HEALTH SERVICES AND OUTCOMES RESEARCH

In 2020, Health Services and Outcomes Research (HSOR) directed its efforts towards supporting decision-making and generating evidence-based data for cluster and national COVID-19 initiatives, while continuing to evaluate clinical and population health programmes. During the pandemic, HSOR helped curate daily dashboard information, study disease dynamics and projection, and plan for capacity assurance and operational execution.

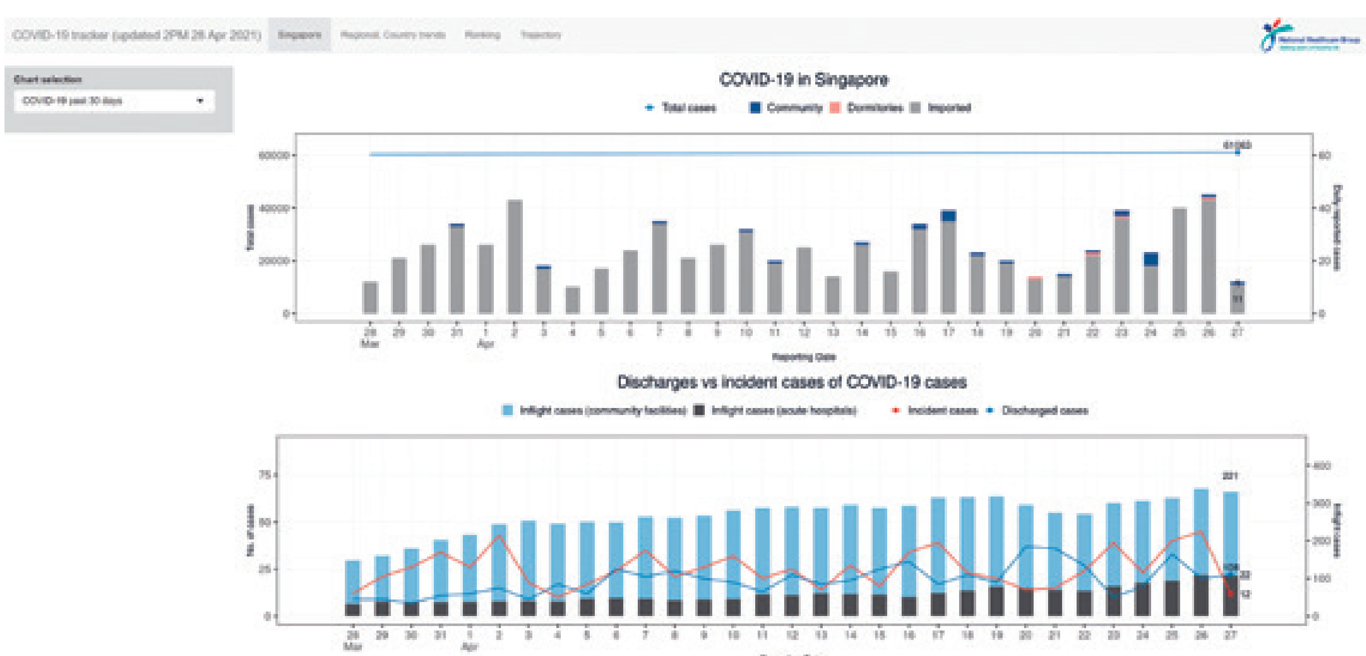
HSOR COVID-19 TRACKER

Since January 2020, HSOR monitored the COVID-19 situation internationally and locally. Information was collated from multiple sources and summarised into regular epidemiology reports. Daily updates, comprising the latest local and global news of the disease, were presented as an interactive dashboard (*https://hsor.shinyapps.io/covid19/*).

The local update covered daily epidemic curves and a detailed breakdown of cases stratified by different factors, e.g., community, dormitories, and imported; Singapore Citizens, Permanent Residents, work- and long-term visit pass holders. It also provided a comparison of weekly numbers of acute respiratory infections (ARI) and dengue surveillance. All local data was extracted from the Ministry of Health (MOH) COVID-19 Situation Reports (*https://www.moh.gov.sg/covid-19*).

