THE MATHEMATICS OF PANDEMICS – THE FORMULA FOR DISASTER
(April 13, 2020)
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This equation used in disaster management for measuring disaster risk will help us better understand and manage this Coivd-19 pandemic:

DISASTER RISK = (HAZARD x EXPOSURE X VULNERABILITY) / CAPACITY

DISASTER RISK

"Disaster Risk" refers to the potential losses and other harmful impacts from a threat or disaster, typically in terms of deaths, injuries and property damage. This risk is minimized with disaster planning by improving mitigation, preparedness or readiness, response, and recovery. More specifically, this risk is reduced by reducing hazard, exposure, vulnerability, and increasing capacity. Disasters may also cause widespread collateral damage such as economic hardship, social unrest, political instability, and destruction of environment.

The main disaster risks of the Covid-19 pandemic are 1) death rate and 2) infection rate. In healthcare terminology, these are mortality and morbidity rates respectively. Some of the pandemic's indirect or consequential damage would be economic recession, job losses, bankruptcies, and social unrest.

HAZARD

"Hazard" is the inherent danger of the threat or disaster. This cannot be influenced nor changed but it could be studied to establish the appropriate countermeasures or cure and to set up the appropriate monitoring and warning systems. Examples are the strength or destructiveness of earthquakes, hurricanes, typhoons, and tsunamis which nothing can be done about, except prepare people and property for their coming and evacuate those in their paths or danger zones.

The Covid-19 hazard is its virulence which consists of 1) its contagiousness or infectiousness and 2) its lethality. The stronger the virulence, the higher the casualties unless offset by lowering exposure and vulnerability and increasing the health system capacity. One measure of a pathogen's virulence is the lethal dose needed to kill 50% of infected hosts. It is like a poison's toxicity or a weapon's killing efficiency. Covid-19 has two or three times the contagiousness of the common flu and is 30 times more deadly. The SARS virus is more infectious and significantly deadlier than Covid-19.

The inherent virulence of a virus like Covid-19 remains the same regardless who gets infected. While the hazards are the same for all those infected, there would be serious and mild cases, symptomatic and asymptomatic ones, and those who recover and those who do not because of differences in their resiliency, physical fitness, natural immunity, and quality of care they received. One does not gamble with this virus and hope to get its milder version. The same virulent viral strain can and will strike everyone. The real bet here is whether one's body can fight it off or not.

While very little can be done with Covid-19's natural virulence, it may change over time for better or for worse. During a pandemic, a virus may become more virulent as it mutates over several waves, increasing, say, from 2% case fatality rate to 10%. Eventually it weakens as it learns to adapt and co-exist with humans like the common flu. By then, the population would have acquired generational or herd immunity against it. The 2-year Spanish flu pandemic came in three deadly waves, the second being the most virulent. There are also theories to be validated that the virulence of viruses is affected by climate - the warmer the less virulent. According to this notion, as seasons change, the virulence may increase or decrease, and places with different climates may experience dissimilar death and infection rates.

EXPOSURE

"Exposure" measures how long and how much victims were subjected to the hazards of a disaster. It is related to their proximity measured in radial distance from the disaster's epicenter or from its pathway in case of moving threats. Relocation and evacuation from danger zones are the main steps to reduce exposure. The exposure risk usually increases exponentially as one gets closer to ground zero as in a nuclear explosion, earthquakes, and volcanic eruption. For threats that gradually move like hurricanes, tsunamis, flash floods, and lahar flows, the danger zones are determined by their predicted paths and their width.

Viral threats such as pandemic outbreaks and global cyberattacks have no definite or fixed centers nor predictable paths. Reducing exposure from their hazards is different from that of typical natural disasters. While they may have epicenters or origin, they can propagate or spread out in random directions at very high speeds using the chain reaction process. Like loose cannons, they can quickly create new faraway epicenters that could be larger and more destructive than the original. The rate of viral spread is often exponential and explosive depending on availability of hosts to infect. The path of destruction is so unpredictable it difficult to know who will be exposed and when.

Unfortunately, Covid-19 was treated like a typical natural non-viral disaster. Most countries lowered their guards with a wait-and-see attitude, thinking that their remoteness from the Wuhan epicenter provided them safe distance from exposure and ample time to prepare. Distance from viral epicenters are never safety buffers from exposure. Precious time was lost in treating this as a China epidemic rather than as a global threat that can and did turn rapidly into a pandemic.

Mass vaccination is the only efficient way to protect everyone from exposure and reduce vulnerability. For global cyberattacks, the immediate installation of anti-virus software or updating to more secure software in all equipment provides a similar system-wide protection. You cannot run nor hide from this invisible virus that is capable of fast, undetectable asymptomatic transmission. Only "shotgun" or total and immediate containment measures would be effective. The gradual and partial steps like regional or state-wide containment measures being implemented currently may not stop its spread. Absent a vaccine for Covid-19, comprehensive containment strategies are the only alternative. These include total travel bans, curfews, stay-at-home orders, community quarantine, total lockdown, and nationwide social distancing. These measures minimize the exposure of the uninfected and prevent cross-infection especially in densely populated areas.

