

Closed monitoring of Malaysia COVID-19 using SEIR compartmental model for first wave trajectory

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Abstract

Malaysia COVID-19 trend trajectory has shown significant improvement since Malaysia employed Movement Control Order (MCO) on 18th Mar 2020. Since then a modified compartmental Susceptible, Exposed, Infectious and Removed (SEIR) model has been developed to monitor closely the development on the epidemic. The model introduced early detection factor in order to measure the reliability of the strategy carried out. The closed monitoring is to estimate the current projection of Reproduction Number (R_0), a number which a single infected person could outspread the virus to other people, and to forecast in the near future of the number of active cases for several days. This is to show that the strategy carried out by the Malaysian government in order to contain the outbreak whether or not has taken into effect within the period of the first wave of the outbreak. The observation carried out has found out that under the Enhanced MCO (EMCO) or the second MCO showed significant reduction in the number of active cases as well as R_0 . Not only that the early detection strategy carried out has shown significant improvement of 2.5 to 3.6 times higher than the first MCO.

Keywords

SEIR, Covid-19 trajectory, Transmission rate control parameters, Rapid test factor, Early detection strategy.

1. Introduction

China has completed their first wave of COVID-19 epidemic. As of 1st June 2020, the total active cases were 76 with total accumulated cases 83017 all over the China. This number has been almost constant since the city of Wuhan had lifted partially the lockdown on 8th April 2020 by allowing healthy residents and visitors to leave [1–4]. The epidemic patterns showing almost the same projection at the beginning with almost for all countries affected [5]. The same goes to China neighbouring country, South Korea with 810 active cases and 11,503 accumulated cases on the same date [6]. At this current rate South Korea had almost completed the three quarter of the epidemic wave. Other countries (based on the same date) were also showing declining in their active cases, Switzerland, Spain, Italy and Germany but the numbers are still in thousand counts.

In terms of deaths, the daily death tolls patterns are still accelerating in most countries, as of 1st Jun 2020 New York showing the highest death tolls so far, with 29,988 in total. The pattern trajectory showing almost similarity even the cause of death has been a subjective matter, which may due to high risk of individuals who were, aged over 60 years and those with underlying conditions such as hypertension, diabetes, cardiovascular disease, chronic respiratory disease and cancer [7, 8]. Other study has shown three possible categories of dying process in COVID-19; predominant terminal organ failure, proportionality of care in the dying process and involvement of COVID-19 in the dying process [9].

The recovery pattern (as of 1st Jun 2020) have shown that 89% of the infected cases were removed from the infected lists and free of virus infection which accounts for 3,286,946 people. This is believed to be the individuals with mild conditions constitutes to

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98% or 3,033,927 people [10]. The high rate of recovery is in line with several reports that can be found in [11, 12]. There were also asymptomatic cases which may contribute to recovery but the majorities were considered as relatively rare cases from the date of identification or report. However the case due to asymptomatic symptoms is still unclear and does not appear to be the major driven of the virus transmission.

The active cases patterns show exponential growth, which later reduce to values range within health care capacity of certain countries. These are the main accountable numbers contributes to SEIR compartmental model, the infected people, the recovered people and the death people, which have been known widely to be the model of any epidemic infectious diseases, particularly in current pandemic COVID-19 [13–18]. Even in tropical country like Malaysia, the SEIR model has been successfully model the dengue outbreak in local states [19–21].

One of the parameter within the SEIR model that contributes the infectivity is known as Reproduction Number, R_0 . This number represents the possible single infected person to spread the virus, if $R_0 < 1$, the outbreak will eventually die. Earlier WHO on Jan 23, estimated the R_0 is between 1.4 and 2.5 [22]. Other studies have also estimated that R_0 to be between 2.24 and 3.58 [23], which believe the outbreak will follow an exponential growth. Some preliminary studies have also shown that R_0 to be between 1.5 and 3.5 [24–26]. This is in agreement with the projection pattern as stated earlier.

In Southeast Asia, Malaysia is the first country to reach total accumulated cases up to 4000 cases as of 6th Apr 2020 [27]. Although Malaysia showed slow progression of the earlier outbreak, with Singapore lead up to 108 total cases followed by Thailand 43 total cases up to 1st Mar 2020, the sudden growth in Malaysia were presumed to be of several reasons that breaks into several clusters.

This paper presents a closed monitoring of Malaysia COVID-19 cases, based on modified SEIR model with control measures/indicators for first wave outbreak period. The objective of the paper is to demonstrate capability of SEIR model in projecting the number of COVID-19 active cases for several days ahead, at the same time becomes a tool for closed monitoring in estimating COVID-19 projection number. The purpose of the monitoring is to estimate the current R_0 and to project the next R_0

within several days. The estimated R_0 will be an indicator whether or not the strategies taken by the government under the MCO and the active measure of early detection by the Ministry of Health (MOH) have taken into effect. The strategy of the estimation is to fit the model with non-linear least square technique to the actual data from China, and use the parameter for Malaysian COVID-19 pattern outbreak. This is based on the preliminary assumption that the pattern outbreak from China will be the same throughout any other countries around the world.

2.COVID-19 first wave Malaysian

In order to understand the overall scenario of the epidemic, *Figure 1* shows the possible timeline clusters of sudden pandemic growth in Malaysia and the enforcement of MCO. In reaction Malaysian government starts to close border on 16th Mar 2020, enacted a 14-days Movement Control Order (MCO) on Mar 18, which has been extended twice to Apr 14 and Apr 28. Under the MCO government and private premises (except essential services), non-essential business, schools, universities and worship places were partly closed, while social and cultural gathering were banned. The police and armed forces were used to control the movement; drones and helicopters were used for monitoring. Those who violated the MCO were penalized and will put under penalty. These were among the measures used to mobilize the enforcement [28, 29].

3.Methodology

The estimation strategy is by looking at the trend trajectory from China. This is based on the assumption that the same pattern of COVID-19 outbreak originated from China will have the same patterns and implications throughout any other places in the world. Five parameters ($\alpha, \theta, k, \hat{\sigma}, \hat{\gamma}, \rho$) need to be estimated by using Levenberg-Marquardt Nonlinear Regression technique for curve fitting and parameter estimation [30–33], which later will be explained in Mathematical Model Description section.

