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How would Widespread Community Transmission of Covid-19 in Sri Lanka look like?

A Population-based Simulation

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Abstract

Widespread community transmission of Covid-19 can overwhelm the capacity of health systems; Sri Lanka is no exception. We simulated the widespread community transmission of Covid-19 in Sri Lanka, using the Susceptibility, Infected and Removed (SIR) model through the Penn State University CHIME Model incorporated to ArcGIS Pro, by introducing one case of Covid-19 to the current population in each of the 26 health districts and running the model for 365 days. The simulation revealed that the number of patients requiring admissions, ICU care, and mechanical ventilation would peak at 1942, 583, and 388 per day, respectively, around 213 days from the onset. The cumulative number of cases needing admission, ICU care, and ventilation will be 245,916, 73,775, and 49,183 after 365 days. Colombo and Gampaha districts will report the highest number of daily total numbers of hospitalized cases over 1680. Health authorities can use the results of such simulations to prepare to face the worst-case scenarios of the Covid-19 outbreak to minimize morbidity and mortality.

Keywords: Covid-19, Community Transmission, SIR Model, CHIME, Outbreak, Simulation, Prediction

1. Introduction

Covid-19 is a viral disease spread across many countries in seven months of its existence on earth. As of 29.10.2020, globally, there have been a total of 44,351,506 cases and 1,171,255 deaths (World Health Organization 2020b). In the meantime, Sri Lanka has reported 9791 cases and 19 deaths by the same date (Epidemiological Unit 2020). The World Health Organization (WHO) recommends a comprehensive package of measures for countries to prepare when there are no cases, sporadic cases, clusters of cases, community transmission, or country-wide transmission (World Health Organization 2020a). Although often misinterpreted, WHO identifies community transmission as "large outbreaks of local transmission defined through an assessment of factors including, but not limited to large number of cases not linkable to transmission chains, large number of cases from sentinel lab surveillance, and multiple unrelated clusters in several areas of country/territory/area".

Determining if a country is in community transmission or country-wide transmission could be quite controversial, as it has been evident from India (Singhania 2020). The decision might carry not only far-reaching public health consequences but also societal and political ramifications. As per the Epidemiological Unit, Sri Lanka, all cases reported have been traced to a source, confirming the disease being confined to a few clusters (Epidemiological Unit 2020). Nevertheless, with the identification of large clusters from an apparel factory and a fish market within the Western Province, the threat of a transition into a community transmission stage has become a considerable debate in the public domain. Given the number and geographical distribution of the aforementioned clusters' primary contacts, the health system must prepare for a future worst-case scenario. The same sentiment has been retreated by the WHO on several occasions by highlighting that the risk of expanding Covid-19 into community transmission and country-wide transmission (World Health Organization 2020a). This paper's focus would be the last two stages, namely, the community transmission and the country-wide transmission. For this paper, we would amalgamate those two stages to "widespread community transmission." We assumed that during widespread community transmission, Sri Lanka's population could be considered uniform population overtime, since the disease will be spreading homogeneously across communities.

While acknowledging the fact that Sri Lanka has so far being successful in confining the outbreak, as well as having a strong preventive and curative health system, it is still essential to visualize widespread community spread in Sri Lanka would look like (Ministry of Health and Indigenous Medical Services 2017; MSN News 2020; Mukhopadhyay 2020). As per the experience from across the world, widespread community transmission of Covid-19, if not appropriately managed, would be the worst ever public health nightmare. Having an idea of the projected number of cases in the community and the numbers who would be hospitalized, those who need intensive care unit treatment, and mechanical ventilation may be essential in preparation for a possible community spread or beyond. Visualizing how the community spread of Covid-19 would look like through projections can be a very helpful exercise for healthcare planners, both from preventive and curative sectors. This is especially crucial since all Covid-19 patients have been offered free care so far, and the government intends to continue to do so. The objective of this exercise was to simulate the widespread community transmission of Covid-19 in Sri Lanka through introducing a single case of Covid-19 to each of the health districts simultaneously with the use of the existing population as the baseline.