VULNERABILITY

"Vulnerability" is the susceptibility of affected groups to the harmful effects of a threat or event. The higher the vulnerability of people or the more vulnerable people are exposed to its hazard, the higher the risk of disaster and casualties. Reducing exposure and vulnerability combined can significantly lower casualty rates and flatten the case curve. Certain factors that make a population of a certain place vulnerable to pandemics are, among others, its poor general health, poor economic and social conditions, inadequate health systems, its low generational immunity, its high average age, its high population density, and its propensity for public gatherings, congregation and travel. Except for population demographics, most of these factors can somehow be controlled or influenced to lower vulnerability and exposure.

While mass vaccination or immunization against Covid-19 is the preferred choice or gold standard to lower the vulnerability and susceptibility of any population regardless of its economic and social conditions and behaviors, this option will not be available in the short to medium term. The containment measures to limit exposure cited above may also lower the population vulnerability by limiting movement and protecting the vulnerable.

Other options to reduce vulnerability are:

- the use of masks, disinfectants and hand hygiene by everyone
- mass testing and contact tracing to identify the infected and isolate them from the vulnerable and uninfected
- boosting one's immune system by keeping fit and healthy with vitamins, proper diet and exercise
- avoiding getting ill or hurt thereby weakening one's defenses against the viral infection.

A healthy body is less vulnerable than one that is not. Its physical fitness and immune system may have a higher chance of fighting off the virus even without vaccines. The healthy if infected may experience milder or no symptoms and may need only home quarantine. Those hospitalized with more serious conditions may have a higher recovery rate, shorter length of stay (LOS) and lower fatality rate.

It is imperative to protect the very vulnerable groups - the old, very young, and the sick- from exposure and infection. Those with underlying illnesses are 5x to 10x more likely to die than those without, depending on their ages above 60. But the most vulnerable group to protect are frontliners – those involved in patient care, rescue, disaster relief, and security who are working continuously to save and protect lives in the midst of this viral storm. They would need complete protection and support in terms of PPE's, food, accommodation, and rest.

CAPACITY

"Capacity" is the ability of a system to rescue or revive disaster victims and protect others from harm. Health system capacity is the most important capacity to ensure and build up during pandemics. Others would be the capacity of security forces to enforce quarantine, lockdowns, social distancing, and mask-wearing, and the capacity of disaster relief personnel to distribute relief goods to those under lockdown so they stay well-fed and healthy and do not break quarantine or get sick.

The higher the capacity in terms of quantity and quality, the higher the recovery rate and the lower the casualty rate. The most critical or "bottleneck" capacities in hospitals are: frontliner staff (doctors and

nurses); ICU beds, quarantine beds, isolation rooms, ventilators, testing kits for patients; masks, PPE's, disinfectants, living quarters and transport facilities for frontliners. Since no vaccine and drug treatment for Covid-19 have been found, medicine supply is currently not a resource of concern. Healthcare frontliners must not only be added but also be adequately protected. A frontliner taken out of action for any reason in the line of duty – infected, quarantined, admitted, or killed – is a huge loss in the health system capacity. A doctor or nurse is equivalent to 1,000 patients.

Hospitals can normally stretch their existing capacities to cope with temporary spikes in patients, like when there is a sudden flow of ER admissions from a major traffic accident, a stampede, mass food poisoning, or seasonal flu. But hospitals cannot cope with sudden and sustained surge loads from pandemic patients. They would always be behind a rising curve. Their capacities cannot be increased indefinitely to catch up because they would reach the physical limits of their available, usable space. To spread the patient load over time and reduce or moderate resource requirements of hospitals, it is imperative to flatten the case curve by increasing the testing rate and lowering vulnerability.

SOME INSIGHTS AND CONCLUSIONS FROM THE EQUATION

Policy makers, health authorities, and government leaders can make use of the disaster risk formula to guide and validate their many decisions in managing and ending this pandemic crisis. Among its important insightful principles are:

- To reduce disaster risks, the hazard, exposure, and vulnerability must be reduced as much as possible while increasing capacity to appropriate levels.
- If vulnerability and exposure, the root causes of infection and patients, are not lowered during a pandemic, increases in capacity will be indefinite and may not reduce fatality rates.
- Reduction in vulnerability and exposure, not increases in capacity, will flatten the curve.
- Disaster risks and losses may not come down if the improvements in capacity, exposure, and vulnerability are insufficient to match the hazard. For instance, partial lockdowns will not be effective in containing this very contagious virus. Adding beds without adding ventilators will not increase capacity and recovery rates as many hospitalized cases land in ICU because of Covid-19's virulence.