that bumps don't go above the healthcare system capacity line. Introducing a safety factor will extend the time required to reach herd immunity. This is not currently considered in the models.

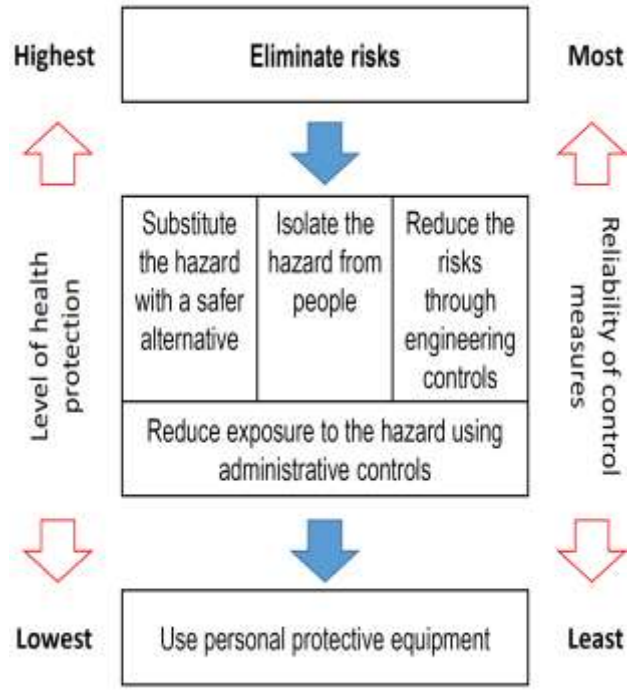
Variable C (Surge quantity of ICU beds-V available for treating COVID-19 patients in Western Australia), is the variable in these models that in the medium to long-term the Western Australian Government is most able to influence. Lashcon (2020) reported on 31/03/2020 that a further 301 ventilators and 200 ICU beds have been ordered by the Government of Western Australia. It is reported that these, *"will arrive in batches. The first due in the coming weeks"*. With the current global demand for medical ventilators along with disruptions to global supply chains due to the COVID-19 global crisis, it is difficult to know from this news article, when these further ICU beds-V might come online.

Litton et al. (2020) further discuss how surge capacity is also dependent on the ability to surge specialist doctors and nurses who manage patients and operate ventilators. They specifically identify not just equipment but the workforce that operates them as limiting factors in successful operating surge ICU beds-V. Should the Government of Western Australia decide to continue pursuing the herd immunity strategy then **Model 1** in this paper can be updated accordingly as further information becomes available. It is noted that whilst a

greater ICU bed-V surge capacity would reduce the time required for achieving herd immunity, it would not be expected to reduce planned deaths under the herd immunity strategy. In fact it is reasonable to expect that under crisis surge conditions with less experienced medical clinicians the Case Fatality Ratio (CFR) would be higher than currently modelled.

There is an extreme risk that the long-term draconian measures required to achieve herd immunity will be socially and politically unsustainable. On 12/04/2020 Speers (2020) describes how *"most house-bound stir-crazy Australians will no doubt be asking over this unusual Easter weekend: when will life return to normal?"* Australia is fortunate not to have the political dysfunction between Federal and State Government's apparent in the United States where the president is reported on 18/04/2020 to have, *"tweeted that Minnesota, Michigan and Virginia should be 'liberated' after demonstrations against social distancing"* (D. Smith, 2020). There is a high political risk that unclear messaging inherent to the herd immunity strategy, will lose the goodwill of Australians that has been essential to Australia's success in flatten the curve. Flattening the curve and then allowing COVID-19 to bubble along and even deliberately increase will not make sense to a lot of Australians. Flattening the curve to zero (elimination) provides a clear public health message that will make sense to most Australians. Australians will almost certainly be willing to endure further short term pain, for long term gain, if the public health messaging is clear.

The risk management hierarchy of control with which many Australians will be familiar, can be used in emergency and crisis situations to quickly identify that eliminating COVID-19 is the control that provides the most reliable and highest level of health protection (refer **Figure 3** following). Corporations and industry also apply the hierarchy of control in limiting economic and financial damage arising from emergency and crisis events. Once the emergency or crisis has subsided more time becomes available for a more detailed analysis of appropriate control measures and their implementation.



