THE IMPACT OF COVID-19 NON-PHARMACEUTICAL INTERVENTIONS (NPIs) IN MALAYSIA

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By

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WHO	World Health Organisation
MOH	Ministry of Health
NPIs	Non-Pharmaceutical Interventions
MCO	Movement Control Order
R_0	Basic reproductive number
R_t	Time-varying reproductive number
SOP	Standard Operating Procedure
CDC	Centre for Disease Control

ABSTRAK

KEBERKESANAN INTERVENSI BUKAN FARMASEUTIKAL COVID-19 DI MALAYSIA

***Latar belakang*:** Pertubuhan Kesihatan Sedunia (WHO) telah mengisytiharkan penyakit COVID-19 sebagai pandemik pada 11 Mac 2020. Pada peringkat awal, langkah-langkah bukan farmaseutikal (NPIs) seperti sekatan pergerakan, penjaran fizikal dan arahan kuarantin telah diperkenalkan bagi mengawal penularan COVID-19. Malaysia juga telah memperkenalkan pelbagai fasa Perintah Kawalan Pergerakan (PKP) sebagai salah satu komponen utama bagi NPIs bagi menangani pandemik ini.

Objektif: Kajian ini adalah bertujuan untuk menilai hubungkait antara intervensi bukan pharmaseutikal dengan penulan COVID-19 di Malaysia.

***Metodologi*:** Kajian ini adalah sebuah kajian analisa masa bersiri yang menggunakan data sekunder daripada Kementerian Kesihatan Malaysia (KKM). Kes insiden harian COVID-19 telah direkod dan dipindahkan ke perisian statistik R. Jumlah kes insiden dan kadar insiden bulanan telah dihitung bagi Malaysia dan semua negeri. Data populasi Malaysia yang terkini telah dimuat turun dari laman sesawang rasmi Jabatan Perangkaan Malaysia. Di samping itu, kami menggunakan pakej 'EpiEstim' bagi mengira anggaran nilai *time-varying reproductive number* (R_t) dan menjana keluk epidemik. Akhir sekali, kami mengira anggaran nilai R_t secara keseluruhan dan menganalisa nilai R_t berdasarkan tempoh PKP bagi Malaysia dan beberapa buah negeri.

***Keputusan*:** Malaysia telah mencatatkan sejumlah 3236 kes baharu COVID-19 dalam pertengahan bulan Mac 2020 berikutan sebuah perhimpunan keagamaan yang besar yang telah diadakan di Petaling Jaya, Selangor diikuti dengan satu lagi peningkatan pada awal September 2020 akibat daripada tercetusnya sebuah kluster selepas Pilihanraya Negeri di Sabah. Dalam pada masa yang sama juga, kami menghitung purata nilai R_t pada hari pertama bagi setiap fasa PKP dan membuat perbandingan. Didapati bahawa nilai R_t secara keseluruhan mencatatkan penurunan dalam julat antara 0.542(0.440, 0.656) dan 1.443 (1.213, 1.693).

***Kesimpulan*:** Walaupun dengan ketiadaan vaksin, NPIs telah dilihat sebagai langkah dan strategi yang ampuh dalam mengawal penularan jangkitan COVID-19 di Malaysia dalam menurunkan nilai R_t ke tahap bawah nilai ambang satu dan seterusnya mengekang pandemik COVID-19 ini.

***Kata kunci*:** COVID-19, langkah-langkah bukan farmaseutikal (NPIs), *time-varying reproductive number* (R_t)

ABSTRACT

THE IMPACT OF COVID-19 NON-PHARMACEUTICAL INTERVENTIONS IN MALAYSIA

Background: World Health Organisation (WHO) has declared a COVID-19 pandemic on the 11th of March 2020. During the early phase, many countries implement non-pharmaceutical interventions (NPIs) such as movement restriction, physical distancing, and quarantine to control the COVID-19 disease transmission. Malaysia, for example, has introduced various phases of movement control order (MCO) as one of the measures for combating the pandemic.

***Objectives*:** To measure the relationship between non-pharmaceutical interventions (NPIs) and confirmed COVID-19 cases transmission in Malaysia.

***Methodology*:** This is a time-series analysis study using secondary data from the Ministry of Health (MOH) Malaysia. Daily confirmed COVID-19 incidence data were captured and analysed using R software. We calculated the monthly incidence and incidence rate for Malaysia and all states. The latest population data for Malaysia was taken from the official Department of Statistics Malaysia (DOSM) website. We used the EpiEstim package to estimate the time-varying reproductive number (R_t) and plot the epidemic curves. Finally, we calculated the overall Rt value and analysed the Rt value related to the MCO for Malaysia and the states.

