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AN IMPROVED SIR MODEL FOR COVID-19 EPIDEMIC IN MALAYSIA

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ABSTRACT

This research study demonstrates a numerical model intended for comprehension the COVID-19 spread of the year 2020 by utilizing the improved SIR model. The paper focuses on deceased rates rather than confirmed cases. A model derived from the standard SIR epidemiological model including asymptomatic and hospitalized, is presented, but includes symptomatic and critical states as well, for better simulate real disease dynamics. A three-dimensional nonlinear differential equation is formulated and solved numerically utilizing the Runge-Kutta's method in MS excel. It appears from the research study that, by looking at the impact of varying people contact rates in populations shown that reducing contact rates by 50%, COVID-19 should be controllable to levels like the seasonal flu. It is additionally indicated numerically that the pandemic can be reduced to a less dangerous level when there are less infected people in contact in the populace.

Keywords: SIR model, COVID-19, epidemic, modeling.

1. INTRODUCTION

The world health organization declared the COVID-19 a pandemic on 11 March 2020 [1]. The epidemic has exploded worldwide with 1, 446, 981 cases and caused 83, 090 deaths by 8 April 2020 [2]. In Malaysia, the first case was reported on 25 January 2020 [3]. By 8 April 2020, Malaysia had reported 4,119 cases and 65 deaths [3].

The epidemic spread mainly depends on the infectivity of the pathogen and the available susceptible population. For a new infection, when disease dynamics are still unclear, the use of mathematical modelling can help estimates the number of cases in worst and simulate prevention steps on infection scenarios. The aim is to reduce the deceased rate and maintain the reproduction number below 0.1 to prevent further spread of infection. Some actions taken by the government to contain the epidemics such as social distancing, closure of schools, universities and offices, avoidance of mass gathering and movement control order, may be applied to the general population and the cases themselves [4].

Malaysia still considers in the early stages of the epidemic. It is vital to predicting exactly how the disease is probably evolving in the population. Examined the differences in COVID-19 spreading manner numerous countries, and planning for rising fresh response has to be adjustable to current circumstances. If the numbers of cases are relatively few, a mathematical simulation approach is appropriate for understanding this epidemic and simulated an appropriate response. Therefore, this work intended to construct an improved Susceptible (S), Infected (I) and Recovered, for the most part, called the SIR Model, as a mathematical model of the COVID-19 epidemic in Malaysia to simulate its infection magnitude, and assessing the impact on healthcare resources and population.

2. METHODOLOGY

2.1 The SIR Model

The Susceptible (S), Infected (I) and Recovered (R) model [5-7] is utilized as a part of the study of disease transmission to demonstrate the association between the number of individuals who are defenceless to an illness, the individuals who are present with the contamination and the individuals who have recouped or kicked the bucket at a given time in a populace. This can be demonstrated to schematically below:

Susceptible (S) $\rightarrow$ Infected (I) $\rightarrow$Recovered (R)

The sickness spread or outbreak is extreme; everyone who gets infected is expelled from the populace either through recuperation or demise. The people is extensive, altered in size, and it is restricted geologically.

From the suppositions, we can compose:

Susceptible (S) $\xrightarrow{\alpha}$Infected (I)$\xrightarrow{\beta}$Recovered (R).

In this model, two parameters α and β would be utilized to portray the transmission and recovery rate separately. The transmission shifts together as the defenceless and infective populace as the contamination relies on upon the connection between the vulnerable class and infective class [8, 9].

The infection rate of a disease is reliant on the death rate, M and the number of individuals who are helpless to the infection. This is the rate at which the ailment is transmitted from a tainted individual to a weak person. The transmission rate α always lies somewhere around 0 and 1. In this way, we have

$$\alpha = \frac{M}{S} \tag{1}$$

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The autonomous differential equations that use variables *S, I, R* is presented as follow:

$$\frac{dS}{dt} = -\alpha SI \quad (2)$$

$$\frac{dI}{dt} = \alpha SI - \beta I \quad (3)$$

$$\frac{dR}{dt} = \beta I \quad (4)$$

Combining equation (2), (3) and (4), we obtain $S(t) + I(t) + R(t) = N$, with N is the total size of the population. All the variables *S, I,* and *R* are bounded above by N [2]. Suppose that each infected individual has k number of contacts from the susceptible compartment per unit time; hence we have

$$\frac{kS}{N} \quad (5)$$

Furthermore, if there is contact made, this will result in the transmission of the disease, then each infected individual infects kzS/N individuals per unit time, with $\alpha = a/N$, where $a = kz$ and z is the transmissibility of infectious disease [10, 11].