	• **Eliminate COVID-19.**
	• Activate emergency and crisis (pandemic) response plans. • Border controls and quarantine. • Testing and tracing, tracing applications. • Education and communication. • Social distancing & personal hygiene. • Immediate / surge medical response. • Treatment and vaccine development. • Herd immunity.
	• PPE: facemasks, face shields, protective gowns, Mechanical ventilation, Extracorporeal Membrane Oxygenation (ECMO). • Build PPE surge capacity.

Figure 3: Hierarchy of control adapted from Safe Work Australia (N.D.) and applied to COVID-19.

Tooze (2020) describes, *"the news on 23 January* [2020]*, that the outbreak of an unknown virus was serious enough for the Chinese authorities to impose a gigantic quarantine"*. The warning signs seemed clear, decisive action needed to be taken by the Australian Federal Government to prevent the COVID-19 entering Australia. In a critique of the UK government's COVID-19 response, Taleb (2020) professor of risk

engineering at New York University's Tandon School of Engineering, explains why they published an academic caution note on 25th January 2020:

> *"Our research did not use any complicated model with a vast number of variables, no more than someone watching an avalanche heading in their direction calls for complicated statistical models to see if they need to get out of the way.*
>
> *We called for a simple exercise of the precautionary principle in a domain where it mattered: interconnected complex systems have some attributes that allow some things to cascade out of control, delivering extreme outcomes.* ***Enact robust measures that would have been, at the time, of small cost: constrain mobility. Immediately.*** *Later, we invoked a rapid investment in preparedness: tests, hospital capacity, means to treat patients. Just in case, you know. Things can happen."*

But government's around the world (including Australia's Federal Government) seemed slow to recognise and react to the COVID-19 threat. Immediate decisive action was not taken to prevent COVID-19 entering Australia. Economically and socially this failure has already been much more costly[2], than if the Australian Federal Government had recognised the early warning signs and taken decisive action to keep COVID-19 out of Australia. This paper is not the place to point the finger of blame, there are established psychological reasons why humans often fail in a crisis (Marshall, 2020); historians will in time carry out detailed analysis and assessments and come to conclusions as to what went wrong. However, applying another risk management principle "lessons learnt" (Marshall, 2020), the Government of Western Australia must not allow the Australian Federal Government to now deter Western Australians from eliminating the COVID-19 threat from within their borders.

Discussing COVID-19 decision making failures, Marshall (2020) describes two psychological phenomena that humans are susceptible to during a crisis:

1. **Group Think:** In uncertain situations there is a psychological human tendency to conform and look to each other for guidance. Marshall (2020) explains:

   "At the level of government and other big organisations, this tendency to conformity can manifest as "groupthink". Intelligent and experienced decision-makers sometimes stop discussing the various options openly and instead uncritically accept whatever plan they think everyone else is settling on"

2. **Functional Stupidity:** Marshall (2020) further explains:

   "*There is a related concept called "functional stupidity", described by Mats Alvesson at Lund University in Sweden and Andre Spicer at City University of London in the UK. The pair found that organisations often hire clever and talented people, but then create cultures and decision-making processes that do not encourage them to raise concerns or make suggestions. Instead, everyone is encouraged to emphasise positive interpretations of events, leading to "self-reinforcing stupidity".*

In the current COVID-19 crisis, governments, other democratic institutions and the public should be familiar with normal human psychology failings. Leadership needs to nurture cultures that are open to constructive challenges in regards the consensus opinion.