***Result*:** Malaysia has recorded 3236 confirmed COVID-19 cases in the middle of March 2020 following a religious gathering in Petaling Jaya, Selangor, followed by

other spikes seen in early September 2020 due to another cluster related to State Election in Sabah. On the other hand, we calculated the R_t value and extracted the mean R_t value at Day 1 of each four phases of MCO and compared it. The R_t value showed an overall decrease in trend ranging from 0.542(95% CI: 0.440, 0.656) and 1.443 (95% CI: 1.213, 1.693).

***Conclusion*:** In the absence of vaccines, non-pharmaceutical interventions (NPIs) are proven to be the best approach for Malaysia to bring down the time-varying reproductive number (Rt) below the threshold value and to curb the COVID-19 pandemic.

CHAPTER 1

INTRODUCTION

1.1 Background of the study

In late December 2019, the world population was shocked by the newly emerging Coronavirus known a COVID-19 which originated from Wuhan, a small city located in Hubei Province in China. Initially, the respiratory cluster was epidemiologically linked to a wet seafood market in Wuhan. However, many of the initial 41 cases reported denied the causal relationships (Zhu *et al*., 2020). Mediated by unrestricted air travel during the early phase, this virus has been spread worldwide in just two months and infected many people. This situation has worsened over time and, in turn, forcing the World Health Organisation (WHO) to declare the current global pandemic event on the 11th of March 2020 (Cucinotta and Vanelli, 2020). All countries in the world have been alerted and started to strengthen their strategies and preparedness to prevent the spreading of this deadly virus. Despite that, there was very much lacking information regarding the characteristics, mode of transmission, and how far the virus could bring to the nations and their people. Such an immediate action must be taken immediately in a very limited amount of time without any delay.

Coronavirus is derived from a Latin word called 'corona,' which means a crown. For years, it has caused multiple human respiratory tract diseases ranging from a mild cold to severe respiratory diseases (Weiss and Navas-Martin, 2005). The present Coronavirus variant that causes the current global threat is Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) or COVID-19. Back in the previous ages,

Coronavirus was associated with various illness levels has caused few global pandemic episodes such as Severe Acute Respiratory Syndrome (SARS) in 2002 and Middle East Respiratory Syndrome (MERS) in 2012 (Cheng *et al*., 2007). Morphologically, Coronavirus is the most giant known enveloped positive single-stranded Ribonucleic acid (RNA) virus, with a size of 8.4 – 12kDa in size. The virus contains five structural proteins, known as the spike protein (S), an envelope protein (E), membrane protein (M), nucleocapsid protein (N), and haemagglutinin-esterase protein (HE). The E protein is the smallest among all proteins and is highly expressed within the infected cell during the viral replication cycle (Van Der Hoek *et al.,* 2004).

There are few similarities between COVID-19 and older SARS and MERS in terms of transmission and harboring animals as the intermediate host before being acquired by humans. SARS was initially (2002) reported in Guangdong province, China. Later the source was investigated and found to be originated from a wet market in Guandong, China (Cheng et al., 2007). It has caused a massive global public health issue after spreading to almost 30 countries and infected around 79000 people with a mortality rate of 9.5 %.

1.2 COVID-19 non-pharmaceutical interventions (NPIs) in Malaysia

Malaysia also is not exempted from facing the impact of the pandemic. In the early phase of the pandemic, Malaysia reported its first case of confirmed COVID-19 involving a group of tourists from China on the 25th of January 2020. They were screened after arrival at Malaysia via Kuala Lumpur International Airport (KLIA), tested positive for COVID-19, and were put in isolation (Azlan *et al.,* 2020). The situation worsened around mid-April when Malaysia's COVID-19 cumulative cases

surpassed 5000 with more than 80 mortalities. A massive religious gathering known as ‘Tabligh cluster’ in Petaling Jaya, Selangor, attended by about 16000 participants, including 1500 foreigners from 25 different countries, has contributed to 55% of the total reported cases up to the date.

Plus, a detailed investigation has shown that the cluster has reached up to the fifth generation of infection. Due to the rapid increment of the cases, the Malaysian government introduced the Movement Control Order (MCO) on the 18th of March 2020 as one of the non-pharmaceutical interventions (NPIs) to control and mitigate the transmission of COVID-19 disease. The major component of NPIs implemented in Malaysia is the Movement Control Order (MCO). MCO was enforced under the Prevention and Control of Infectious Diseases Act 1988 (Act 342) and the Police Act 1967. Anyone violating the law will be fined not more than RM1000 or jailed for not more than six. All Malaysians need to stay at their home during the MCO period except those working in vital sectors and for essential purposes such as seeking medical treatment and buying groceries for the family members.

