Effects of Movement Control Order on mitigating spread of COVID-19 in the early phase of the outbreak in Malaysia

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Abstract. We propose a mathematical model to investigate the early outbreak of COVID-19 in Malaysia. The model emphasizes the role of the government’s Movement Control Orders (MCOs) as population-wide lockdown measures and the potential benefit of mass testing on disease spread. We fit this model to the reported active COVID-19 cases to estimate model parameters. We also assume transmission rates change with respect to stages of MCOs and compare the differences in rates to assess the effectiveness of different levels of MCO restrictions. The estimated parameters match the observed data well, and our results suggest a slowing of the trajectory of COVID-19 outbreak in the country, indicating that the series of MCOs taken to counter COVID-19 transmission are having a significant positive effect.

1. Introduction
In Malaysia, the first cases of COVID-19 started appearing on 25 January 2020 involving travellers from China arriving via Singapore. The country’s Ministry of Health (MOH) managed to keep this first wave under control until a four-day religious gathering from 27 February until 1 March involving approximately 16,000 people at the Sri Petaling mosque compound on the outskirts of Kuala Lumpur led to hundreds of new cases [1]. Before the official nationwide lockdown implemented to contain the infection, already nearly two-thirds of COVID infections in Malaysia had been linked to this gathering.

In response to the COVID-19 epidemic, more than one-third of the world population was locked down as part of the mitigation and suppression strategy first proposed by Imperial College London, United Kingdom [2]. Such a strategy is aimed at reducing the spread of infection, protecting health services and saving lives [3]. To help counter the COVID–19 epidemic, the government of Malaysia initiated the Movement Control Order (MCO) as a preventive measure to slow down the transmission of the virus in the country effective on 18 March 2020. Since then, Malaysia has gone through subsequent extensions and modifications of the Movement Control Order with all the strict actions recommended by the World Health Organisation (WHO). The timeline of COVID-19 and control measures implemented in Malaysia is depicted in figure 1.
The order included a general prohibition of mass movements and gatherings across the country. Restrictions were also made on the entry of all tourists and foreign visitors into the country. Additionally, Malaysians who had just returned from overseas would be required to undergo a health check and 14-day quarantine (or self-quarantine). During the MCO period, the government also ordered the closure of all kindergartens, government and private schools, including public and private higher education institutions, and almost all government and private premises except those involved in essential services.

![Figure 1. The timeline of COVID-19 and control measures implemented in Malaysia from 25 January 2020. The red arrows are the events in the COVID-19 outbreak while the blue arrows are the control measures.](image)

After the first week of the MCO, Malaysian Prime Minister Muhyiddin Yassin announced the Enhanced Movement Control Order (EMCO), which was to last until 14 April and then extended twice until 3 May. Subsequently, the Conditional Movement Control Order (CMCO) until 9 June was then implemented as the number of cases in Malaysia was expected to peak in mid-April. Later, the CMCO was replaced with the Recovery Movement Control Order (RMCO), which took effect from 10 June 2020 to 31 August 2020 with more lenient restrictions.

Our work is aimed at investigating the dynamics of the COVID-19 epidemic in Malaysia. In this study we address some fundamental issues and also the effect of public health measures during MCO that will mitigate the final size of the epidemic in the country.

2. Methods

2.1. Data

We obtained data of laboratory-confirmed COVID-19 cases in Malaysia from the Ministry of Health (MOH) of Malaysia [8]. Data including the number of reported confirmed cases, cured cases, and deaths. The number of active cases are the number of infected cases that have been hospitalized or isolated. The dataset that starts from day 5 of lockdown measures, or 22 March, until 4 May 2020, is used for model calibration, while the dataset from 5 May onward is applied for model validation.
2.2. Model Development

We can capture the spread of the epidemic across the populations reported in the data using a simple ordinary differential equation (ODE) model:

\[
\begin{align*}
\dot{H} &= \beta(t)H - cH, \\
\dot{I} &= cH - (r + \delta)I, \\
\dot{R} &= rI, \\
\dot{D} &= \delta I,
\end{align*}
\]

(1)

where \( H \), \( I \), \( R \), and \( D \) represent the population of hidden infected, identified infected, recovered, and deceased individuals. The simplicity of the model allows us to quickly consider a variety of scenarios and readily, and even explicitly, assess the sensitivity of the model to parameter estimates.

Note that our system is an SIR model with two infected states, hidden and identified, and without the susceptible, \( S \), population. For simplicity, we assume the susceptible population remains constant, which is reasonable considering that a very small fraction of Malaysia’s population is infected (less than 0.025%). We also assume that once infecteds are identified, they are isolated from the population and no longer infect others. With this assumption, only hidden infected individuals infect others at rate \( \beta(t) \). As the infection develops, infected individuals progress from hidden to identified states at rate \( c \) and the recover or die at rates \( r \) and \( \delta \). A diagram of model (1) is shown in figure 2.