There are currently many unknowns about COVID-19 and these demand a systematic risk assessment approached. Unknowns have to be considered in strategic COVID-19 risk assessments. Risks that need to be considered include:

[2] Janda (2020) reports on an Australian Bureau of Statistics (ABS) survey that concludes COVID-19 lockdowns, that have become necessary because the Australian Federal Government failed to keep COVID-19 out of Australia, has *"cost 1.6 million Australians their incomes… … in the first week of the total COVID-19 lockdown".*

- The herd immunity strategy may be unsuccessful in that persons recovered from COVID-19 infection may have limited or only temporary immunity. Willis (2020) reports how Professor Rawlinson from the University of New South Wales said;

  > *"What you might do is look at the other four coronaviruses … that cause the common cold every year", "We know that [this immunity] lasts for sort of months to years, so we could expect that SARS-CoV-2 immunity would not be forever.", "If you look at SARS, people became immune and they probably remained immune for up to a couple of years, and then it started to decline".*

- The herd immunity strategy may be unsuccessful in that COVID-19 may mutate such that persons who were previously immune are no longer immune.
- An effective COVID-19 vaccine may be available within 12-18 months, meaning deaths, social disruption and economic cost caused by draconian health control measures under the herd immunity strategy were unnecessary.
- There is a risk of COVID-19 "wild fire" type flare-ups under the herd immunity strategy resulting in healthcare system capacity being exceeded periodically with higher death rates than modelled in this paper. This would be unlikely under the elimination strategy.
- There are serious COVID-19 health risks other than death. N. Smith (2020) describes long-term damage to the lungs and other organs of many who survive the disease.
- Development of a vaccine may take a lot longer than 12-18 months, or even never be achieved (Khan, 2020), meaning Western Australia has to control borders indefinitely under the elimination strategy. However risk mitigations measures against this are, the elimination strategy buys time during which Western Australia's COVID-19 healthcare system capacity should continue to be built, and during which understanding of COVID-19 and COVID-19 treatments are both likely to significantly improve. Time also allows for democratic consultation such that should Western Australia ever decide to return to the herd immunity strategy it can be done with the full understanding and consent of the Western Australian public. Should Western Australia ever decide to return to the herd immunity strategy, these mitigations measures will lead to much shorter periods of draconian public health measure, less deadly outcome, and lower associated social, economic and political risk.
- It may not be business as usual in the post COVID-19 world. The COVID-19 crisis is still in the early stages of playing out. COVID-19 has introduced significant global economy and geopolitical risks that may impact key Western Australia exports. Governments need to hope and work for the best but plan for many different feasible scenarios.

There are many other risks that most likely could, and should be identified and quantified with suitable mitigation strategies and controls identified. Bringing in specialists from a wide range of fields who identify health, economic, and community risks is a common practice on large scale commercial projects in Western Australia. HAZID workshops provide a qualitative tool for undertaking this quickly and there are excellent and experienced risk workshop facilitators in Western Australia. The process typically identifies risks that need more quantitative assessments (models in this paper provide an example of quantitative risk assessment) and the results of these will further inform the process. Typically the results of the risk workshops are distributed to stakeholders with feedback providing further added value to the process. The result is the systematic consideration and evaluation of all risks. An elimination strategy will provide the time for these risk assessment processes to be undertaken in a deliberate and systematic manner.

Implementing a strategy that plans for the death of 5 300 to 25 300 elderly and otherwise vulnerable persons is not only a medical, social and economic matter. It also has significant ethical and moral implications, especially if an opportunity to implement an alternative much less deadly strategy is missed.

Based on the latest census, Australian Bureau of Statistics (2018) reports that 61% of the Australian population are affiliated with a religion or spiritual belief. Whilst Christianity remains the dominant religion, other prominent religions include Islam, Buddhism, Hinduism, Sikhism and Judaism with many other spiritual beliefs e.g. Australian Aboriginal traditional beliefs, also practiced (Australian Bureau of Statistics, 2018). Further it's probably safe to say that Australians who are unaffiliated with a religion or spiritual belief still maintain strong core ethical and moral values.

N. Smith (2020) describes how, *"it's not a choice between the economy and people's lives; it's a choice between short-term economic losses or extended economic losses combined with mass death*".

Ethics and spiritual leaders in Western Australian should be consulted as to whether it is ethically and morally acceptable to plan for the likely death of up to 5 300 to 25 300 elderly and otherwise vulnerable persons in Western Australia under the herd immunity strategy when the alternative less deadly elimination strategy is likely still possible and less economically and socially damaging.