The estimation of the curve projection is based on current infected numbers and daily newly COVID-19 cases. The objective of the projection is to estimate the possible number of active cases and reproduction number R_0 , where R_0 represents the average number of people to which a single infected person will transmit the virus. We introduced step function, $\beta(t)$, that consist of early transmission rate and control measure parameters to estimate for the next

projection curve. The step function is needed for future curve projection for any changes based on the current and previous number of active cases at any particular time (dates).

The steps involved in making the projection and estimating the mentioned parameters will be explained in the model description sections.

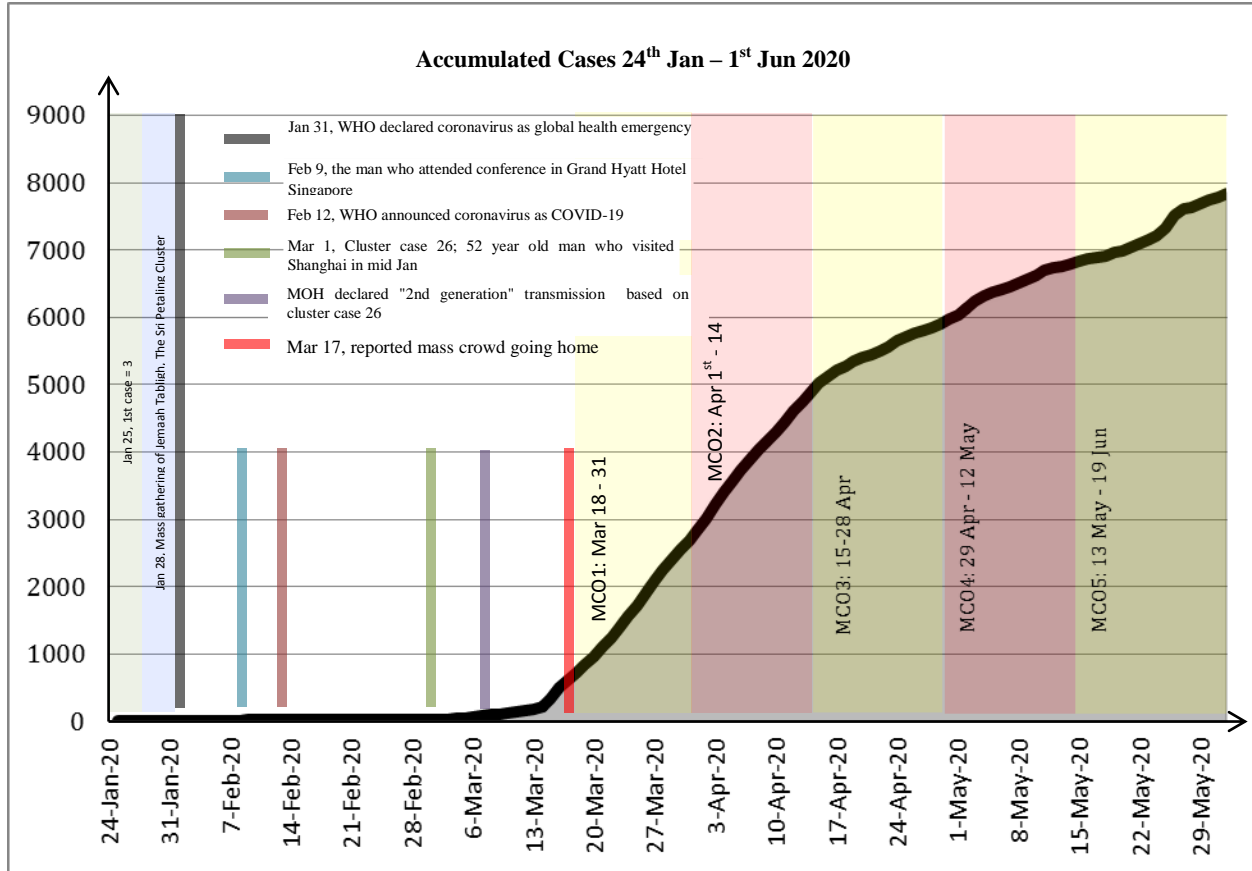


Figure 1 Malaysia COVID-19 brief timeline

(Note: MCO1: 18-31 Mac 2020; MCO2: 1-14 Apr 2020; MCO3: 15-28 Apr 2020; MCO4: 29 Apr-12 May 2020; MCO5: 13 May – 9th June 2020)

3.1 Model descriptions

Our model is based on a simple SEIR compartmental model. We adopted the model based on the framework from [34, 35]. Both used control measures to estimate the confirmed infected cases at current time with control transmission rate equation. Two common parameters were introduced to see the effect of the pandemic outbreak of Spanish flu influenza in 1918, later used to see the effect for COVID-19 outbreak in China. The first parameter was earlier introduced by [34] as school-term forcing, later the term changed by [35] to governmental action effect to see the effect of control parameter on the possible COVID-19 projection. The second term was human behavioral response to death. This is to see the response of individuals to the severity cases related to deaths.

We adopted and modified both model to suite the possible solution of current projection, especially by looking at the curve trend projection in China. Equations (1) to (11) show the derivation of the SEIR compartmental model. $S(t)$ represents the susceptible population that can be infected with N total number of population. Our early assumption on susceptible population equals to $0.9N$ an assumptions made by [35]. $E(t)$ is the exposed individuals who goes under quarantine for period of 14 days [36, 37]. $I(t)$ is the confirmed cases infected with official report and not considering the individual with onset symptom. $R(t)$ is removed which individual considered as free from virus infection. $R(t)$ can then be further split into individual two recovered $\mathfrak{R}(t)$ and death $D(t)$. At any time the total number of population equals to $0.9N = S(t) + E(t) + I(t) + R(t)$. From equation

(2) the expression $\hat{\sigma} \frac{\sigma}{i_p} \mathbf{E}(t)$ represents the confirmed cases with σ as mean latent period or mean incubation period of 5.1 days [7,36,38], i_p represents the maximum incubation period of 14 days and $\hat{\sigma}$ represents the rate of individuals with confirmed detection. Meanwhile the term $\hat{\gamma} \frac{\gamma}{i_p} \mathbf{I}(t)$ represents the individuals free from the virus with mean infectious period γ equals to 5 [35,39], and $\hat{\gamma}$ is the rate of removed.