2.2 The Improved SIR Model

For COVID-19, one of the challenges includes an asymptomatic contagious period. Through compartmentalizing that state, different contact rates can be explored. Many countries used isolation approaches for symptomatic individuals, which can affect the contact rate as well, which is also justifies a new compartment. This improved model focused on disease spread and lethality, as illustrated in Figure-1.

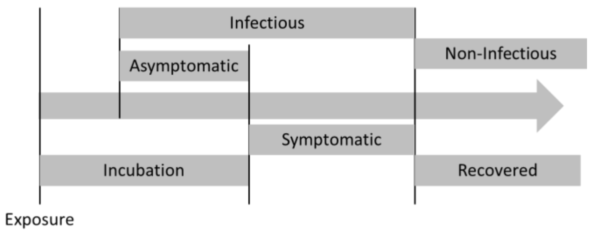

Figure-1. Timeline for COVID-19 infection.

This model (as in Figure-2) is given named as SASHCriDR, for Susceptible - Asymptomatic-Symptomatic-Hospitalized-Critical-Deceased-Recovered. The deceased compartment for merely assisting in tracking that trend.

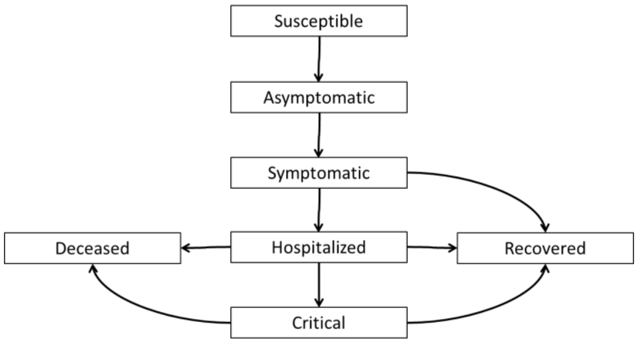

Figure-2. SASHCriDR model diagram.

The model has parameters such as:

- β: the contact rate represents the percentage of the susceptible infected per infected person per day.
- γ: The contagious rate represents the percentage of asymptomatic person, those who exposed and become infectious per day.
- ε: The symptomatic rate represents the percentage of asymptomatic person who begins to show symptoms per day.
- α: The hospitalized rate represents the percentage of the symptomatic contagious population that put into isolation per day.
- φ: The recovery rate represents the percentage of infectious person who recovers per day.
- ω: The deceased rate represents the percentage of an infected person who dies per day.

The model allows some rates to be different for the different compartments, e.g., the contact rate for the asymptomatic and symptomatic population may be different. Hence, the governing differential equations can be express as follows:

$$\frac{dS}{dt} = \Lambda - \mu S - \left(\beta_{S_y} S S_y + \beta_H SH + \beta_C SC\right) \quad (6)$$

$$\frac{dE_a}{dt} = \left(\beta_A S S_y + \beta_H SH + \beta_C SC\right) - \gamma E_a - \mu E_a \quad (7)$$

$$\frac{dS_y}{dt} = \gamma E_a - \varphi S_y - \omega_{S_y} S_y - \varepsilon S_y - \mu S_y \quad (8)$$

$$\frac{dH}{dt} = \varepsilon E_a + \varepsilon S_y - \varphi_H H - \omega_H H - \alpha H - \mu H \quad (9)$$

$$\frac{dC}{dt} = \alpha H - \varphi_C C - \omega_C C - \mu C \quad (10)$$

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$$\frac{dR}{dt} = \varphi_{E_a} E_a + \varphi_{S_y} S_y + \varphi_H H + \phi_C C - \mu R \tag{11}$$

$$\frac{dD}{dt} = \omega_{E_a} E_a + \omega_{S_y} S_y + \omega_H H + \omega_C C \tag{12}$$

The compartments are all normalized values for representing a proportion of the total population. When the birth rate Λ and the natural deceased rate μ are 0, then $S + E_a + S_y + H + C + D + R = 1$. In this model, it is assumed that the recovery rate is the same for all compartments ($\varphi_{S_y} = \varphi_H = \varphi_C$), the asymptomatic deceased rate is zero ($\omega_{E_a} = 0$), and that the contagious symptomatic, hospitalized and critical case deceased rates are equal ($\omega_{S_y} = \omega_H = \omega_C$).