Modelling in this paper produces widely varying results depending on the true asymptomatic COVID-19 infection rate. It is essential for the Government of Western Australia to establish robust evidence regards local asymptomatic COVID-19 rates of infection, before even considering returning to a herd immunity strategy such that the true duration and planned number of deaths under such a strategy can be assessed with a far greater degree of confidence.

If necessary the Government of Western Australian must go it alone in immediately adopting the elimination strategy. This will provide leadership to the whole of Australia. Western Australia's isolation makes this possible. However the elimination strategy will be far better if adopted by the Federal Australian Government and all Australian states. The Government of Western Australian should work towards the elimination strategy being adopted immediately right across Australia.

Conclusions

1. The herd immunity strategy is likely to result in 5 300 to 25 300 deaths in Western Australia that would largely be avoided under an elimination strategy.
2. The herd immunity strategy is likely to require 0.9 to 4.4 years of draconian public health measures that would largely be avoided under an elimination strategy.
3. Evidenced based on immune response to other coronaviruses indicates natural COVID-19 immunity will be short-term making it unlikely the natural herd immunity strategy will be successful long-term.
4. There was just 1 new case of COVID-19 spread from an unknown source in Western Australia over the week 12th to 19th April 2020. As of 19/04/2019 there had been a total of 14 case of unknown source or just 2.6% of cases. This provides anecdotal evidence that there are low rates of undetected asymptomatic COVID-19 infections in Western Australia, meaning the higher number of deaths (25 300), and the longer period of draconian health measures (4.4 years) are likely. Conversely it means there is currently a high chance of the elimination strategy being successful.
5. There are serious COVID-19 health risks other than death, such as long-term damage to the lungs and other organs of many who survive the disease.
6. The herd immunity strategy has significant health, economic, social, political, ethical and moral risks that are greatly reduced under the elimination strategy.
7. The requirement to deliberately increase COVID-19 infection and death rates, and greatly extend draconian health measures under the herd immunity strategy has not been clearly communicated to the Western Australian public and is likely to cause confusion if it is. An elimination strategy will allow the communication of a clear public health message to the Western Australian public.

8. There are currently many unknowns regarding COVID-19 (asymptomatic infection rates, immune response, effective treatments, ability to create a vaccine). The elimination strategy will allow time for the development of a greater understanding of COVID-19 leading to better informed strategies and likely better outcomes in the future. Continuing the herd immunity strategy at the current time negates these likely future improvements.
9. The Government of Western Australia should continue to build surge healthcare system capacity, just in case.
10. The Government of Western Australia should immediately adopt an elimination strategy and campaign for the same across the whole of Australia.

Appendix 1: Models, Variables and Variable Values used in Modelling.

To inform strategic COVID-19 debate the following quantitative **Model 1** and **Model 2** have been developed.

MODEL 1: TIME REQUIRED IN YEARS TO REACH HERD IMMUNITY IN WESTERN AUSTRALIA WITHOUT EXCEEDING THE HEALTHCARE SYSTEM CAPACITY.

Model 1 has been developed to provide a quantitative assessment on the time required in years to achieve herd immunity in Western Australia whilst ensuring the curve is flattened sufficiently to ensure excess deaths do not occur as a result of Western Australia healthcare system capacity being exceeded. To assist specialist further develop Model 1 and non-specialists understand it as it currently stands, its development is described as follows:

a. AB is the population of WA requiring COVID infection so as to achieve herd immunity.
b. CD^{-1} is an academically preferred way of writing C/D. It defines the maximum rate of COVID patient throughput that can be achieved per mean times ICU bed-V access is required without overloading the healthcare system capacity.
c. E/365 converts the mean time that patients who need access to ICU-Beds require that access, from days to years as the final results will be outputted in years, but practicing clinicians think in days.
d. $CD^{-1}(E/365)^{-1} = bc^{-1}$ which is an academically preferred way of writing b/c. It defines the maximum rate of COVID patient throughput that can be achieved per annum in Western Australia without overloading the healthcare system capacity.
e. $AB(CD^{-1}(E/365)^{-1})^{-1} = ad^{-1}$ which is an academically preferred way of writing a/d. It defines the times in years required to achieve herd immunity in Western Australia without overloading the healthcare system capacity if there were no asymptomatic COVID-19 cases.
f. (1-F) is the fraction of total COVID-19 infected persons considered COVID-19 patients. It takes into account the fraction of asymptomatic COVID-19 infected persons.
g. $(AB(CD^{-1}(E/365)^{-1})^{-1})(1-F) = ef$. It defines the times in years required to achieve herd immunity in Western Australia without overloading the healthcare system capacity taking into account the fraction of asymptomatic COVID-19 infections.