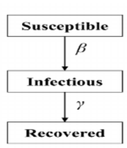
2. Methods

In visualizing how the widespread community transmission of Covid-19 would like in Sri Lanka, we had to approaches to adopt, simulation, or prediction. Input data and initial conditions are used in simulations to calculate the outputs. However, in predictions, the model response at a future time point is calculated using the current and past values of measured input and output values, in addition to the initial conditions (Mathworks 2020).

Out of the two options in hand, the prediction modeling with the epidemiological data of the number of cases reported so far from Sri Lanka was quite intuitive. However, the spread of the disease in Sri Lanka has been confined to specific populations such as returnees to the country, repatriates, Navy sailors, inmates of substance abuse rehabilitation centers, apparel industry employees, and fishery communities in particular locations. Hence, using past case numbers from such heterogeneous clusters for a widespread community spread, which by definition occurs in a homogeneous population, was irrational and illogical. Thus, we decided to carry out a simulation instead of a prediction to visualize the widespread community spread of Covid-19 in Sri Lanka.

There are various models used to simulate the progress of outbreaks. In the current exercise, we used the Susceptibility, Infected, and Removed (or recovered) model in predicting the Covid-19 Cases (Li and Zhang 2017; Weisstein 2020b, 2020a). SIR model consists of three compartments:

- **S** for the number of **s**usceptible,
- **I** for the number of **i**nfectious, and
- **R** for the number of removed through recovery or death of individuals.
- N = S+I+R,
- ß = the average number of contacts per person per time
- λ = Number of infected individuals



$$\frac{dS}{dt} = -\beta SI$$
$$\frac{dI}{dt} = \beta SI - \gamma I$$
$$\frac{dR}{dt} = \gamma I$$

Equation 1: SIR Model Equation

SIR model assumes the population to be confined to three compartments, susceptible, infected or recovered. As per the SIR model, an individual would move across different compartments as the outbreak progresses; however, that individual could be present only in one of the three compartments at a given time (Weisstein 2020b, 2020a).

As per the SIR model, the number of susceptible persons will decrease as the number of infected persons rise, peak, and decline. Correspondingly, the number of removed persons will gradually increase.

We used COVID-19 Hospital Impact Model for Epidemics (CHIME) Version 1.1.5 developed by Penn State University, which uses a modified SIR model, which is available as an application of the ArcGIS Pro Covid-19 Modelling Toolbox by Esri (Environmental Systems Research Institute (Esri) 2020; Weissman et al. 2020).

We obtained the Regional Director of Health Services (RDHS) area wise population data from the Department of Census and Statistics through the Medical Statistics Unit of the Ministry of Health, Sri Lanka, and obtained the written permission to use the same in the simulation exercise.

The simulation scenario began assuming the country has reached widespread community transmission at the time of the commencement of the model. This means, the current exercise did not take into consideration the reported epidemiological data for the modeling process, as would have been done in prediction.

Instead, we simultaneously introduced one case of Covid-19 to each Regional Director of Health Services area (equivalent to administrative districts) on Day Zero. Correspondingly this would mean having 26 Covid-19 cases on Day Zero of widespread community spread in Sri Lanka.

Sri Lanka so far maintains a policy of admitting all Covid-19 positive patients to a treatment center, which means the hospitalization rate to be 100%. We argued this to continue during a widespread community transmission. Hence, we kept the default hospitalization rate of 2.5% in the CHIME model as a reasonable estimate. Further, we agreed with the default social distancing going forward to be kept at 45% to be quite reasonable from the Sri Lankan perspective also since with the relaxation of the Continous Covid-19 curfew, social distancing measures were not promising as they used to be. For these reasons, we decided to adhere to the default constant model parameters used in the CHIME model during the current exercise, as shown in Table 1. The model was run for a period of 365 days. The outputs were obtained for the country as a whole as well as per RDHS areas.