$$\frac{d}{dt} \mathbf{S}(t) = -\frac{\beta(t)}{N} \mathbf{S}(t) \mathbf{I}(t) \quad (1)$$

$$\frac{d}{dt} \mathbf{E}(t) = \frac{\beta(t)}{N} \mathbf{S}(t) \mathbf{I}(t) - \hat{\sigma} \frac{\sigma}{i_p} \mathbf{E}(t) \quad (2)$$

$$\frac{d}{dt} \mathbf{I}(t) = \hat{\sigma} \frac{\sigma}{i_p} \mathbf{E}(t) - \hat{\gamma} \frac{\gamma}{i_p} \mathbf{I}(t) - \partial \mathbf{I}(t) \quad (3)$$

$$\frac{d}{dt} \mathbf{R}(t) = \hat{\gamma} \frac{\gamma}{i_p} \mathbf{I}(t) + \partial \mathbf{I}(t) \quad (4)$$

Equation (4) can be further extended into two further equations known as Recovery and Death if one likes to estimate the severity of cases. By rewriting equation (4):

$$\frac{d}{dt} \mathbf{R}(t) = \hat{\gamma} \frac{\gamma}{i_p} \mathbf{I}(t) \quad (5)$$

$$\frac{d}{dt} \mathbf{D}(t) = \partial \mathbf{I}(t) \quad (6)$$

where $\mathbf{R}(t)$ represents the individuals, who are no longer infectious and on track to free from the effects of the virus plus the individuals who died from severe cases. $\mathbf{R}(t)$ represents the recovered individuals and free of infection while $\mathbf{D}(t)$ represents the death people at rate ∂ . The control parameters that incorporated with the SEIR model are shown in the following equations:

$$\frac{d}{dt} \mathbf{P}_r(t) = \rho \hat{\sigma} \frac{\sigma}{i_p} \mathbf{E}(t) \quad (7)$$

$$\frac{d}{dt} \mathbf{P}(t) = \rho \hat{\sigma} \frac{\sigma}{i_p} \mathbf{E}(t) - \frac{\lambda}{\lambda_{max}} \mathbf{P}(t) \quad (8)$$

Where $\mathbf{P}_r(t)$ represents the function of quickness in early detection starting from the onset symptom to actual reported cases that control by the parameter ρ . $\mathbf{P}(t)$ represents the public positive response and reaction to the government order on movement control with λ as mean public reaction to MCO fixed

at 11.2 days. Whereas λ_{max} represents maximum public reaction fixed at 21 days [34].

The cumulative number of cases can be obtained from:

$$\frac{d}{dt} \mathbf{A}(t) = \hat{\sigma} \frac{\sigma}{i_p} \mathbf{E}(t) \quad (9)$$

By neglecting the number of recovery and deaths the cumulative reproduction number can be computed as:

$$\mathbf{R}_0 = \frac{c\Delta \mathbf{I}(t) + c\Delta \mathbf{R}(t)}{c\Delta \mathbf{R}(t)} \quad (10)$$

However, the time variant reproduction number can be obtained numerically inside the SEIR model by using equation (3) and (4) as shown by [13, 40, 41]. We used control parameters to see the variance of the curve projection as discussed previously with few modifications. Equation (12) shows the transmission rate with control parameters:

$$\beta(t) = \beta_0 \cdot (1 - \alpha) \cdot e^{-\theta \cdot \mathbf{P}_r(t)} \cdot \left(1 - \frac{\mathbf{P}(t)}{N}\right)^{k \cdot k_{max}} \quad (11)$$

Where $\beta(t)$ represents the time domain transmission rate with basic transmission β_0 equals to 1.68. This is also based on assumption of initial R_0 equals to 2.8 [23, 26, 35, 42] with an assumption that $R_0 = \frac{\beta_0}{\gamma} \cdot \frac{\sigma}{\sigma + \mu}$ [35, 41]. α represents the enforcement of government under the movement control order earlier known as $H(t)$ school term forcing equals to -1 when schools closed [34]. $\mathbf{P}(t)$ represents the public positive reaction and response function with strength k . We used normalized value of k later used for fitting purposes by multiplying it with constant $k_{max} \rightarrow \infty$. The modification of $\mathbf{P}(t)$ was made based on the number of active cases rather than number of severe cases of death. $\mathbf{P}_r(t)$ is the function to represent the early virus detection strategy that incorporate with the current number of confirmed infected individuals (equation 7) with θ as the parameter control. The effect of early detection can be seen with the following ratio:

$$\xi_r = \frac{1}{\theta} \quad (12)$$

The early test indicator of equation (13) can be seen with the sudden increase of infected number, higher number of ξ_r means more individuals will have earlier detection. The modified SEIR model developed is based on the assumptions that there are no zoonotic cases and no emigration rate.

The system configuration is based on the SEIR model of the Equations (1) to (4), known as compartment model. It starts from compartment $\frac{d}{dt}S(t)$, $\frac{d}{dt}E(t)$, $\frac{d}{dt}I(t)$, and ends with compartment $\frac{d}{dt}R(t)$. The estimation process works along the equations by calculating all parameters numerically, as set in Equations (7) to (12).

4.Results and discussion

We present the results in two sections, the effect of control parameters and the closed monitoring of R0 for Malaysia COVID-19. The dataset were obtained from worldometer for accumulated cases, active current cases, daily new cases, incremental numbers, number of recovery and number of deaths. The active current cases are used to estimate the reproduction number, R0, as well as the removed (number of deaths plus number of recovery) for modelling. The estimation is set until the end of May 2020 for Malaysia first wave COVID-19.

4.1The effect of control parameters

The effect of control parameters can be seen from the two earlier work [34, 35] but with few modifications. Here we only present the effect of early detection strategy. The equation (12) incorporates with three parameters to see the magnitude variations; we

maintained the effect of governmental strategy on MCO as α and the effect of public response as normalized k. The effect of early detection strategy θ is motivated by reported cases from China on 12 Feb 2020 where newly reported cases suddenly rose to 14108 individuals in a single day [1]. The report can be found on several news [43–45].

Figure 2 shows the fitting results before and after the rapid test techniques employed by the China government. It was found out that the rapid test carried out by the Chinese government manage to detect almost twenty times faster than the normal lab test. Table 1 tabulated the parameters for the two periods.

Figure 3 shows the effect of early detection test strategy for China overall fitting results from 22 Jan 2020 until 1st April 2020. By increasing the ξr by factor 0.2 it shows that an increasing number of positive COVID-19 (to show early detection) due to active action from the government to control the outbreak. On the other hand, by increasing ξr the outbreak could end almost at the same time and the numbers of active cases were very close for each projection towards the end. The basic fitting result parameters are shown in Table 1, which later use for probable projection for Malaysia COVID-19.