Other restrictions include the prohibition of mass gathering, closure of all factories, institutions, and facilities except primary essential services like healthcare, utilities, and security forces. Table 1.1 as below summarizes the details regarding the movement restrictions:

Table 1.1: Phases of MCO with details of NPIs

Phase	Details of NPIs
MCO phase 1 to phase 4	i. Total prohibition of movement and mass gathering nationwide, including religious activities, sports, social and cultural events. ii. For enforcement purposes, all worship places, business premises need to be closed except for hypermarkets, public markets, and groceries. Suspension of all religious activities in mosques, including Friday prayer. iii. Restriction for Malaysians to travel abroad. For travelers who are returning from abroad, they need to undergo health screening and voluntary self-quarantine for 14 days. iv. Restriction for all tourists and visitors from entering the country. v. Closure of all kindergartens, public and private schools, boarding schools, international schools, tahfiz centers, and other lower and middle learning institutions and pre-university. vi. Closure of public and private higher learning institutions and Technical and Vocational Education and Training Institute nationwide. vii. Closure of all public and private sectors except for essential services such as water, electricity, energy, telecommunication, courier, transportation, water and irrigation, oil & gas, fuel & lubricants, broadcasting, financial, banking, healthcare, pharmacy, fire and rescue, prison, seaport & airport, security, defense, cleaning services, groceries, and food supply.
CMCO	i. Closure of international border and prohibition of international travelling . ii. Prohibition of any entertainment and recreational activities, including cinema, theme park, and museum. iii. Prohibition of all types of gathering, including festival ceremonies and religious activities. iv. Prohibition of any conference and exhibition. v. Restriction of interstate travelling.

Table 1.1, Continued

Phase	Details of NPIs
RMCO	i. Closure of international border and prohibition of international travelling. ii. Prohibition of any sports event organisations. iii. Prohibition of contact sports. iv. Closure of waterparks. v. Closure of public swimming pool. vi. Restriction of Malaysians for travelling abroad and for foreign tourists to enter the country. vii. Closure of karaoke centers, indoor children's playground in the shopping mall. viii. Closure of pubs and nightclubs. ix. Closure of reflexology centre. x. Prohibition of ship cruising. xi. Prohibition of any activities that are prone to large gatherings with no possible social distancing

There are four phases of MCO in Malaysia, namely MCO phase 1, MCO phase 2, MCO phase 3, and MCO phase 4, which later proceeded with Conditional MCO (CMCO), and Recovery MCO (RMCO). MCO phase 1 started on the 18th of March 2020 until the 31st of March 2020, MCO phase 2 continued on the 1st of April 2020 until the 14th of April 2020, MCO phase 3 began from the 15th of April 2020 until the 28th of April, and the last phase (MCO phase 4) continued from the 29th of April until the 3rd of May 2020. As the stages going on, the government also announced a more relaxed movement restriction and opened more economic sectors to allow the

industries to continue their operation. CMCO started from the 4th of May 2020 until the 9th of June 2020, flowing a satisfactory risk assessment by the Ministry of Health. Most citizens were allowed to return to work with strict compliance to SOP like mandatory temperature screening and facemask, maintaining physical distancing at the workplace of at least one metre, and reduced capacity of permitted workers in an office. Adjustment needed to be done by the Head of Department to ensure that minimum workers were in the office area while the others continued working from home. RMCO, on the other hand, was introduced to supersede CMCO by mainly focusing on the reconstruction of the economy again. RMCO began on the 10th of June 2020 until the 31st of December 2020. Almost all the social, educational, religious, and economic sectors will resume their operation. Interstate travel also was allowed for casual and tourism purposes (NST, 2020). Apart from that, Enhanced MCO (EMCO) and targeted EMCO (TEMCO) were additional measures taken to curb any extraordinary surge in COVD-19 cases in specific localities and regions. The health authorities will conduct a mass COVID-19 screening involving the whole residence in the EMCO / TEMCO areas to determine the local infection rate for quick control and mitigation strategies. No movement in to or out of the EMCO / TEMPO areas was allowed for two weeks.

Furthermore, the government has introduced various up-to-date standard operating procedures (SOP) and regulations to educate citizens about new norms and ensure a high compliance rate through the National Security Council. Security forces such as Royal Malaysia Police and Royal Malaysian Army will come down to the communities and public areas for patrolling and monitoring the situation. As part of technology advancement, the government has developed an artificial intelligence (AI) based application known as MySejahtera for more accessible tracking history of

movements among the citizens within the country in case of any new cluster or outbreak. Additionally, the app's user will be continuously notified about the nearby cases within one kilometre radius for self-warning. Multiple media platforms, especially radios and televisions, keep broadcasting the health promotion messages, reminding people about the COVID-19 hazards, and updating the communities regarding the current update and situations. Plus, all premises allowed to operate during the MCO must provide temperature screening tools, hand sanitizer, MySejahtera two-dimensional code for entry and exit records, and limiting the number of visitors at a specific time to prevent overcrowding.