The global update consisted of daily epidemic curves and trajectories by regions and countries. It tracked cumulative and daily cases, cumulative and daily deaths, case fatality rates, and mortality rates per million population. The global update also comprised a table that ranked the severity of the COVID-19 situation in countries around the world. This allowed the classification of regions and countries by different indicators, e.g., cumulative cases, daily cases, case fatality rates, latest doubling times, etc. The global update derived data mainly from Johns Hopkins University (*https://coronavirus.jhu.edu/map.html*), and was supplemented by information from Worldometers (*https://www.worldometers.info/coronavirus/*).

Figure 1: Local Epidemic Curve of Last 30 Days.



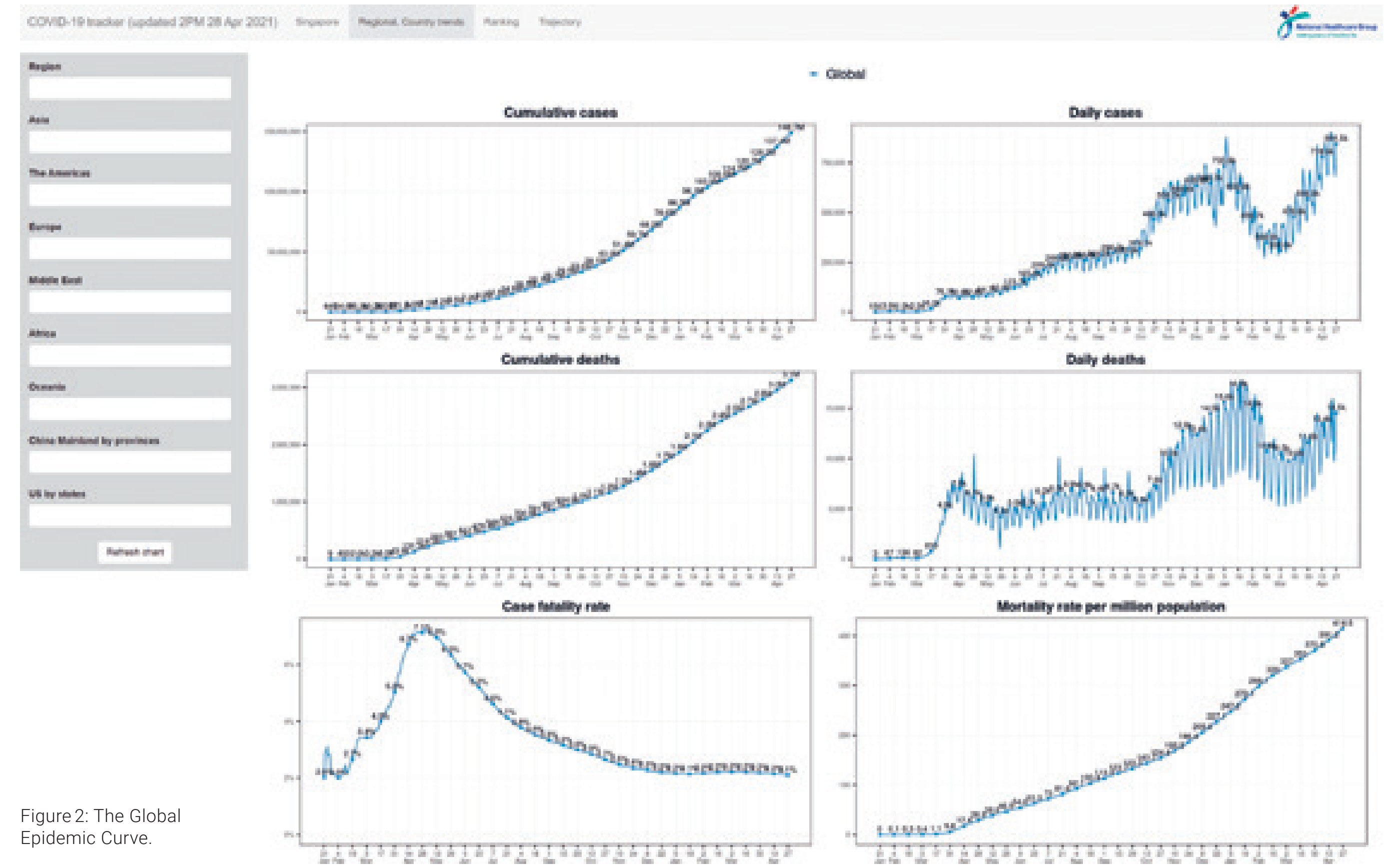


Figure 2: The Global Epidemic Curve.