3. RESULTS AND DISCUSSIONS

Simulation for the model is done via MS Excel to understand the model numerically and to plot the result of the simulation. Figures-3 show the simulation results for normal spreading in the population without the enforcement of Malaysia movement control order. From Figure-3, it was observed that the quantity of people susceptible to the COVID-19 disease remains high and the same for the initial 20 to 24 days. As these people come into contact with infected individuals and start to show symptom or side effects of the disease, they are taken into the hospitalized compartment. Nonetheless, as the disease is constant, there is an increase in hospitalized, critical and deceased individual after 24 days of infection begin. In Figure 4, the deceased rate keeps on increasing to about 34045 individuals at the end of 100 days simulation, while for hospitalized and critical, each gain the peak of 187083 individuals and 30029 individuals at day 50. Towards the end of the 100 days period, the hospitalized and critical individuals decrease while the deceased individual increases linearly. The same goes for those who recovered from COVID-19, begins to turn saturated at the curve when simulation goes near day 100.

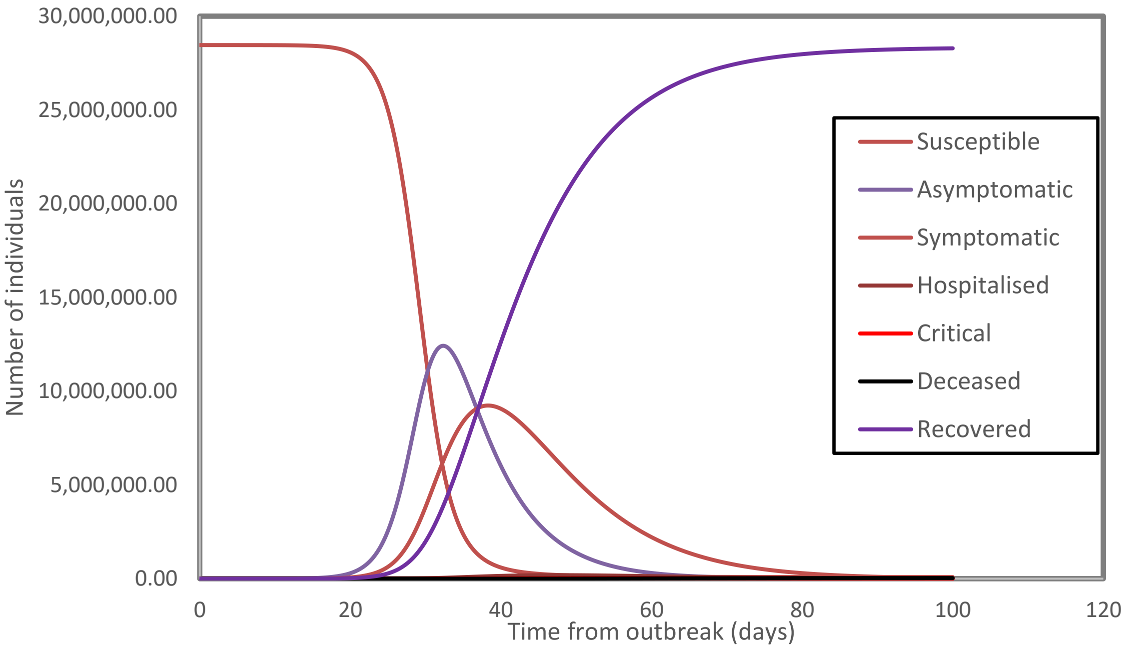

Figure-3. Simulation results for normal spreading in the population without the enforcement of MMCO.

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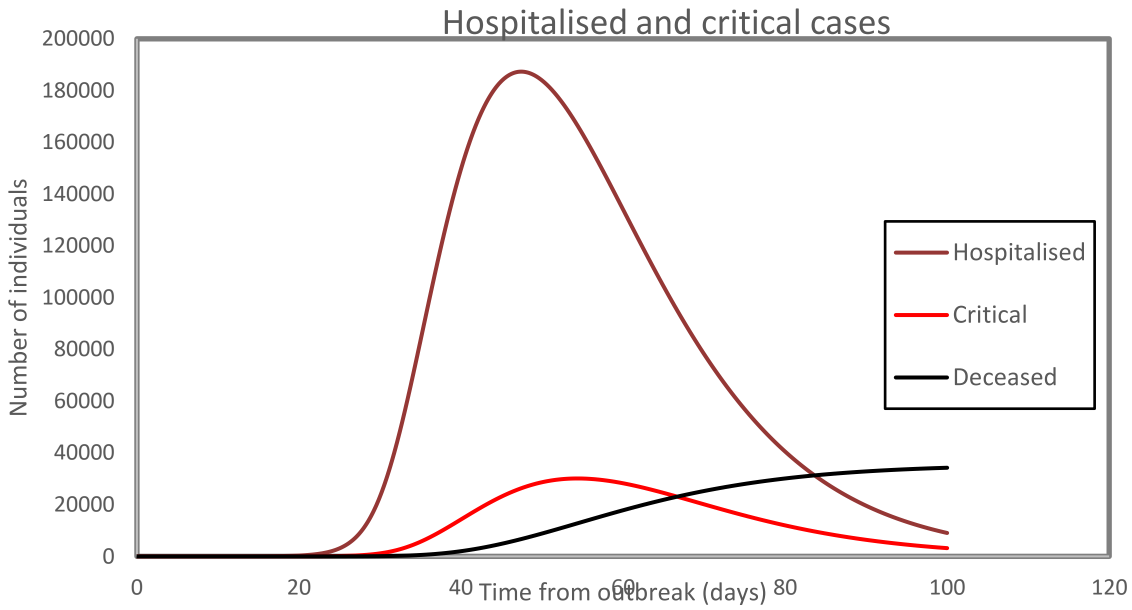