$$\textbf{Time Required (Years)} = (AB(CD^{-1}(E/365)^{-1})^{-1})(1-F)$$

Model 1

Model 1 is based on six variables **A-F** as given in **Table 3**.

Table 3: Six Variables used in Model 1.

Model Variables	Units
A. Population of Western Australia	People
B. Fraction of Western Australia population needing to be infected with COVID-19 to achieve herd immunity.	N/A
C. Surge quantity of ICU beds-V available for treating covid-19 patients in Western Australia.	ICU-Beds-V
D. Fraction of cases that are critical and so likely to require ICU beds-V.	N/A
E. Mean time that critical COVID-19 patients are likely to require ICU beds-V.	Days
F. Fraction of Western Australia COVID-19 infected persons that are asymptomatic.	N/A

There follows discussion on variable A-F values used in this paper that are then inputted into **Model 1.**

Variable A: Population of Western Australia.

Population Australia (2020) gives the population of Western Australia as 2.72 million people at the end of 2019. This is considered an authoritative source and will be used for Variable A in this paper.

Variable A	**=**	**Population of Western Australia**
	=	**2 720 000 people**

Variable B: Fraction of Western Australia population needing to be infected with COVID-19 to achieve herd immunity.

Variable B is the fraction of the Western Australia population that need to be infected with COVID-19 to achieve herd immunity in Western Australia. 60% is a figure commonly quoted for COVID-19 in regards Variable B (Greenbank, 2020), with van Schaik (2020) providing expert commentary on the reasoning behind this. In summary Variable B is dependent on the reproduction number or R0 value for COVID-19. The reproductive number is the number of infected people on average that an infected person infects. Once the R0 value falls below 1 in a population, COVID-19 will naturally die out. It is early days and Variable B is likely to change and become better defined as the COVID-19 crisis develops and a better understanding of COVID-19 develops. Rises in R0 would lead to rises in the value for Variable B which would lead to an increased in time required to achieve herd immunity in Western Australia, whilst drops in R0 will lead to drops in Variable B which would lead to a reduced time required to achieve herd immunity in Western Australia.

For the purposes of this paper the 60% value will be used for Variable B. 60% when given as a fraction equals 0.6.

Variable B	**=**	**Fraction of Western Australia population needing to be infected with COVID-19 to achieve herd immunity.**
	=	**0.6**

Variables C –E Introduction.

Variables C, D & E all relate to the availability of ICU beds with ventilators (ICU beds-V) that are available in WA and the likely demand on those ICU beds-V for the treatment of critical COVID-19 patients. The availability of ICU beds-V is generally considered the bottleneck in the healthcare system and so availability and demand are critical factors in identifying what the healthcare system capacity in WA is, for treating critical COVID-19 patients.

Variable C: Surge quantity of ICU beds-V available for treating COVID-19 WA patients in Western Australia

In what is considered a current (6/4/2020) and authoritative source, Litton et al. (2020) report on a detailed survey of ICU's across Australia. The report identifies that there are currently 179 ICU beds available in Western Australia. Litton et al. (2020) further reports that there are 151 standard + 53 other ICU ventilators (total 204) in Western Australia. This means there are currently sufficient ventilators for all 179 ICU beds to be considered ICU beds-V in Western Australia.

In modelling utilised by the Commonwealth Government of Australia[3], Moss et al. (2020) gives the baseline assumption that "half of currently available ICU beds would be available to COVID-10 [sic] patients". Conversely this means that 50% of baseline ICU beds-V are considered not to be available for COVID-19 patients. Therefore for the purpose of modelling Variable C in this paper it is assumed that 50% (89) of baseline ICU beds-V in Western Australia are not available for treating COVID-19 patients.