1.3 Reproductive Number (R_0 and R_t)

Basic Reproductive number represents the new number of secondary cases estimated to be generated from a single case in a population who have never been immunised before and are fully susceptible to the disease. It serves as a fundamental indicator in visualizing the dynamic of communicable disease at the beginning. Malaysia has implemented various methods of NPIs and constantly measures the favorable effect of these measures and is evaluated accordingly for any essential adjustment.

For this purpose, time-varying reproductive number (R_t) is used instead of R_0 because it is more reliable for a partially susceptible population and to access the current situation. Ideal estimating of R_t needs an exact documented generation time between the infector and infectee. However, this generation time is difficult to establish between the infected pairs because of resource limitations and the dynamic of the disease. Surveillance systems are only able to capture the incidence of symptoms instead of the incidence of infection. Thus, R_t depicts the delayed dynamic

transmission because of associated time lag, which could die to incubation period and delayed reporting (Lim *et al.*, 2020). As for the alternative, a serial interval is used in the estimation of R_t in this study. The serial interval can be defined as the time between the onset of a symptom of the infector (primary case) and the infectee (secondary case). Du *et al.* (2020) estimate that a mean serial interval for COVID-19 of 3.96 (95% CI 3.53–4.39) days, with an SD of 4.75 (95% CI 4.46–5.07) for COVID-19 transmission reported in China mainland excluding Hubei Province. Another study finding showed that serial interval is proportionally related to isolation time. Early isolation time contributes to shorter serial interval time [mean: 3.3 (2.7, 3.8) days; SD: 4.5 (4.1, 4.9) days] (Ali *et al.*, 2020).

1.4 Problem Statement

The Government of Malaysia has introduced various control programs for combating the COVID-19 pandemic. One of the significant steps taken was implementing the non-pharmaceutical interventions (NPIs) across the country. Apart from that, there was also the closure of all international borders and public places, work from home policy, and many more. However, the impact of these control programs is not thoroughly studied in terms of the effectiveness and to identify any gap for improvement for a better future outcome.

1.5 Rationale of Study

This study provides the objective measures of the impact of non-pharmaceutical interventions (NPIs) in Malaysia. This will benefit the policymaker from the Ministry of Health and National Security Council to quantify the overall effect of the NPIs

programs. Apart from that, it also can show the impact of NPIs at different states and different measures of COVID-19 transmission at different periods of movement control order (MCO). Later, the findings will also help the related stakeholders make better decisions and improve the current COVID-19 control strategies.

1.6 Research Questions

1. What is the overall trend of new confirmed COVID-19 cases in Malaysia from March 2020 until December 2020?
2. What is the trend of new confirmed COVID-19 cases at different MCO periods?
3. What are the overall effects of NPIs on time-varying reproductive number (R_t) for Malaysia and states?
4. What are the effects of NPIs on time-varying reproductive number (R_t) at different phases of MCO?

1.7 Research Objectives

1.7.1 General objective

To measure the relationship between non-pharmaceutical interventions (NPIs) and confirmed COVID-19 transmission in Malaysia based on data from March 2020 until December 2020.

1.7.2 Specific objectives

1. To assess the overall trend of new confirmed cases of COVID-19 in Malaysia.

2. To identify the trend of new confirmed cases of COVID-19 at different phases of MCO, CMCO, and RMCO.
3. To estimate the overall effect of NPIs on time-varying reproductive number (R_t) for Malaysia and states.
4. To estimate the effect of NPIs on the time-varying effective reproduction number (Rt) at different phases of MCO.

CHAPTER 2

LITERATURE REVIEW

2.1 Non-pharmaceutical interventions

Non-pharmacological interventions (NPIs) are not a relatively new method of prevention of infectious disease. Historically, NPIs have been practiced in few episodes of pandemics worldwide, such as during the plague and the infamous Spanish influenza outbreak in 1918. Back in 1348, during the plague outbreak, the concept of quarantine had been used. The authorities had ordered those who had contracted the disease to be taken out of the city to prevent them from infecting other susceptible individuals (Alimohamadi *et al.,* 2020). About a century later, a most deadly contagious disease pandemic has struck the world's population, knows as 'Spanish flu.' The disease spread so fast through soldier mobilisation across the globe and resulted in nearly 100 million death tolls across big continents worldwide. The culprit was a newly emerging virus without much knowledge about the transmission mode, pathophysiology, and unfortunate effect that it can cause. (Markel *et al.*, 2007) reported that, in the United States, cities such as New York that reacted early towards the flu pandemic by mounting a rigidly enforced application of mandatory quarantine and isolation measures had shown a longer time to reach peak mortality and lower number of deaths. However, the advantages of these interventions were unequally distributed. Those cities acting relatively early in layered strategies appeared to experience the most benefits in mitigating the disease spread.