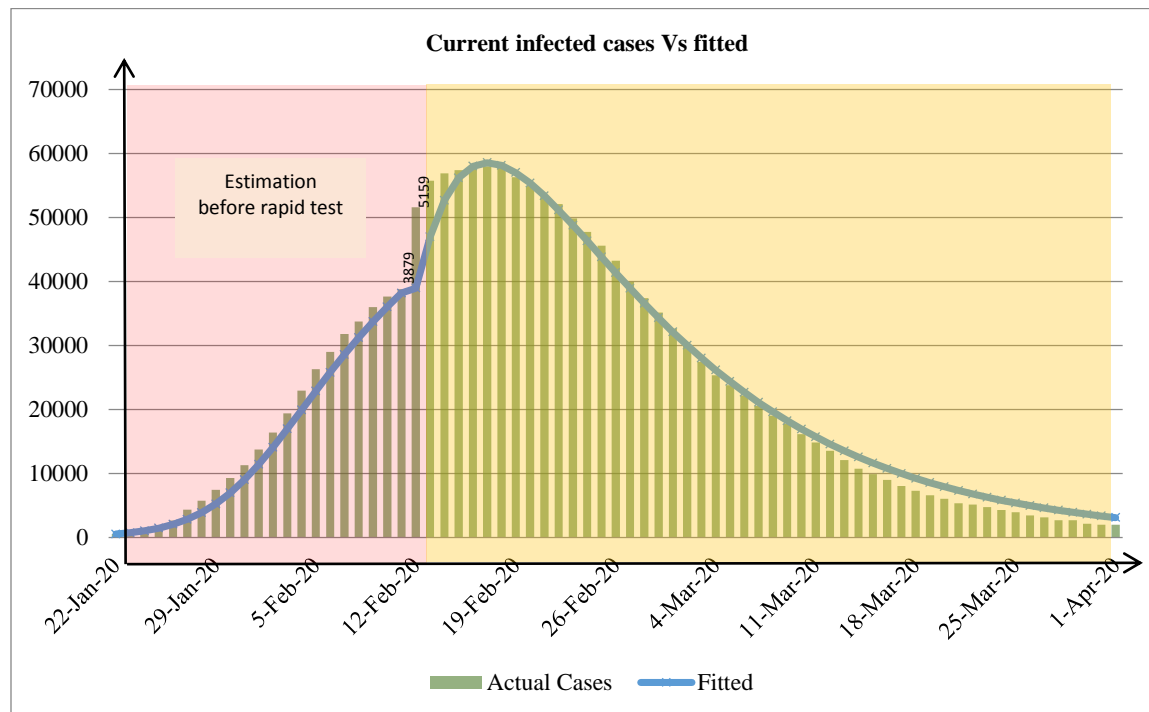


Figure 2 Current infected cases for China vs estimated curve using Lavenberg-Marquadt regression techniques with rapid test parameter (Data fitted until 1st Apr 2020).

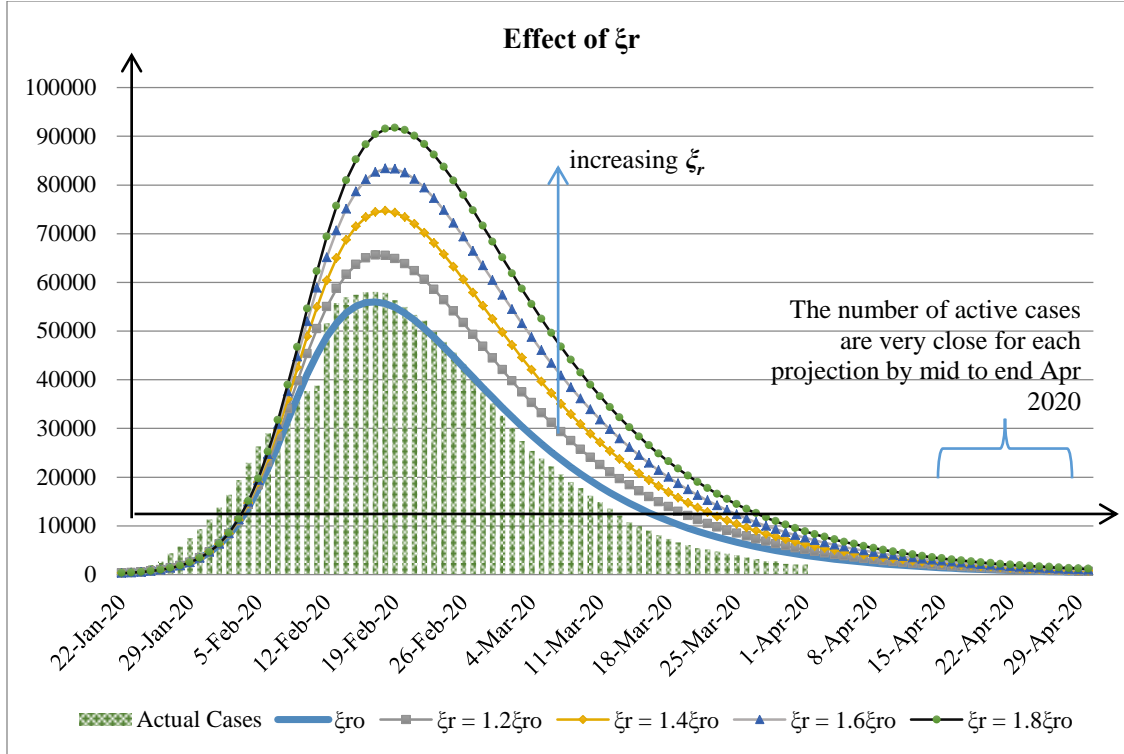


Figure 3 The effect early test indicator ξ_r (Data fitted until 1st Apr 2020 for China).