ESTIMATING TRANSMISSION PARAMETERS OF COVID-19 CLUSTERS IN SINGAPORE

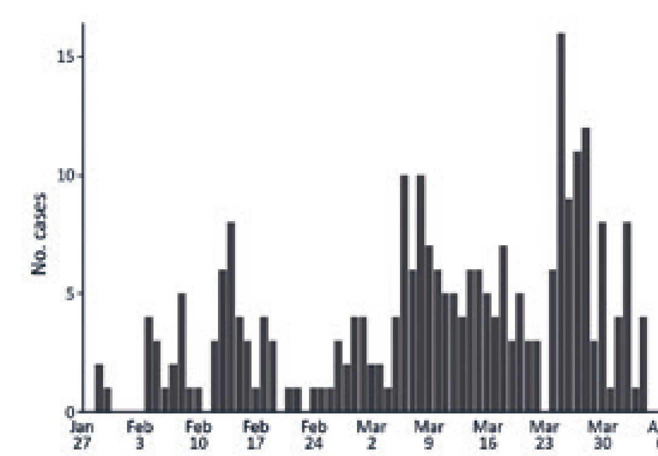
HSOR collaborated with the National Centre for Infectious Diseases (NCID) and the University of Hasselt, Belgium, to examine the underlying disease transmission dynamics of COVID-19, pertinent in guiding the use of outbreak control measures and minimising the impact of the pandemic. The basic reproduction number (R_0) of an epidemic denoted the average number of people a person infected in a completely susceptible population. However, knowing the R_0 alone was insufficient. Other parameters, like the incubation period, serial interval (i.e., the length of time between symptom onset of two cases) and generation interval (T_g) (i.e., the length of time between the points of infection for two linked cases), provided critical insights on the transmission chain.

Additionally, as conventional outbreak control measures are centred on isolation, contact tracing, and treatment of symptomatic cases, the prevalence of pre-symptomatic transmission (*p*) in a population would help steer measures to address potential transmission among those with no apparent symptoms. Hence, estimates of R_0, T_g, and *p* were generated using published symptom onset data of cases in Singapore.

The data used covered the outbreak in Singapore from 23 January 2020 to 6 April 2020 (Figure 3). Specifically, information from confirmed COVID-19 cases classified by MOH and linked to local clusters, was studied. Date of symptom onset (DOOs) were extracted, and cases with DOOs unavailable were excluded from the analysis (Figure 4). Index cases were identified and potential infectors of each case were based on available information of the cases' known contacts and published case links. Applying a heuristic technique, potential infectors who could have transmitted the COVID-19 infection to the confirmed cases were sensibly included.

The infector-infectee pairs constructed were subsequently used to estimate the serial and T_g distribution for established clusters in Singapore. Through a Bayesian Markov Chain Monte Carlo procedure and its estimated parameters, the corresponding distribution of R_0, and subsequently *p*, were established by simulating infections and computing the proportion of pre-symptomatic transmissions.

Figure 3: Epidemic Curve of COVID-19 Clusters (Singapore), January-April 2020.



HEALTH SERVICES AND OUTCOMES RESEARCH

A person infected with COVID-19 was estimated to pass the infection to another individual in 3 days, and 72% of simulated infections were pre-symptomatic transmissions (Table 1). Due to the short mean generation interval and consequent high prevalence of pre-symptomatic transmission, public health control measures had to be responsive to these characteristics in order to be effective. Universal masking up in the community would limit transmission independent of symptoms. Contact tracing would have to include the period before symptom onset, and adopt a digital approach to be more comprehensive and less labour-intensive.