In the current situation, the World Health Organisation (WHO) has recommended NPIs in facing the worsening threat of COVID-19 pandemics. Various components of NPIs, including hand hygiene, face mask application, quarantine, and isolation, are encouraged depending on the severity of the disease in particular countries or states. A bigger scale of NPIs such as travel restrictions, especially by air mode, closure of schools, and premises can be enforced if necessary (WHO, 2019). A study in China reported that a combination of NPIs usage might interrupt the disease transmission up to 67-fold (interquartile range 44–94-fold). The findings also showed that practicing social distancing can prevent a surging number of cases, although without travel restriction enforcement. (Chowdhury *et al.,* 2020) states that in a study conducted across 16 different countries globally, assuming a basic reproductive number of 2.2, by systematically applying NPIs, it can bring down the mean reproductive number from 0.8 to 0.5, with little effect over the intensive care unit hospitalization rate. Also recommended for low-income countries to practice social distancing periodically for giving time for proper development of clinical measures and prevention and minimizing economic impact. Meanwhile, to lift the restriction and associated lockdown within five-month times, the best way suggested could be the combination of weekly universal testing, facemask application, and contact tracing with concurrent lockdown (Goscé *et al.,* 2020)

2.1.1 *Movement Restriction*

Few countries like Italy and China have imposed a bigger-scale ‘community-wide containment’ or ‘lockdown’ where regular NPIs measures seem insufficient to contain the infection dynamic. Lockdown is an intervention applied to a particular community or region to minimize people's movements into and out of the infected

area. In a practical setting, lockdown can be a partial or total lockdown. Most industries are forced to temporarily shut down their services except for essential services like health sectors, security forces, and food markets. (Wilder-Smith and Freedman, 2020) mentions in his report that during such community-wide containment, people are encouraged to use the social media platform wisely to communicate regular updates and health advice and prevent fake information from circulating, creating unnecessary panic situations. Further, the author also stressed about firm partnership and cooperation between the legal authorities and local administrations to ensure a high compliance rate within the community and possible legal fines and penalties to those who violate the restriction order.

A national-level lockdown can prevent immigrants from entering the country through international borders using air travel or land transports. A study in China during the early days of the pandemic comparing the correlation between confirmed cases of COVID-19 to the domestic air travellers before and after the containment period showing a substantial reduction from ($r=0.98$, $r2=0.97$, $p<.05$) to ($r=0.91$, $r2=0.83$, $p=NS$). This is further supported by the increase in doubling time of COVID-19 cases from two days (1.9, 95% CI:1.4-2.6) to four days (3.9, 95% CI:3.5-4.3) because of the lockdown effect (Lau *et al.*, 2021). However, despite the successful outcome observed by the lockdown intervention in China, more attention needs to be given to the numerous new and rapidly growing epicentres outside of China to retard the COVID-19 progression. The level of seriousness in tackling these growing issues and the degree of transparency in reporting the new cases may vary from country to country (Lau *et al.*, 2021). On the other occasion, Linka *et al.* (2020) also reported a similar study result where travel restriction has contributed to the delay of the disease spread in many European countries. For instance, Austria has called off almost 95%

of its flight schedule, which subsequently reduced the number of new cases reported to a current fraction of 10% of its all-time high for the past three weeks.

2.1.2 Quarantine and isolation

Quarantine is considered one of the most effective ways of controlling the spread of communicable diseases. It involves separating the healthy individual who has been exposed to a contagious disease so that if they become infected, they will have no chance of infecting other persons. During ancient times, the Italian government issued quarantine orders to a ship arriving at the Venice port from a plague-infected port. The ship had to anchor and waited for 40 days for the incubation period to get over before the exposed passengers were confirmed to be disease-free and asymptomatic (Wilder-Smith and Freedman, 2020). Another example was during the SARS outbreak in 2003. In Taiwan, all travellers coming back from an area infected with SARS were subjected to a mandatory quarantine order for ten days and stratified further according to their risks. The intervention was revised later after much information about the SARS virus transmission mode and behaviour had become available, including permission for self-isolation at home (Cetron and Simone, 2004). In general, quarantine can be voluntary or mandatory by the authorities. People under quarantine orders should be monitored for any symptom onset. Once they develop any symptoms particular to the disease, they should be immediately isolated into a designated treatment centre. Ideally, quarantine should work very well in the setting where case detection and associated contacts can be identified in a quick time manner (Wilder-Smith and Freedman, 2020).