Table 1 SEIR fitting parameters before and after rapid test by China

Parameters	α	ρ	k	$\hat{\sigma}$	$\hat{\gamma}$	θ	ξ_r
Before rapid test	0.01064	0.00018	0.12968	0.49450	0.02807	0.39161	2.6
After rapid test	0.16828	0.00137	0.00100	4.20643	0.28621	0.01992	50.2
Overall Fitting test result	0.01000	*0.00279	0.00100	*0.48555	*0.24486	0.01244	$\xi_{r0} \approx 80.4$

*note: These parameter values will be used later for probable projection for Malaysia COVID-19 (later known as SEIR parameters)

4.2 The results on first wave trend trajectory for Malaysia

Based on the fitting results obtained in Table 1, the fitting parameters will be used for the next projection results. We used Levenberg-Marquardt Nonlinear Regression technique to estimate the current projection to estimate the current value of control parameters α, θ and k . By combining the fitted SEIR parameters and current fitting parameters from Malaysia active current cases and daily new cases the new projection would be possible. The possible new projection is made by estimating the current value of R_0 from curve fitting since beginning to current date and multiplies by the factor ξ_r . This is based on the assumption that no changes or intervention at current time. Hence the projection factor (PF) is given by:

$$\left. \begin{aligned} \text{Projection Factor (PF)} &= \xi_r \cdot R_0 \\ \theta &= \frac{1}{PF} \end{aligned} \right\} \quad (13)$$

and fed into Equation (12).

The first full projection was made on 22nd Mar 2020 as shown in Figure 4. New $\beta(t)$ is introduced for overall possible projection at 22nd Mar 2020 with estimated $R_0 \approx 2.23$. The peak number of active cases was expected to be around 3600 people on 5th Apr 2020. The expected $R_0 < 1$ is estimated to be in the early April to mid-April 2020, which in agreement to Malaysian government MCO1 and MCO2 end dates. In actual case, the peak number of active cases was 2596 people on 5th Apr 2020.

The second projection $\beta(t)$ was introduced on 26th Mar 2020 with an estimated R_0 equals 2.37, which shows no declining projection since 22nd Mar 2020, until expected to go down by 6th Apr 2020 as shown in *Figure 5*. The rapid increase was believing to be the cause of the Tabligh Sri Petaling cluster [46]. However, on 6th Apr 2020, under the second MCO, the margin begins to expand and the number falls far below the estimation with the margin of 205 as shown in *Figure 5*.

Hence *Figure 6* shows new projection made on 5th Apr 2020 to see the new pattern projection until the end of MCO2. It was estimated that by 5th Apr 2020, the estimated R_0 to be 1.12. Until 9th Apr 2020, the actual projection was still remained intact. The number of active cases follows closely to the estimated projection. At this current rate the estimated R_0 was 1.03, and expected to reach below 1 by 14th Apr 2020 with $R_0 \approx 0.92$. The analysis can be seen in *Figure 6*.

Under the second MCO the government has enforced an Enhanced MCO (EMCO). This includes active test by the MOH in order to have earlier detection, earlier isolation and earlier treatment. Starting 27th Mar 2020, with EMCO specific locations were

subjected to a stricter order for 14 days, if a large cluster was detected within the area in order for the government to conduct a thorough COVID-19 test towards all residents. Among the orders are all residents or visitors are forbidden to exit or entering the area, all business are closed, adequate food supplies will be given by authorities, medical base will be established within the area and all roads are blocked [47].

As a result on 15th Apr 2020, new assessment were made to see the actual progress and found out that the Malaysian government were doing very well under the second MCO. This is clearly seen from *Figure 7*. The pattern shows that since 5th Apr 2020 a significant reduction on the number of active cases were far below the estimated projection with margin of 204 people by 14th Apr 2020, and $R_0 \approx 0.84$, far from earlier projected curve. This shows a good sign that the strategy begin to take place under the second MCO. In order to see the estimated R_0 , a new projection was made on 14th Apr 2020 to forecast for the next projection and expected to have around 1997 active cases by 21st Apr 2020 with $R_0 \approx 0.6$.