Surge healthcare system capacity is the total ICU beds-V that could be achieved by pulling all available resources including stockpiled, anaesthetic, non-invasive and veterinary ventilators together (Litton et al., 2020). Litton et al. (2020) report a total surge capacity of 561 ICU beds and 403 ventilators. This gives a current total surge capacity of 403 ICU beds-V in Western Australia.

The Variable C in this paper will be derived from the 403 ICU beds-V surge capacity that could currently be possible under emergency and crisis conditions as reported and compiled by the numerous medical professionals in Litton et al. (2020) and 89 baseline ICU beds-V continuing to be required for non-COVID-19 patients.

Variable C	**=**	**[Surge ICU bed-V availability] – [Non COVID-19 ICU bed-V requirements]**
	=	**403 – 89**
	=	**314 ICU beds-V**

Variable D: Fraction of cases that are critical and so likely to require ICU beds-V.

Worldometer (2020) report that *"based on all 72,314 cases of COVID-19 confirmed, suspected, and asymptomatic cases in China as of February 11, a paper by the Chinese CCDC released on February 17 and published in the Chinese Journal of Epidemiology has found that"* 4.7% were assessed as critical.

The Government of Western Australia (2020) do not provide specific statistics on critical COVID-19 cases in daily snapshots. However the following information is available as of 19/04/2020 and can be used to estimate Variable D for Western Australia.

a. Total of 426 COVID-19 recovered cases in Western Australia as of 19/04/2020 (Government of Western Australia, 2020);
b. Total of 7 COVID-19 cases in Western Australia resulting in death as of 19/04/2020 (Government of Western Australia, 2020);
c. a + b above gives 433 total closed cases in Western Australia as of 19/04/2020;
d. In addition Imperial College make the assumption that 50% of those in critical care will die (Ferguson et al., 2020)

The following calculation can now be used to estimate the Western Australia Case Fatality Ratio (CFR) taking into account the typical delay from onset of symptoms to death (Ghani et al., 2005).

Western Australia CFR (as a fraction)	=	b/c
	=	7/433
	=	0.01616 (or 1.6%)

[3] Publishers acknowledge that whilst this research paper has been used by the Commonwealth Government for modelling COVID-19 and released to the public on 07/04/2008, it is currently in draft form and has not yet been submitted for peer review.

Based on assumption d above the Western Australia CFR is multiplied by 2 to find the critical case rate as follows.

Variable D = Australian CFR (as a fraction) * 2
= 0.0161 * 2
= 0.0323 (or 3.2%)

It is noted that this value of 0.323 based on Western Australian data is lower than the 0.047 given by the *Chinese Journal of Epidemiology* previously. It is assumed this is due to either higher COVID-19 detection rates, a healthier population, better medical treatment in Western Australia or environmental factors such as lower pollution. The 0.032 value will be used in modelling for this paper.

Variable D = Fraction of cases that are critical and so likely to require ICU beds-V.

= 0.0323

E. Mean time that critical COVID-19 patients are likely to require ICU beds-V.

Variable E is time that critical COVID-19 patients are likely to require ICU beds-V. Both (Ferguson et al., 2020) in modelling utilised by US and UK governments, and (Moss et al., 2020) in modelling utilised by the Commonwealth Government of Australia, use the assumption that patients require an average of 10 days in ICU[4] if critical care is required. This same assumption of 10 days ICU beds will be used for Variable E in this paper.

Variable E = Mean time that critical COVID-19 patients are likely to require ICU beds-V

= 10 days

It is noted that this assumption for Variable E may well significantly underestimating the mean time that critical COVID-19 patients are likely to require ICU beds-V. Worldometer (2020) describe that in the *"Report of the WHO-China Joint Mission published on Feb. 28 by WHO, which is based on 55,924 laboratory confirmed cases"*, the observed time from onset of severe disease to clinical recovery for severe and critical cases of COVID-19 was 2 – 5 weeks, whilst the time from onset of severe disease to cases with a fatal outcome was 1-7 weeks. At this stage the Government of Western Australia should have access to Australian and Western Australia specific clinical data not available to the public or the authors of this report which would be useful in establish that Variable E is not being significantly underestimated in modelling in this paper. Should the value for Variable E be underestimated compared to the 10 day assumption used, the time required to achieve herd immunity may be significantly higher than that found by modelling in this paper.