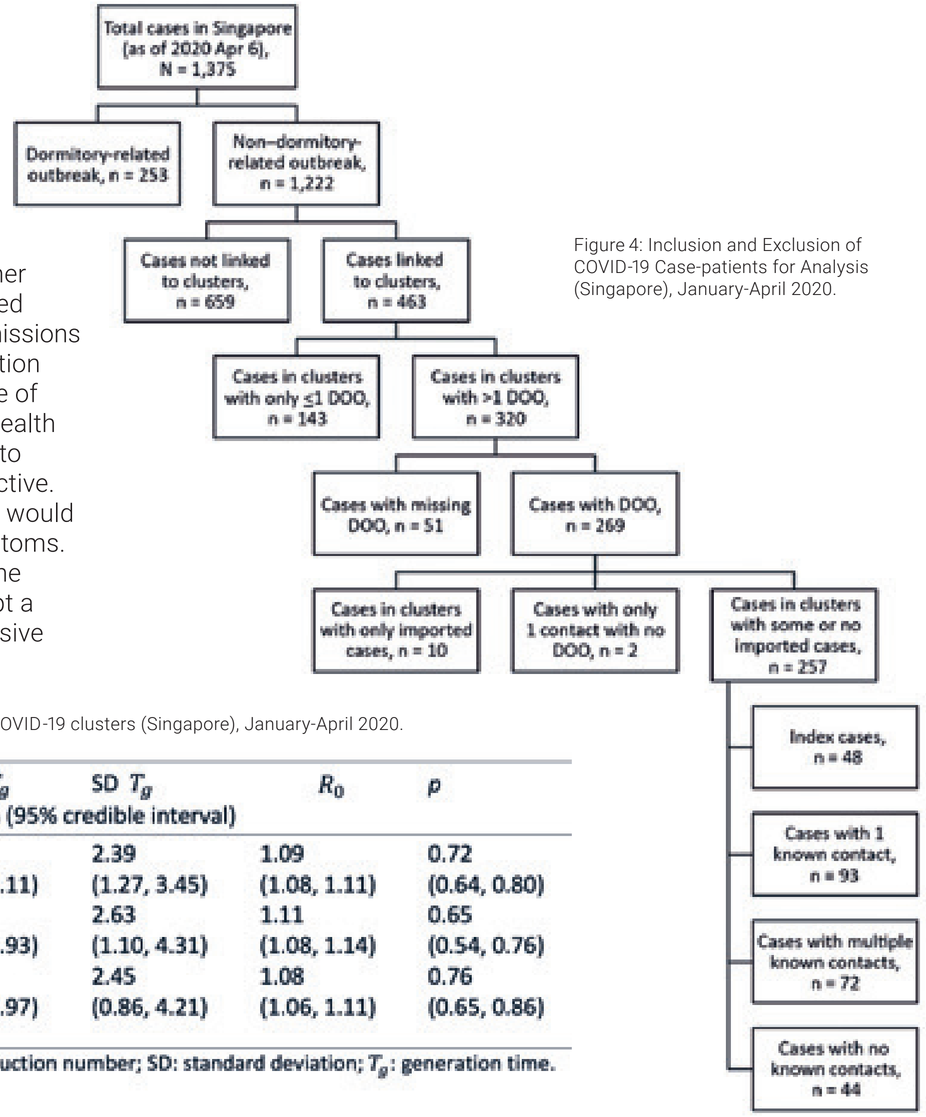


Figure 4: Inclusion and Exclusion of COVID-19 Case-patients for Analysis (Singapore), January-April 2020.

Table 1: Estimates of Transmission Parameters of of COVID-19 clusters (Singapore), January-April 2020.