Table 1 : Constant Model Parameters Used

Parameter	Value
Doubling time in Days	5
Social distancing going forward	45
Date of Social Distancing Measures	Day 1
Hospitalization %	2.5
ICU % (Total Infections)	0.75
Ventilation % (Total Infections)	0.5
Infectious Days	10
Average Hospital Length of Stay (Days)	7
Average Days in ICU	9
Average Days on Ventilator	10
Source: Environmental Systems Research Institute (Esri). *ArcGIS Pro* (version Chime Model v1.1.5). Covid-19 Modelling Toolbox. Redlands, CA.: Esri, 2020.	

3. Results

SIR model outputs for Sri Lanka for Covid-19 during community spread and beyond Sri Lanka are shown in Figure 1.

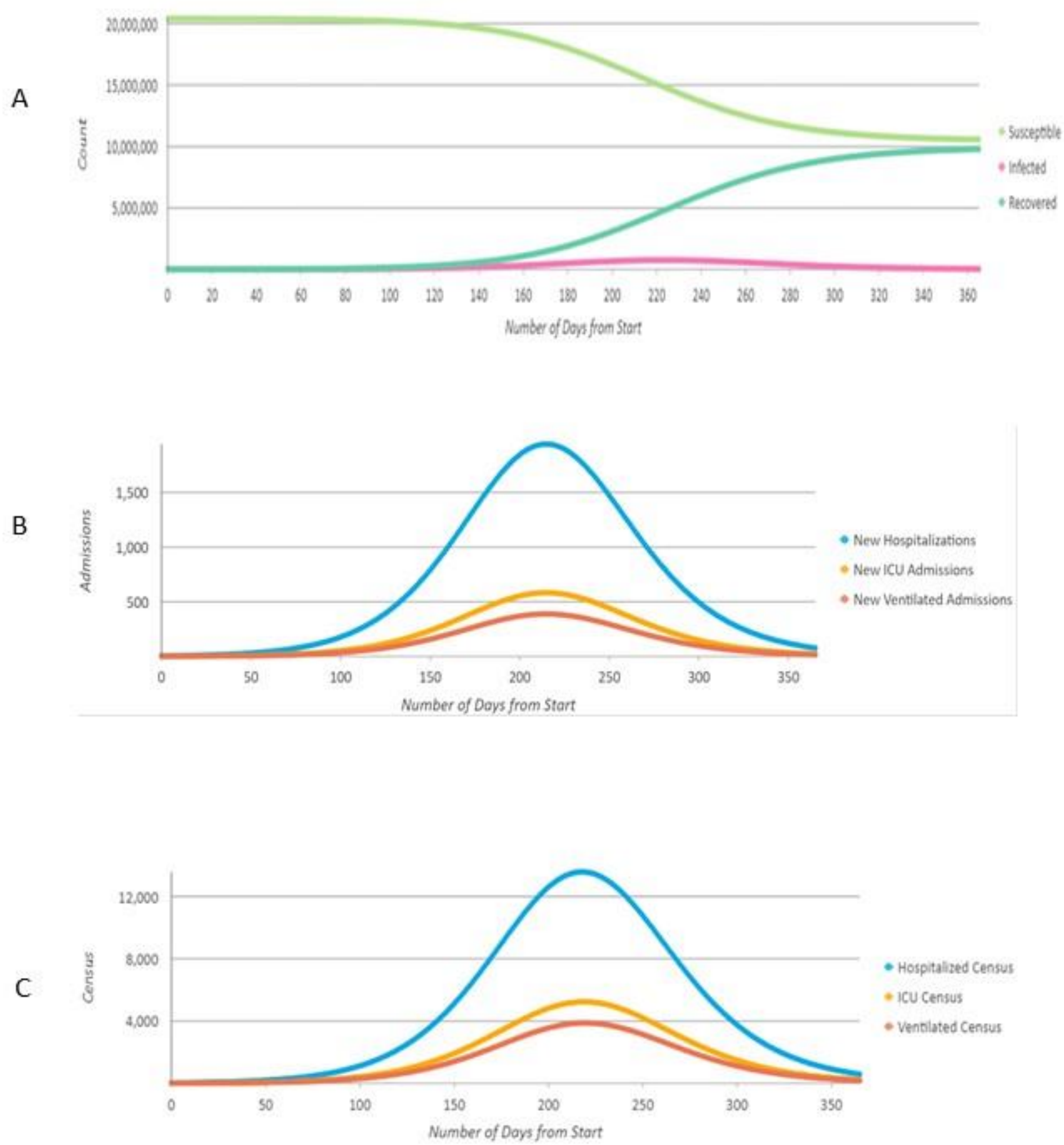


Figure 1 : SIR Model Outputs

As shown in Figure 1A, when the first hospitalized case from community spread is reported, the projected total susceptible population will be 20,408,073 while it would gradually decrease to stabilize at around 10,571,762 at the end of 365 days of the projection period. Similarly, the number of persons infected in the community at the time of the first admission of the case to the hospital would be 1576 persons. The number of infected persons in the community would rise to its peak of 761,932 on day 223 of the simulation period, to decrease to 42,137 persons by day 365. The number of persons removed at the time of the first case being admitted to the hospital would be 360, while this would peak on day 223 to 4776287 and subsequently would reduce to 9796111 by day 365.

The daily admissions for the Covid-19 during community spread and beyond in Sri Lanka is shown in Figure 1B.

As per Figure 1B, it is seen that the daily new hospitalizations, daily new ICU admissions, and new ventilated admissions will peak to 1942, 583, and 388 by day 215.

The daily hospital census (Midnight Total) for Covid-19 community spread and beyond in Sri Lanka is shown in Figure 1C.

As per Figure 1C, it is observed that the peak of the hospitalized census (midnight total) will be reached on day 218 to 13583. In the meantime, the peak ICU census (midnight total of patients admitted in ICU) and ventilated census (midnight total of ventilated patients) per day will reach on day 219.