Figure-4. Simulation results hospitalized, critical and deceased individuals for normal spreading in the population without the enforcement of MMCO.

On the contrary, Figure-5 shows that the deceased decrease significantly after the government enforce the Malaysia movement control order (MMCO). Clearly, from Figure-5, the susceptible individuals reduce significantly during the MMCO period. This is due to less contact among individual in a public area such as school, workplace or shopping mall. Additionally, those who get infected recovered faster as they get better focus and healthcare from the hospital, which is less saturated with COVID-19 patients, hence the recovered individual increases in a short period of time. Obviously, once can notice a significant drop in any part such as asymptomatic, symptomatic and as well as the deceased rate. From Figure-6, notice that the hospitalized individuals drastically decreases from day 20 to day 30, which shows that less COVID-19 patients in hospital give space and extra time and equipment for use on other COVID-19 patients, that helps them recovers faster and reduce deceased rate. In Figure-6, it is estimated that the peak of the hospitalized individual is around 4432 individuals, while the critical is around 205 individuals and the deceased is around 228 individual at the end of 100 days simulation period. There is a significant decrease in the deceased individual during MMCO for about 98% compared to the simulation without MMCO.

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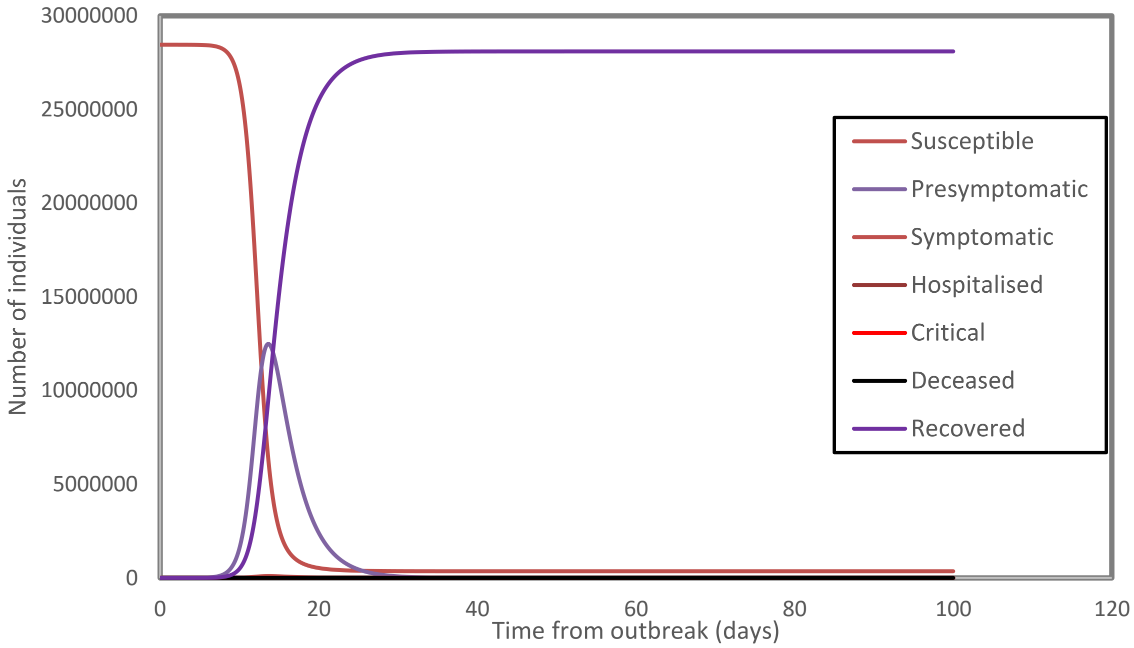

Figure-5. Simulation results with MMCO enforcement on COVID-19 spreading in the population.