On the other hand, isolation works oppositely. We define isolation as the separation of infected persons from the community to protect the healthy one. An

isolation room should be installed with negative pressure equipment for proper ventilation. Despite that, isolation of influenza patients is always delayed because patients can already become infected before the onset of symptoms, which has caused ineffective breaking down the transmission (Okunade, 2018).

According to World Health Organisation (WHO), few considerations need to be taken prior to quarantine the contacts of COVID-19 cases. It is vital to ensure understanding among the people through effective communications on the absolute requirement and appropriate support. Authorities should provide clear, transparent guidance and should engage in a constructive relationship with communities. Besides that, quarantined people should have access to healthcare services, necessities, and financial and psychosocial support. In this current COVID-19 outbreak, WHO recommends that all contacts to confirm COVID-19 cases should be quarantined for at most 14 days from the last date of exposure (WHO, 2020). This is supported by a study recruiting 181 confirmed COVID-19 in China that showed the median incubation period for the virus is 5.1 days and expect that nearly all the infected people will manifest their symptoms within 12 days of infection (Lauer *et al.,* 2020).

2.1.3 Physical distancing

Physical distancing is an essential part of NPIs for controlling the spread of infectious diseases like COVID-19. Keeping oneself away from symptomatic individuals and avoiding large groups or gatherings can reduce the direct transmission of COVID-19. This could be a tremendous challenged due to regional cultural and religious practice. Muslims mainly used to perform congregation prayer will be much affected with this new norm practice. The currently practiced rules that stipulate a

specific physical distance (1 or 2 metres) between individuals are based on the outdated universal framework of respiratory droplet size. The size of the droplets will determine how far it travels (Jones *et al.,* 2020).

Meanwhile, a disease transmitted via airborne, such as measles, can travel further in concentrated clouds and requires extended physical distancing (Bourouiba, 2020). A meta-analysis study involving 172 observational studies across 16 countries and six continents found out that practicing a physical distancing of one metre or more successfully decrease the transmission of the virus, compared to less than one metre (pooled adjusted odds ratio 0·18, 95% CI 0·09 to 0·38). This will further lower with the combination use of facemask and respirator (Chu *et al.,* 2020). Physical distancing can be applied at crowded places, communities, and workplaces. If not possible, reduction of the occupants and shift working system may benefit. Only small proportions are allowed to present themselves at the workplace while other workers continue doing their tasks from home. In their study, Ahmad *et al.* (2018) concluded that physical distancing at the workplace and other NPIs showed a median decline of 75% in the influenza attack rate in the general population.

2.2 Measuring transmission of disease

Globally, infectious diseases significantly impact the public health system by controlling and mitigating the transmission and spread of the diseases. For example, in 2013, infectious disease has caused over 9 million mortalities and 45 million years lost due to disability (Naghavi *et al.,* 2015). Nowadays, contagious diseases also include emerging infectious diseases such as Middle East Respiratory Syndrome (MERS) and Coronavirus 2019 (COVID-19). Infectious diseases are transmitted from

an infected person, animal, or contaminated object to another susceptible host, and it also involves the role of agent, host, and environmental factors. Therefore, the ability to measure the transmission of the infectious disease in terms of magnitude and transmissibility rate can significantly impact planning, controlling, and mitigating the outbreak and construct mathematical modelling for predicting future attacks or resolution. A commonly used indicator by most epidemiologists around the world is the disease reproductive number (R).

2.2.1 Trend

In descriptive epidemiology, we use a few parameters or indicators such as prevalence, incidence, and incidence rate to describe the epidemiological background and determine the disease's trend and progression. However, in communicable or infectious diseases, incidence and incidence rate are the more preferred indicators. According to the CDC definition, the incidence is the occurrence of new cases in a population over a specific period. In contrast, incidence rate or attack rate refers to the proportion of new disease cases diagnosed in an initially disease-free population at a specified time interval over population at risk at a specific time interval and usually expressed in per unit population of 10,000 population or more (CDC, 2020). Both indicators help provide information regarding the growing epidemic. However, the incidence rate is a more accurate way of telling the actual burden of the disease in a community and serving input data in optimising resource allocations.