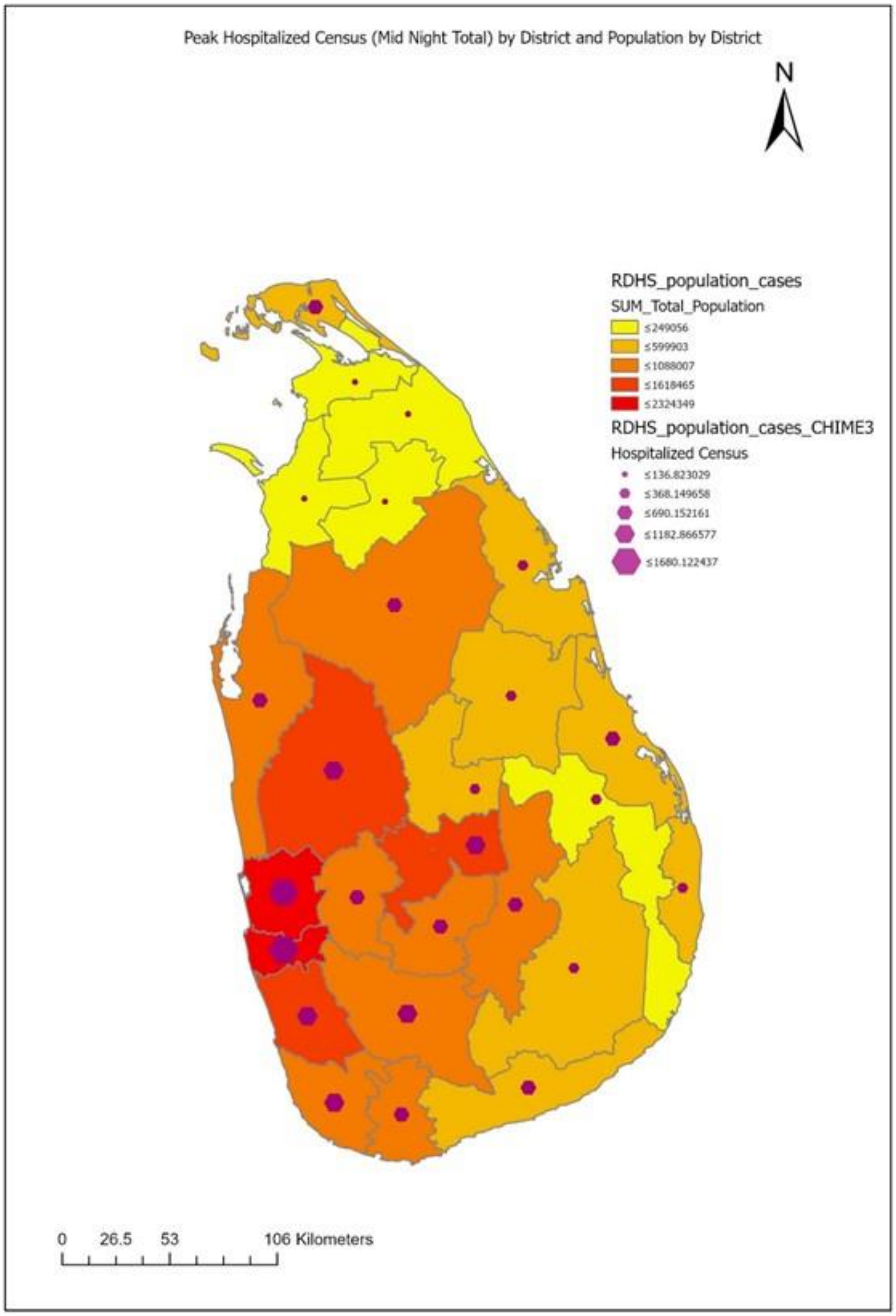


Figure 2 : Peak Hospitalized Census (Mid Night Total) and Population by District

As per Figure 2, it is evident that the highest number of hospital census (midnight total) of cases at the peak will be reported from Colombo and Gampaha RDHS areas, which will be over 1680 cases per day. The lowest number of hospital census (midnight total) of cases at the peak will be reported from Mannar, Kilinochchi, Mullaitivu, and Vavuniya RDHS areas.

4. Discussion

Widespread community transmission of the Covid-19 outbreak would be the worst public health nightmare, with rising demands on the health systems with alarming morbidity and mortality (World Health Organization 2020a). Trying to visualize how such a scenario would look like must not be ignored, the only reason being the denial of the possibility of such an occurrence. At the outset, it must be noted that simulations are estimates to be used by health systems planners wisely, in the backdrop of many other factors. Unique demographic factors, health-seeking behaviors, and health system characteristics of a country should be taken into consideration when applying simulations into actual public health interventions. Further, the methods used to predict the progress of Covid-19 have been quite diverse and debated (Anastassopoulou et al. 2020; Cyranoski 2020; Roda et al. 2020). On the contrary, such drawbacks should not prevent the use of existing methods in visualizing the progress of the outbreak. The results of such simulations should be seen as predictive evidence to formulate public health decisions than to find faults of health systems and prevailing public health interventions, hence should create a constructive dialogue and a productive debate directed towards pre-emptive, stepwise augmentation of capacity (Weissman et al. 2020).

During the current study, we used an application using the SIR modes, which is one of the simplest compartmental epidemiological models available (Environmental Systems Research Institute (Esri) 2020; Weissman et al. 2020). The susceptible populations were limited to specific groups since the beginning of Covid-19 in Sri Lanka, starting with returnees from high-risk countries to substance abusers to returning migrants to armed forces (Director General of Health Services 2020). Nevertheless, when the Covid-19 outbreak goes to the community spread, the community will behave more or less in a homogeneous way. Hence, the application of the SIR model across homogeneous populations could be justified during widespread community transmission.