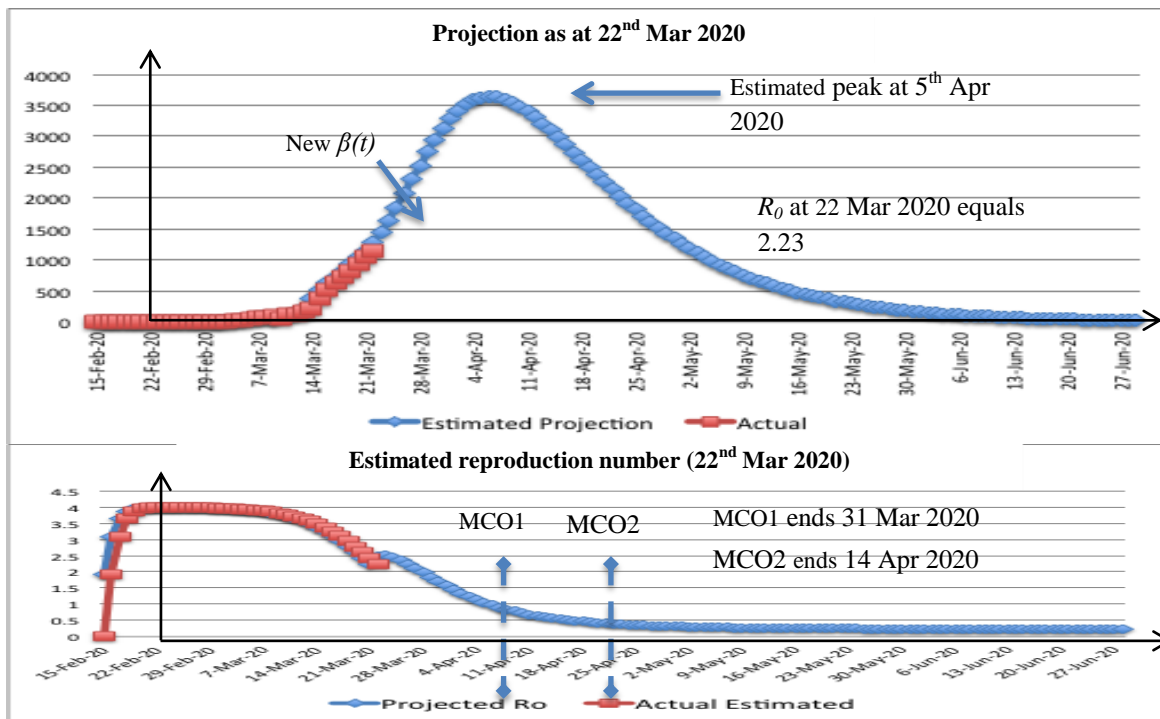


Figure 4 First full projection on 22nd Mar 2020

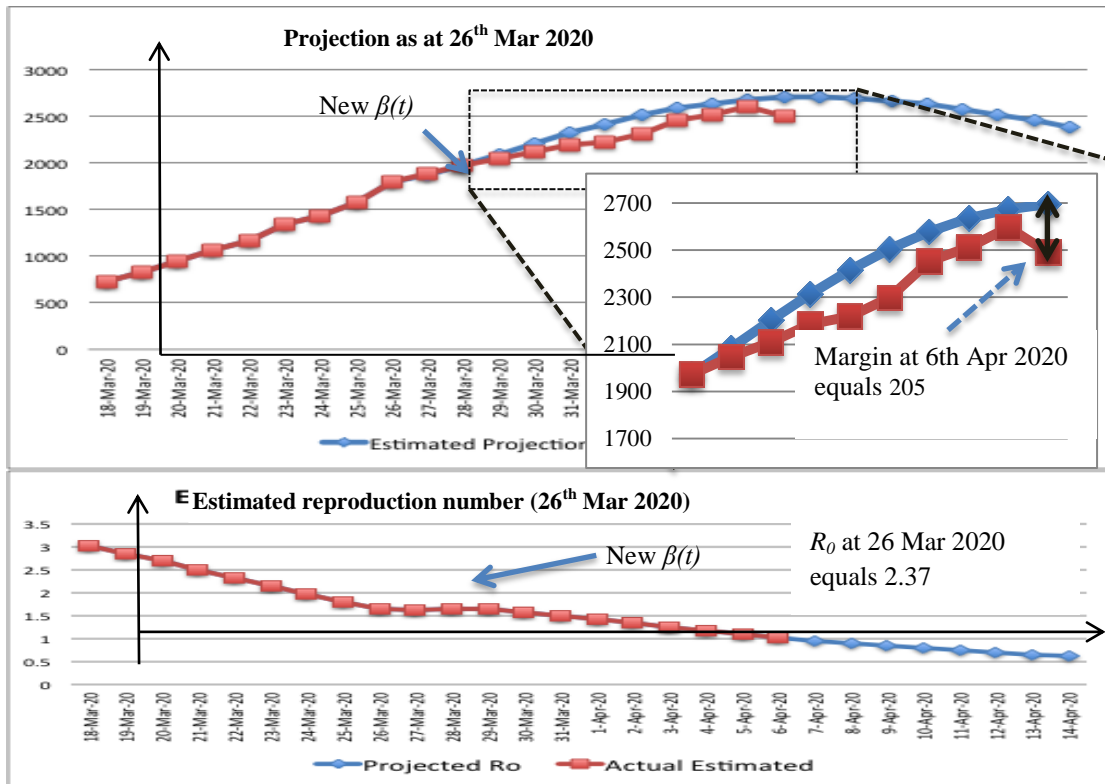


Figure 5 Second projection on 26th Mar 2020

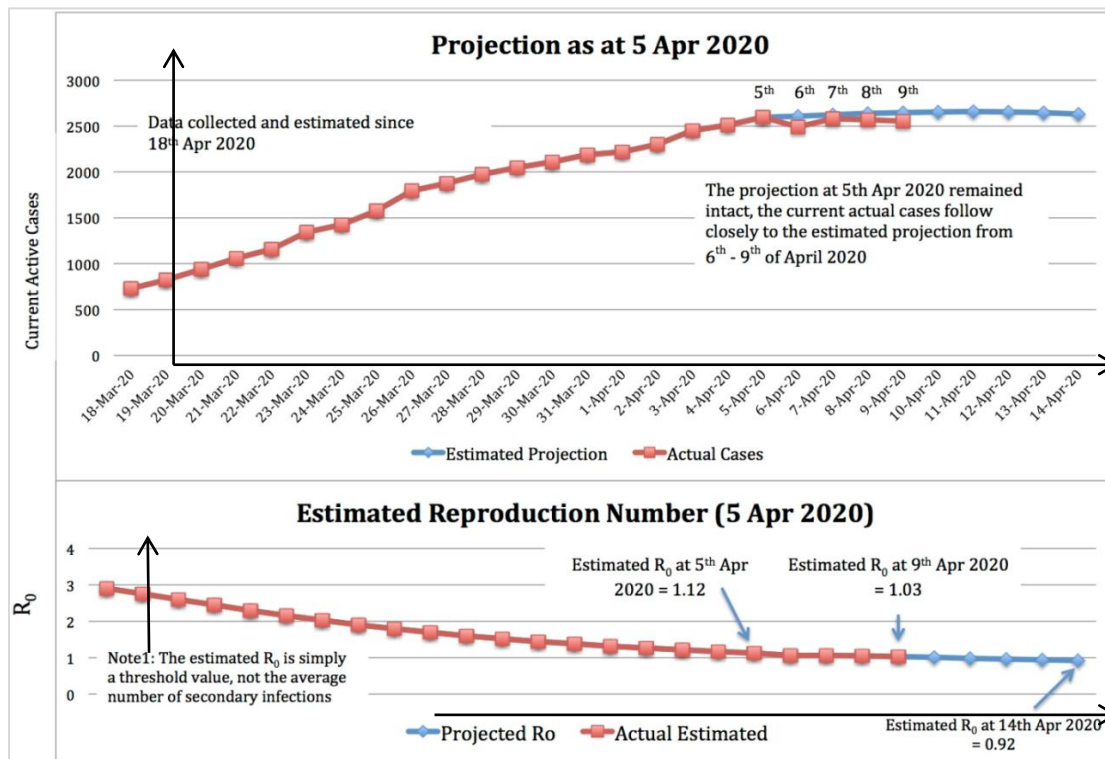


Figure 6 Third projection at 5th Apr 2020

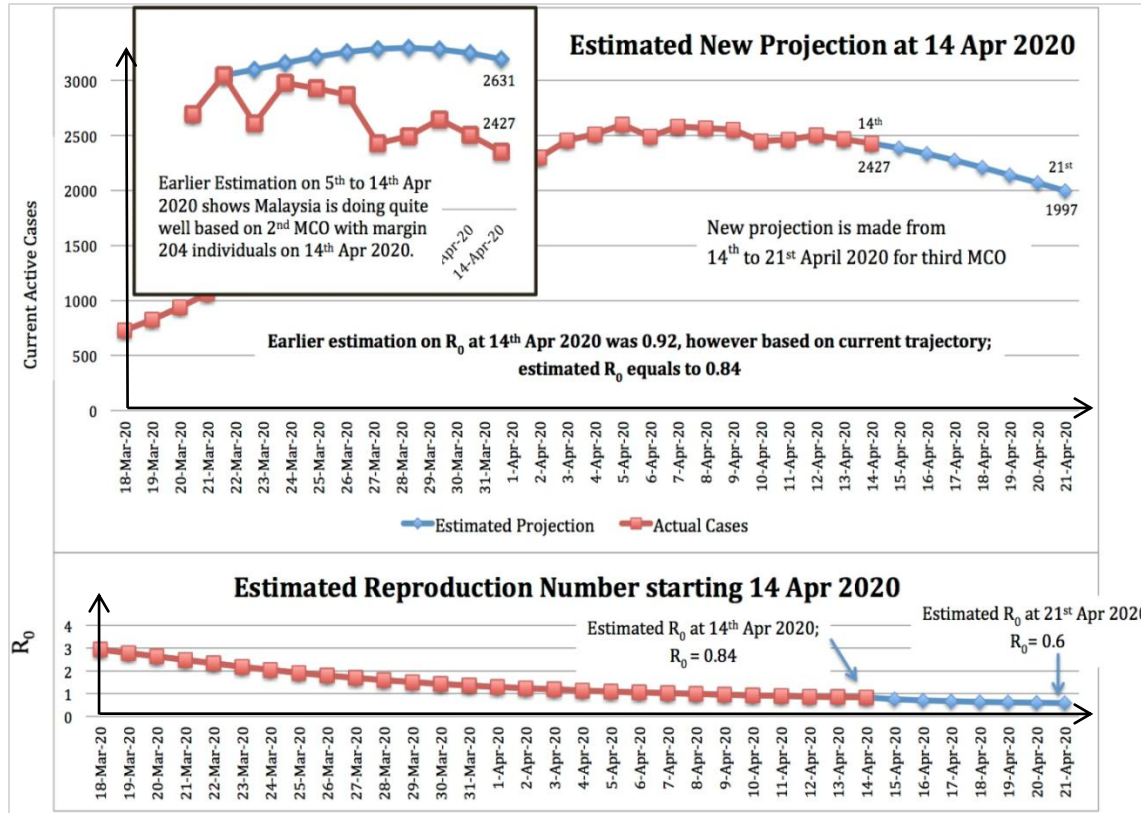


Figure 7 Fourth projection at 14th Apr 2020 under third MCO

Table 2 shows the fitting parameters for closed monitoring projection during the 1st and 2nd MCO. The SEIR parameters were set fixed, that obtained from China trend trajectory (referring to Table 1). Note that the ξ_r for second MCO shows significant higher numbers with approximately between 2.5 to 3.6 times higher than the first MCO. This shows that the early detection strategy under the EMCO carried out by the government have shown a very significant improvement.

Figure 8 shows the fitting results for the period of two months starting 15th Feb 2020 until 14th Feb 2020 under closed monitoring. The date on 15th Feb 2020 is the date of data available from [10], three days after the WHO announced that the 2019 novel coronavirus name change to COVID-19. The fitting shows successful results for the actual number of active cases and follows closely to the actual number of daily cases.

Table 2 Fitting parameters during MCO

SEIR Parameters (fixed)		$\rho = 0.00279; \hat{\sigma} = 0.48555; \hat{\gamma} = 0.24486;$			
Dates of Projection		α	k	θ	ξ_r
1 st MCO: 18 th – 31 st Mar 2020	22 nd Mar 2020	0.42632	0.000001	0.28654	3.49
	26 th Mar 2020	0.43036	6.4911E-06	0.26247	3.81
2 nd MCO: 1 st – 14 th Apr 2020	05 th Apr 2020	0.41808	0.002376	0.08848	11.30
	14 th Apr 2020	0.42232	0.00211	0.10074	9.93