Besides that, incidence also is vital in measuring the trend of the disease. Plotting the incidences over a unit of time can generate an informative epidemic curve. An epidemic curve is a histogram that can easily conclude a timely distribution of the

diseases Information such as the size of the outbreak, the pattern of spread, time trend, outlier, and incubation period of the disease. Commonly identified spread patterns from an epidemic curve are a point source, continuous common source, propagated source, and intermittent sources. All these patterns can give a general idea to the epidemiologist about the behaviors and characteristics of the disease (BMJ, 2020)

2.2.2 Reproductive numbers

Apart from that, epidemiologists use advanced statistics to assess the trends of the disease. This is achieved by measuring the disease transmissibility rate in the community at the state or national level, known as the disease's reproductive number. The reproductive number is a fundamental indicator for studying the contagiousness or transmissibility of communicable disease dynamics. There are two types of reproductive numbers: basic reproductive number (R_0) and time-varying reproductive number (R_t). Basic reproductive number (R_0) is determined at the initial stage of an epidemic or outbreak where all people are not immune and susceptible to the disease. However, in practice, due to the dynamic transmission of the newly discovered disease, it is more convenient to estimate the value of R_0 to get the exact value. Epidemiologists work backward after the pandemic to accurately establish the reproductive number of a particular disease.

On the other hand, time-varying reproductive number (R_t) is used to quantify disease transmission in a timely manner and to measure the effectiveness of the control steps taken. We use parameters like incidence cases, serial interval, and onset time to estimate R_t. However, exact serial interval and symptom onset time are not commonly available during the early pandemic, leading to bias R_t. In an actual situation, the

surveillance system can only report the incidence of symptoms, not the incidence of infection. Thus, R_t reflects the delayed transmission of the disease due to time lag in ascertaining the infection (Lim *et al.*, 2020).

Three main parameters are used to calculate the reproductive number (R), namely the duration of the infectious period, mode of transmission, and contact rate. Therefore, anything that can influence the contact rate, including population density, community organization, and seasonality, will eventually affect the R_0 (Delamater *et al.*, 2019). In simple words, the outbreak is expected to continue if R_0 value is more than one and about to decay if R_0 is less than one (Diekmann *et al.*, 1990). The magnitude of the R_0 will determine how big the outbreak scale is. The larger the value of R_0, the larger the epidemic wave. Besides that, R_0 estimation also is useful in determining the proportion of the population that need to be vaccinated to achieve herd immunity within the particular group (Anderson and May, 1985)

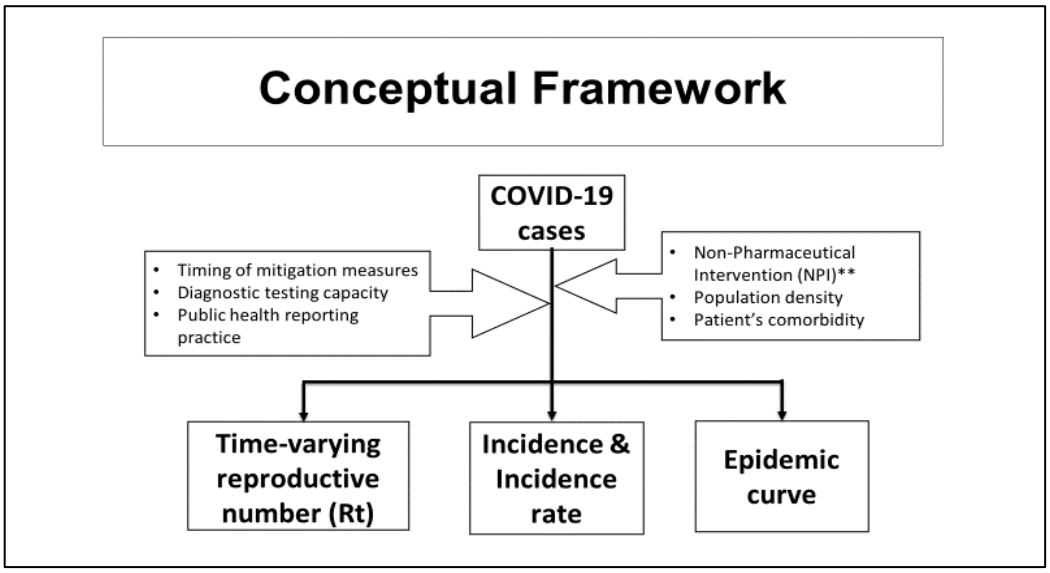

Figure 1.1: Conceptual framework

CHAPTER 3

METHODOLOGY

3.1 Study design and location

Time series analysis of confirmed COVID-19 cases data for Malaysia and all states in Malaysia.