Effect of lockdown measures

The trend of epidemics depends on the strength of interventions. Because of that, classical SIR models cannot be used to represent and fit the data effectively [9]. Hence, it is necessary to develop a dynamic model accounting for prevention and control measures to predict the trajectory of the COVID-19 epidemic.

To capture the effect of MOH lockdown measures, we assume governmental policies only influence the infection rate \( \beta(t) \) and do not affect disease progression parameters \( c \), \( r \), and \( \delta \). Furthermore, we assume \( \beta(t) \) is piecewise constant with different values for each of the three phases of MCO: MCO phase 1 from 18 to 26 March, EMCO from 27 March to 3 May, and CMCO from 4 May to 9 June. To remove transient effects of initial measures coming into place, we model the system from day 5 of lockdown, or 22 March. Hence, \( t = 0 \) days corresponds to the
beginning of 22 March, \( t = 5 \) corresponds to the beginning of 27 March, and \( t = 44 \) corresponds to the beginning of 5 May. Thus, \( \beta(t) \) is defined as

\[
\beta(t) = \begin{cases} 
\beta_1, & 0 \leq t < 5, \\
\beta_2, & 5 \leq t < 44, \\
\beta_3, & t \geq 44.
\end{cases}
\] (2)

where \( \beta_1, \beta_2, \) and \( \beta_3 \) are the constant infection rates during MCO phase 1, EMCO, and CMCO, respectively.

**Effect of Mass Testing**

It has been proposed that group testing schemes could significantly increase mass testing efficiency under different prevalence rates [10]. However, true prevalence rates are unknown as in most countries, large-scale population testing has still not been introduced. In the context of the current COVID-19 epidemic in Malaysia, tests are often restricted to specific groups, such as healthcare workers, individuals with known COVID-19 exposure or individuals showing any coronavirus symptoms.

Herein, we evaluate the effect of mass testing at different transmission rates corresponding to different phases of MCO in (2). The modified dynamical model in (1) takes the form

\[
\begin{align*}
\dot{H} &= \beta(t)H - cH - qH, \\
\dot{I} &= cH - (r + \delta)I + qH, \\
\dot{R} &= rI, \\
\dot{D} &= \delta I,
\end{align*}
\] (3)

where \( q \) is the increase in rate hidden infected individuals, \( H \), are identified and quarantined to the population of identified infecteds, \( I \).

3. Results

3.1. Parameter Estimations

The parameters in Models (1) are listed in Table 1. Understanding these epidemiological parameters is of importance to predict the trend of the outbreak, as well as to guide clinical management and prevention of the outbreak [11]. In this study, we use the optimization toolbox in Simulink, MATLAB that solves nonlinear least-squares curve-fitting problems of the form

\[
\min_x \|f(x)\|_2 = \min_x \left( f_1(x)^2 + f_2(x)^2 + \ldots + f_n(x)^2 \right)
\] (4)

The objective function (4) computes a vector of differences between predicted values and observed values by using the ‘lsqnonlin’ function in Matlab.

Since the implementation of the first MCO on 18 March, the Malaysian MOH has responded to the unfolding epidemic by extending and adjusting responses to contain the outbreak. The proposed model and parameters together with data from the Malaysian MOH can be used to estimate the effectiveness of government measures. We obtain the parameter fits for Model (1) shown in Table 1, and a plot of the model simulation against data is shown in figure 3.
Table 1. Parameters and initial conditions fitted to data from [8]. All parameters have units of 1/day.

| Param. | Definition | Model (1), [95%CI] |
|--------|------------|-------------------|
| \(\beta_1\) | Infection rate during MCO | 0.109, [0.098, 0.12] |
| \(\beta_2\) | Infection rate during EMCO | 0.074, [0.067, 0.082] |
| \(\beta_3\) | Infection rate during CMCO | 0.106, [0.095, 0.116] |
| \(c\) | Transition rate from hidden to identified infecteds | 0.116, [0.104, 0.128] |
| \(r\) | Recovery rate | 0.048, [0.043, 0.053] |
| \(\delta\) | Death rate | 0.001, [0.001, 0.0012] |
| \(H(0)\) | Initial hidden infecteds | 1712 (estimated) |
| \(I(0)\) | Initial identified infecteds | 1157 [9] |
| \(R(0)\) | Initial recovered population | 139 [9] |
| \(D(0)\) | Initial deceased population | 10 [9] |

Figure 3. Simulation of Model (1). Best data fits for deaths \(D\), identified infecteds \(I\), recovereds \(R\) and total cases \(I + R + D\), from 22 March to 9 June. Asterisks indicate the data from MOH and solid curves display the model solution using estimated parameters.