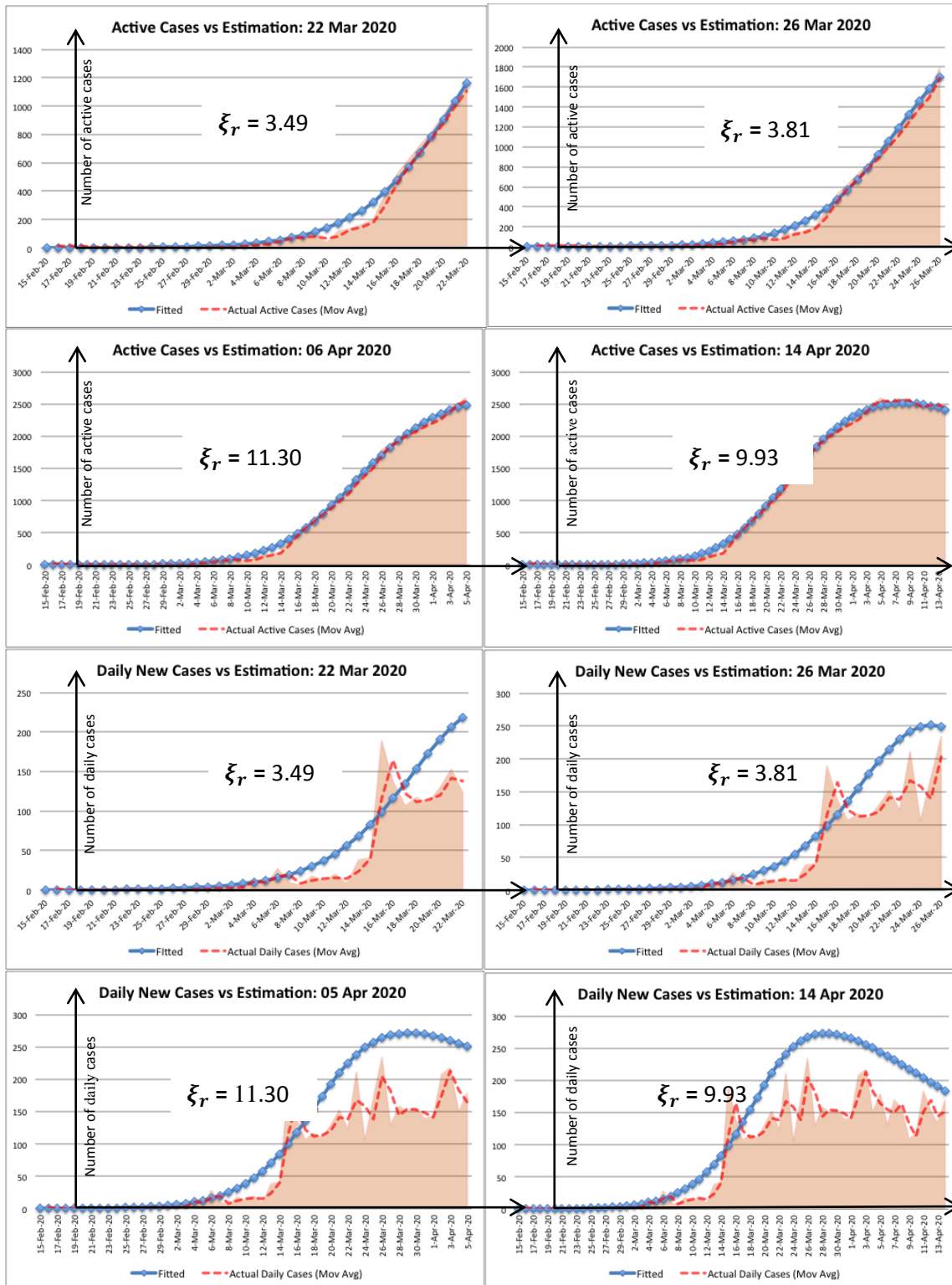


Figure 8 Fitting results with active cases and daily infected cases for the selected consecutive dates and its corresponding early test indicator

Figure 9 shows the probable full trajectory of COVID-19 until end of Jun 2020, updated on 20th Apr 2020, and Malaysia is currently following the best trajectory.

The full projection is based on several assumptions:

- The trajectory is based on the best and worst possible gradient at the peak number of active cases.
- The actual trajectory may or may not follow the best or the worst case. It depends on the current situation and assessments.

- The lines trajectory would be possible under the current control MCO and positive public response and reaction towards the order.
- The trajectory may be disrupted if at any time the MCO is loosening or retracted.

As listed in the items above, the limitation of the estimation and projection is clearly for higher number of days in estimation. The projection was unable to predict closely for more than two weeks. It is therefore consecutive and closed monitoring for few days would be able to estimate the projection quite accurately.

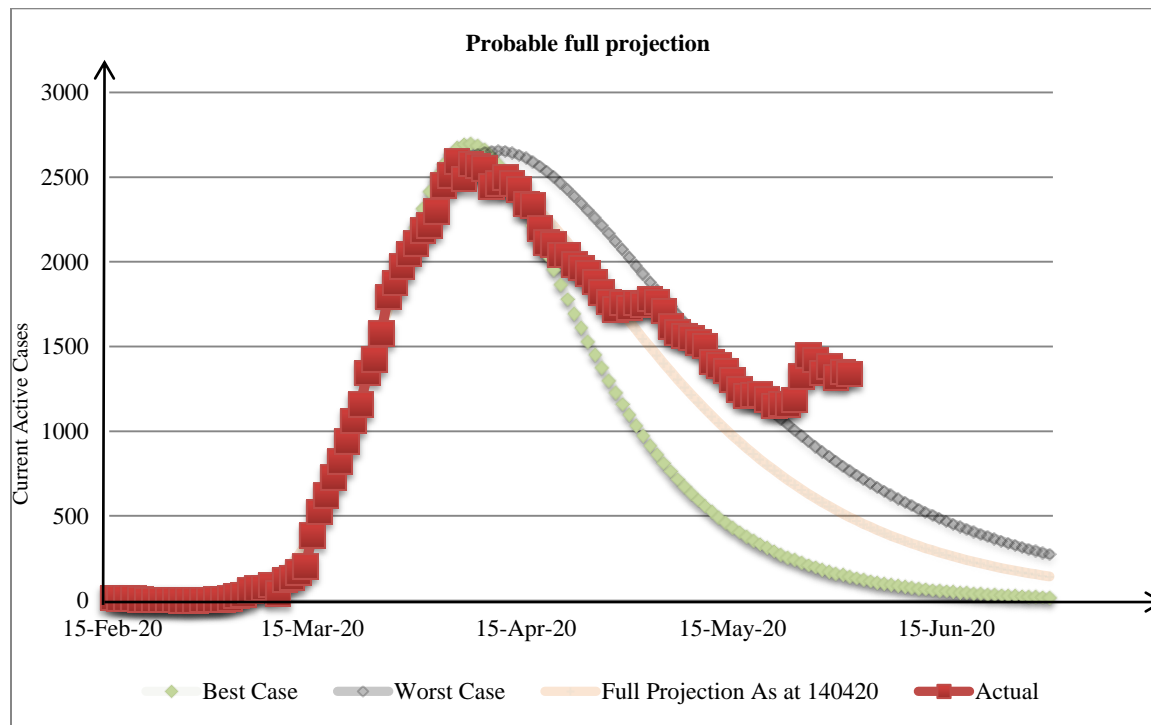


Figure 9 Probable full projection with current trend trajectory, updated 01st Jun 2020

5. Conclusion

This paper presents a closed monitoring of Malaysian COVID-19 using a modified SEIR compartmental model for first wave trajectory. The modified SEIR model has shown the capability in assisting and closed monitor the Malaysia COVID-19 trajectory, which proven in agreement to the Malaysian government MCO strategy. The model also suggested three parameter indicators, the enforcement strategy under MCO by the Malaysian government, the early detection strategy for COVID-19 of infected people and positive response and reaction from the public. This is in line with result taken and monitored for Malaysia COVID-19 trajectory. The implementation

of MCO by the Malaysian Government has proven to be effective in reducing the R0 consequently the number of active cases. The second MCO or EMCO is proven to be more effective than the first, which incorporates active screening detection for earlier isolation and treatment, which can be shown by the indicator parameter ξ_r higher under the EMCO. All these of course will not be succeeded if the government received poor response from the public, which will jeopardize the positive trend current trajectory. In conclusion, the strategies proven to be effective and in agreement to the suggested modified SEIR model presented. The future work of the model would be to incorporate the model with secondary infection for longer prediction projection. A

secondary infection is people who have already recovered and get infected again for second time. This in turn will have a higher chance to estimate the projection number more closely.

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Conflicts of interest

The authors have no conflicts of interest to declare.

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