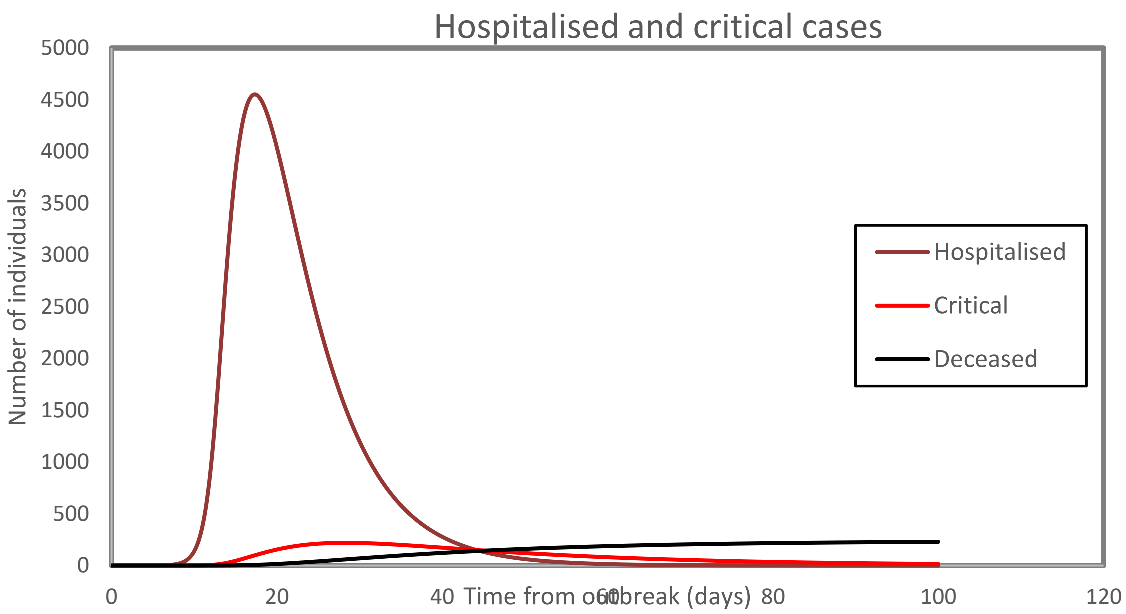

Figure-6. Simulation results with MMCO enforcement on COVID-19 spreading in population for hospitalized, critical and deceased individuals.

4. CONCLUSIONS

In this research study, the COVID-19 disease is modelled and considered utilizing the improved SIR model with added parameters. The non-linear frameworks of the differential mathematical statement were explained numerically utilizing the Runge-Kutta's method for simulating the infection time of 100 days using MS Excel. For effortlessness, Malaysia, as one of the countries that were hit incredibly by COVID-19 epidemic in March 2020 was utilized for this research study. As expressed before, modelling an infection dynamics requires that we research whether the infection spread could achieve a scourge level or it could be eradicated. The COVID-19 disease is spread to a great extent through contacts between an infected individual and a non-infected individual. Infected individuals cannot be altogether isolated from whatever is left of the vast populace. The partition must be done when an affected individual visits a healthcare centre.

Conversely, public health specialists can keep the disease from forming into an epidemic by decreasing $S(0)$ by offering medical care and healthcare equipment to the individuals who are vulnerable to the infection. The contact rate can be decreased independently from anyone else confinement of powerless people furthermore the transmissibility can be lessened by empowering the washing of hands and the utilization of hand sanitizers. The enforcement of MMCO also helps significantly in preventing the spread of COVID-19 by decreasing the public contact rate.

Considering past worldwide healthcare crisis such as in 2009 Influenza pandemic, the SARS scourge, the 2014 Ebola episode and others, mathematical models are crucial and important to gauge the typical aggregate number of diseases and toward the end of such episodes. A certainty is that a convenient identification of an outbreak stays of central significance in controlling the spread of the COVID-19 disease and other infections.

Modelling the event of the COVID-19 epidemic outbreak numerically can help the researcher and healthcare centre to analyze the epidemics and prevent further outbreaks which may be deadly later on. The general pattern of the epidemic has been introduced, and this can be changed to represent different parameters for better understanding and to examine future outbreaks.

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