3.2. Impact of Movement Control Orders

To assess the differential effects of the different stages of the Movement Control Orders, we fit different infection rates \(\beta_1\), \(\beta_2\), and \(\beta_3\) for each of the three periods corresponding to MCO phase 1, EMCO, and CMCO. From our parameter estimates for Model (1), we immediately see how strong the effect of lockdown measures were, since the more stringent EMCO led to a 32% decrease in infection rate \(\beta_2\) compared to the infection rate \(\beta_1\) during MCO. The introduction of CMCO caused the infection rate \(\beta_3\) to return to nearly the same level as the infection rate \(\beta_1\) of MCO.
3.3. Basic reproductive number $R_0$

The basic reproductive number $R_0$ refers to the expected number of secondary infectious cases produced by a typical index case in an entirely susceptible population [12] such that if $R_0 > 1$, then the model is unstable and an increase in the number of cases will occur. But if $R_0 < 1$, then the disease cannot invade the population, and the number of cases will decline. The basic reproductive number over time in our model (1) is given by

$$R_0(t) = \frac{\beta(t)}{c}. \quad (5)$$

$R_0$ values for the COVID-19 epidemic in Malaysia shows that the outbreak is relatively stable and the implementations of MCO have significantly decreased the epidemic risk of COVID-19. However, especially since $R_0 = 0.908$ is very close to 1, the existing control and prevention strategies must not be taken lightly to contain the virus’s further spread.

3.4. Impact of mass testing

From Model (3) for mass testing, we obtain an effective reproductive number of

$$R_{eff}(t) = \frac{\beta(t)}{c+q} = \frac{\beta(t)}{c} \left( 1 - \frac{q}{c+q} \right) = R_0(t) \left( 1 - \frac{q}{c+q} \right)$$

Using the model, we can evaluate the effectiveness of mass testing in comparison with the MCOs. From (5), the transition from MCO to EMCO led to a 32% reduction in $R_0$ from $\beta_1/c = 0.916$ to $\beta_2/c = 0.622$. To achieve the same reduction by combining MCO with mass testing, we need mass testing to remove at least $q/(c+q) = 32\%$ of hidden infected people from the population before they turn up in hospital with active infections. This level of efficacy corresponds to a quarantining rate of $q = 0.0546$ of the hidden infected population per day.

On the other hand, the combined effect of MCOs and mass testing are cumulative, and figure 4 shows how mass testing can lead to improved disease dynamics for different values of $q$, when the infection rate $\beta = 1.2$, which allows $R_0 = 1.01 > 1$ in the absence of mass testing ($q = 0$).

![Figure 4](image-url)

**Figure 4.** The effect of mass testing on disease dynamics for infection rate $\beta = 1.2$ for mass-testing quarantine rates $q = 0$, 0.04, and 0.08, which corresponds to mass testing that can remove an additional $q/(c+q) = 0$, 25%, and 40% of hidden infected people from the population.
4. Discussion

We propose an ordinary differential equation (ODE) model to investigate the outbreak of COVID-19 in Malaysia and the effect of various government interventions. Our model takes the form of a standard SIR model with the variation that we consider the susceptible (S) compartment to be constant and include a Dead (D) compartment. We also divide the infected population into two subpopulations, hidden (undiagnosed) and identified (diagnosed). For simplicity, we assume all hidden infecteds eventually get diagnosed and progress to the identified category. This simplification does not account for a population of asymptomatic infecteds who transition from the hidden infected population to the hidden recovered population without every being diagnosed. On the other hand, the size of such a population is hard to estimate with our available data and modelling such a subpopulation is a possible extension for future work. We estimate our parameters by fitting our models to MOH data on populations of infected individuals, recovered individuals, and deaths.

Using our model, we investigate the impact of lockdown measures in the form of Movement Control Orders, and the potential benefit of mass testing on disease spread. We conclude that the Movement Control Orders provided the most effective benefit by substantially reducing the infection rate $\beta$. Although we cannot compare the impact of MCO phase 1 against a true control case of uninhibited disease progression, the positive effect of lockdown measures was already apparent in the 32% decrease in infection rate during the stricter EMCO versus the initial MCO (see parameter fits for Model (1) in Table 1). Furthermore, mass testing can provide a benefit in addition to lockdown measures, yet to provide a substantial improvement beyond existing measures, mass testing would have to be comprehensive enough to capture about 25% to 30% of hidden infected individuals before they turn up at hospitals with active infections.

In conclusion, our study provides an overview of the transmission dynamics of COVID-19 in Malaysia. Our findings suggest a slowing down of the trajectory of COVID-19 outbreak in the country, indicating that the series of MCOs taken to counter COVID-19 transmission are taking into effect.

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