F. Fraction of Western Australia COVID-19 infected persons that are asymptomatic.

Variable F is the fraction of Western Australia COVID-19 infected persons that are asymptomatic. Asymptomatic COVID-19 persons are those person who have either no symptoms or such mild symptoms that they are not tested for COVID-19 in Western Australia and so are not reported in Western Australia COVID-19 case statistics.

[4] Moss et al. (2020) gives a value of 10 days in ICU beds, whilst Ferguson et al. (2020) states those receiving critical care and in ICU are assumed to require either ventilation or Extracorporeal Membrane Oxygenation (ECMO). For the purposes of this paper it is also assumed than 10 days is required on average in ICU beds-V in line with Imperial College assumptions given by Ferguson et al. (2020).

Heneghan, Brassey, and Jefferson (2020) provide a current (06/04/2020) survey of 21 international reports that have been used to estimate the percentage of COVID-19 infected persons that are asymptomatic. The survey finds that between 5% (lower range) and 80% (upper range) of COVID-19 infected persons are asymptomatic, with a broad range of values falling in-between these lower and upper ranges.

The wide range of values for Variable F affects the results obtained from **Model 1** profoundly. Randomised COVID-19 immune response testing studies commencing soon around the world may provide a more authoritative value for this variable over the coming weeks. Ideally similar trials should be undertaken in Western Australia as these will also take into account variables such as Western Australia's COVID-19 testing regime in estimating the fraction of Western Australia COVID-19 infected persons that are asymptomatic.

In the meantime and for the purposes of this paper the lower and upper ranges reported by Heneghan et al. (2020) of 5% and 80% will be used, as well as a midrange value of 50%. Three results will be generated with the fractions 0.05 (5%), 0.5 (50%) and 0.8 (80%) used for Variable F.

Variable F	**=**	**Fraction of Western Australia COVID-19 infected persons that are asymptomatic**
	=	**0.05 (Lower-range)**
	=	**0.5 (Mid-range)**
	=	**0.8 (Upper-range)**

MODEL 2: QUANTITATIVE ASSESSMENT ON THE EXCESS DEATHS THAT ARE LIKELY TO OCCUR IN WESTERN AUSTRALIA UNDER A HERD IMMUNITY STRATEGY THAT MAY BE AVOIDED UNDER AN ALTERNATIVE ELIMINATION STRATEGY.

Model 2 is used to provide a quantitative assessment on the excess deaths that are likely to occur in Western Australia under a herd immunity strategy the majority of which could likely be avoided under an alternative elimination strategy.

Excess Deaths = ABG(1-F)

Model 2:

Variables A, B and F.

Variables A, B and F are the same as Variables A, B and F used in Model 1 previously.

Variable G. Western Australia Case Fatality Ratio (CFR) as a fraction.

Variable G is the Western Australia Case Fatality Ratio (CFR). The CFR was assessed previously whilst calculating Variable D for Model 1. It was found to be 0.016 (1.6%).

Variable G	**=**	**Western Australia Case Fatality Ratio (CFR) as a fraction**
	=	**0.016**

About the Author

Simeon holds a 1st class honours degree in environmental engineering and a post graduate certificate in occupational health & safety management. He is a Professional Member of the Institute of Engineers Australia and a Chartered Professional Member of the Australian Institute of Health and Safety. He has 20 years industrial experience in operational and strategic risk management.

Disclosure statement

Simeon acknowledges that he has a vulnerable diseased family member and elderly friends. Simeon therefore acknowledges that he is at greater risk of personal tragedy under the herd immunity strategy than the general population of Western Australia who do not have diseased or elderly family members or friends.

No other potential conflict of interest are reported by the author.

To facilitate researchers wanting to check sources here's a link to the endnotes pdf library for this paper.

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