During this study, we used a population-based approach in visualizing how the Covid-19 community spread and beyond would look like. Instead of using the past epidemiological data as the basis of the predictions, we simulated the spread of the disease by introducing one case of Covid-19 case at the same time to all RDHS areas. This would be very unlikely in the real-life scenario; however, what we wanted to do in this exercise was to have a baseline idea of how widespread community spread would look if it happens in Sri Lanka. In addition, this was probably the "best" of the worst-case scenarios since each health district gets only one case of Covid-19 to start with, which is obviously too optimistic to occur in real life. What this implies is that if the "best" of the worst-case scenarios is alarming, the worse of the worst-case scenarios would be much threatening and demanding. Nevertheless, such a "best" of the worst-case scenarios would be more influential in advocating for preparedness; hence all health systems are inherently reluctant to accept that their systems could fail in times of crisis.

According to the simulation, the peak of the outbreak will occur around Day 218 – 220 (after about seven months of the commencing of the community transmission. At the peak, the country may need around 1942, 583 and 388 beds, ICU beds, and ventilators per day at the peak. As per the Ministry of Health reports, the total number of hospital beds for treatment purposes in the country as of 30.10.2020 is to be around 5485 (Director General of Health Services 2020). In the meantime, the total ICU beds in use will be 146. It is evident that even if the community transmission occurs, the country may have challenges in catering to the need for beds, ICU beds, and ventilators that may arise.

Even though the current policy of Sri Lanka is to admit all patients who are diagnosed with Covid-19 to be admitted to a designated Covid-19 hospital, this may not continue to be feasible in a time of community transmission with increased demand. Hence, it was decided to use the default 2.5% value of hospitalization provided in the model, based on statistics from the USA, which is currently going through a community transmission. If the current decision of admitting all Covid-19 patients to a hospital without a triage system, it is likely that the hospitals will be overwhelmed even before the peak of the community transmission.

It should be noted that during the current model, the artificial demarcation between the stages before the community transmission and beyond has been made. The number of cases has been reset to zero prior to running the model during the community transmission and beyond. Even though it would be difficult to distinguish between the onset of community transmission and the preceding stages, for the current model, this approach was adopted. In retrospect, the total number of cases during the community transmission and beyond is likely to be much higher than during the preceding stages; hence this approach could be justified.

CHIME model has been added value by incorporating it into the ArcGIS Pro software, therefore it was possible to carry out the model for each of the RDHS areas. Even though during the current study, the model was run at RDHS level, the same could be done at Medical Officer of Health areas (The grass root level health administrative division) as per the requirement.

However, one possible significant drawback of the CHIME model, as stated out by its developers from the PENN State University, was that it recommends only a maximum prediction period of 30 days; however, if the peak does not occur within that period, it is recommended to increase the duration accordingly (Penn Medicine 2020). It is likely that as one moves further in time, the more uncertain the projections become; however, projections still could be useful. We reemphasize the point that we mentioned at the beginning of the discussion on model estimates here. The results of this model should only be treated as estimations, as they are susceptible to the model assumptions, data, and parameters that we use. Considering the above facts, during the current study, we used a prediction period of 365 days that was able not only to capture the peak but also to return the curve to the baseline.

Further research needs to be carried out incorporating factors other than the population, such as the actual case number, socioeconomic and demographic vulnerabilities, and health systems capacities in simulating widespread community spread in Sri Lanka.

5. Conclusion

Widespread community transmission of Covid-19 could be a public health nightmare, Sri Lanka being no exception. The health authorities must be ready for the worst-case scenarios, as quantified through this exercise, to ensure adequate public health response to reduce morbidity and mortality in case of widespread community transmission.

6. Acknowledgement

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