Infectee type	Mean T_g	SD T_g	R_0	p
	Median (95% credible interval)			
All cases (N=209)	3.44 (2.79, 4.11)	2.39 (1.27, 3.45)	1.09 (1.08, 1.11)	0.72 (0.64, 0.80)
Cases with only 1 known contact (N=93)	3.93 (3.00, 4.93)	2.63 (1.10, 4.31)	1.11 (1.08, 1.14)	0.65 (0.54, 0.76)
Cases with only multiple or no known contact (N=116)	3.03 (2.13, 3.97)	2.45 (0.86, 4.21)	1.08 (1.06, 1.11)	0.76 (0.65, 0.86)

p: pre-symptomatic proportion; R_0: basic production number; SD: standard deviation; T_g: generation time.

ESTIMATING INTENSIVE CARE UNIT BED CAPACITY DURING THE COVID-19 PANDEMIC USING WHAT-IF ANALYSIS

COVID-19 mortality rates across the globe were affected by multiple factors, including hospital resources, healthcare manpower, and intensive care unit (ICU) bed capacity, etc. Due to limited data in the early phase of the pandemic, it was challenging to make informed decisions in the management of critical healthcare resources, such as ICU bed capacity. To provide information for decision makers to plan surge bed capacity to meet the needs of critically ill patients requiring ICU care, surge demand on ICU beds from COVID-19 patients was estimated, based on patient data during the early phase of the pandemic (23 January to 19 March 2020) in Singapore.

The average number of cases was estimated using local COVID-19 admissions, and the What-If Analysis was applied to assess the associated ICU bed demand. The values of the underlying parameters, i.e., ICU admission rate and average length of stay (ALOS), were either estimated from Singapore reports, or referenced from population data in China. In the analysis, it was assumed that 5% to 20% of confirmed COVID-19 cases would be admitted to ICU, and that the ALOS in ICU ranged from 7 to 15 days. For brevity, we considered scenarios of lower and upper bounds of ICU admission rates and ALOS, that is, ICU admission rates were 5%, and 20%; and ALOS were 7 and 15 days, respectively. If 5% of new COVID-19 cases were admitted to the ICU, the hospital would need 4 to 30 ICU beds. Similarly, the hospital would require 14 to 120 beds for a 20% admission rate (Table 2).

Table 2: Estimation of ICU Bed Capacity Required.

Bed estimation for an ICU admission rate of 5%		
Daily cases	ICU ALOS = 7	ICU ALOS = 15
10	4	8
40	14	30
Bed estimation for an ICU admission rate of 20%		
Daily cases	ICU ALOS = 7	ICU ALOS = 15
10	14	30
40	56	120

MATCHING OF MIGRANT WORKER DORMITORIES TO PUBLIC HEALTH PREPAREDNESS CLINICS (PHPCS)

As part of planning of COVID-19 operations, it was necessary to organise the medical needs of unwell migrant workers efficiently. They were housed in dormitories of varying sizes at different locations across Singapore, and specific Public Healthcare Preparedness Clinics (PHPCs) were appointed to take care of their medical needs. The migrant workers were usually sent to the nearest PHPCs if they required care. However, planning was needed to ensure these clinics were not overwhelmed.

In April 2020, at the height of the outbreak in the dormitories, HSOR was asked to study the adequacy of coverage of some 300 PHPCs for about 1000 dormitories. A mathematical model based on Mixed Integer Programming (MIP) was developed for this purpose using IBM ILOG CPLEX Optimization Studio.

Using this model, all dormitories were assigned to the nearest PHPCS with the condition that no PHPC needed to manage more than a given number of workers. Some larger dormitories needed more than one PHPC to cover their medical needs. The results from this project were shared with the Joint Task Force, comprising MOH, Ministry of Manpower (MOM), and Ministry of Defence (MINDEF). This helped facilitate their operations and planning during the outbreak in the dormitories.

FORECASTING STEADY STATE PREVALENCE OF COVID-19 IN MIGRANT WORKER DORMITORIES

HSOR reported a forecast of infections in migrant worker dormitories (as at 24 May 2020) using infectious disease transmission modelling and assumptions on baseline parameters.

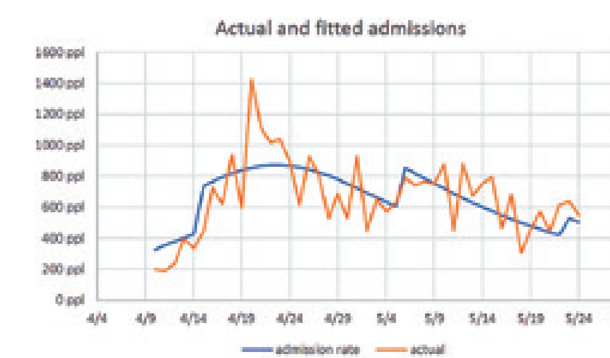
A 2-flow (asymptomatic and symptomatic) Susceptible-Infectious-Recovered (SIR) model was built to calculate baseline parameters and forecast COVID-19 transmissions in these dormitories. Baseline historical transient incidences from April to May 2020 were used in the model (Figure 5). Baseline model parameters were calibrated or based on assumptions from literature (Table 3). A system dynamic modelling software was implemented to derive transmission flows with pre-specified assumptions (Figure 6).

Key assumptions of the model were:

- There was a large pool of infected and infectious cases in migrant worker dormitories at the end of March 2020.
- There were separate streams for symptomatic and asymptomatic patient pathways.

The steady state SIR model forecast by HSOR, as of 24 May 2020, reported 45,000 Polymerase Chain Reaction (PCR) cases (new infections) and 106,000 seropositive cases (past infections). Results generated were reasonably close to publicly available data published by MOH — On 14 December 2020, MOH announced that there were 54,000 PCR cases and 98,000 seropositive cases in the migrant worker dormitories. The model results were similar when we simulated varying testing capacities of the migrant worker dormitories.

Figure 5: Baseline Historical Transmissions.



Parameters	Value	Remarks
Population	320,000	FW population
Basic reproduction number (R_0)	2.6	Assume natural R_0
Initial asymptomatic patients	55,000	Assume to reach based on R_0=4 from 20 April 2020
Initial symptomatic patients	400	Function of initial asymptomatic state
Ratio of asymptomatic: symptomatic infection rates	8:1	Anecdotal assumption/calibrated
Infectious period	5 days	
Time to isolate symptomatic patient	2.5–3 days	2 days as pre-symptomatic, 1 day to isolate
Mean duration of infection in asymptomatic patient	25 days	Patient will be PCR+ for 25 days
Swab test capacity	1,000–3,000/day	Ramped up from 10 April 2020
Average length of stay (ALOS) in Community Isolation Facility	25 days	

Table 3: Baseline SIR Model Parameters .

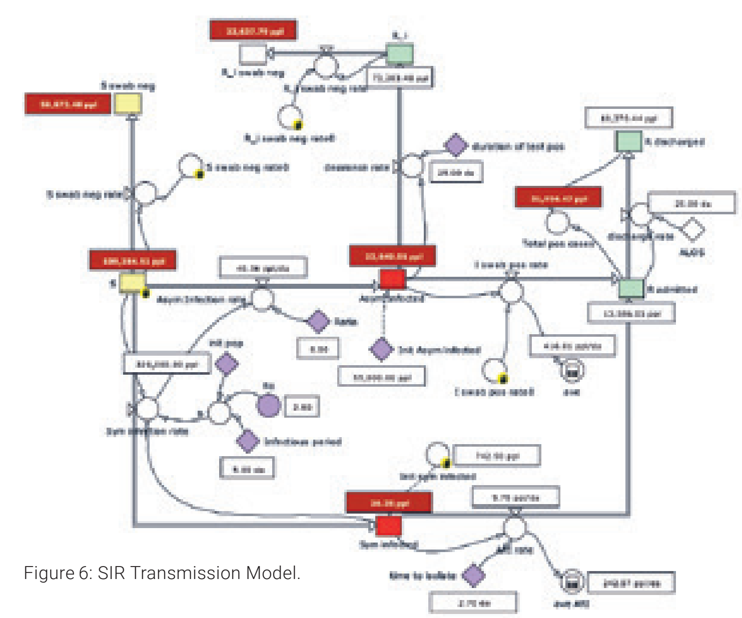


Figure 6: SIR Transmission Model.