3.2 Source of confirmed COVID-19 data

This study utilized the secondary data readily available from the official website of the Ministry of Health Malaysia (MOH) through the following link: Terkini Harian | COVID-19 MALAYSIA (moh.gov.my). This was the authentic primary source of confirmed COVID-19 incidence cases reported in Malaysia. The incidence data in this website were constantly being updated regularly a daily basis. Alongside incidence, the website also published other variables such as recovered numbers and death tolls for public concern. We included the data starting from the 4th of March 2020 until the 31st of December 2020.

Besides that, Malaysia confirmed COVID-19 cases data was also downloaded from this website: https://ourworldindata.org/coronavirus/country/ malaysia in Microsoft excel format. We compared the data from both sources. However, there were few discrepancies noticed in the early reporting of the data. Hence, data from the MOH website was chosen and used in this study.

3.3 Ethical approval

This study has already got approval from the Human Research Ethics Committee of Universiti Sains Malaysia (USM/JEPeM/20110576). However, it did not require national-level ethical approval because the data source was of aggregated format, publicly accessible, and did not provide any sensitive personal information for our interest or any third party-use.

3.4 Data management

Data collected for this study was loaded into Microsoft Excel 2019 and R statistical software for processing and obtaining the result. There were two parts of data management. The first part was Malaysia or national data. The data was downloaded from ourworldindata.org in Microsoft Excel.xlsx format, whereas for the MOH website, the information was extracted and manually tabulated using Microsoft Excel 2019. Both sources were compared, and subsequently, the data MOH website was chosen for reliability. The second part was the data for the states in Malaysia. Data for states was extracted manually from MOH websites on a daily basis and tabulated in Microsoft Excel 2019. A Microsoft Excel.xlsx table consisting of 364 rows (including header) with few columns, namely the states/Malaysia, the total number of confirmed cases, total number of deaths, and total number of recovered, was constructed. Data was input on a daily basis. We used the R statistical software version 4.0.2 to clean, identify and detect any incomplete, missing data or wrongly input format. Data analysis was started on the 4th of March 2020 until the 31st of December 2020. Results of the finding were presented in multiple figures and charts for better visualisation and interpretation.

3.5 Data analysis

3.5.1 Incidence of confirmed COVID-19 cases

We used R statistical software version 4.0.2 with an Incidence and EpiEstim packages to analyse and calculate incidence. The incidence cases output later will be displayed in a tabulated form and terms of epidemic curves. The trend should be observed and interpreted from the output graphical presentation.

3.5.2 Trend analysis

We performed trend analysis by calculating the incidences and incidence rates per 100,000 population for Malaysia and all the states. For a more convenient way, monthly incidences and incidence rates (approximately 30 days) were used instead of daily count. To get the incidence rate per 100,000 population, the monthly incidence cases (numerator) were divided by the total populations of Malaysia / states and (denominator) and times by 100,000 population. The source of population data was downloaded from the official Department of Statistics Malaysia (DOSM) website through the link Department of Statistics Malaysia Official Portal (dosm.gov.my) in Excel.csv format.

3.5.3 Epidemic curve and Time-varying reproductive number (R_t)

Time-varying reproductive number (R_t) is a more suitable indicator for looking at the dynamic transmission of the disease. Unlike basic reproductive number (R_0), it only estimates the likelihood transmissibility of the disease at the very beginning of the pandemic where all populations are equally susceptible to contracting the disease, and no interventions are done, whether pharmaceutical or non-pharmaceutical. For generating the epidemic curve and estimating the time-varying reproductive number

(R_t), the raw Excel data would be imported and loaded into R Integrated Development Environment (IDE). We selected all rows and two columns containing the date and incidence cases and integrated them into a unique package developed for this purpose called 'Incidence' and 'EpiEstim' packages. EpiEstim package utilized a time series of confirmed COVID-19 incidence cases and the distribution of COVID-19 serial interval. Serial interval (SI) is defined as the time interval between the onset of symptoms of an infector (primary case) and the onset of symptoms of the infectee (secondary case). Few studies like Rai B. *et al.* (2021) conducted earlier proposing a different value of SI, mainly because of the dynamic factor of transmissibility in this novel virus. For this study, we use serial interval (SI) with a mean interval of 3.96 days (95% CI 3.53–4.39 days), standard deviation (SD) 4.75 days (95% CI 4.46–5.07 days) to calculate the R_t with sliding windows average of seven days. (Du *et al.*, 2020).

CHAPTER 4

RESULT

4.1 Incidence of confirmed COVID-19 cases in Malaysia and all states

The incidence of confirmed COVID-19 cases in Malaysia has continued to rise since the first case reported on the 25th of January 2020, especially across the Klang valley areas like Selangor, the Federal Territory of Kuala Lumpur, and Negeri Sembilan. These states and Federal Territories mainly received imported cases from outside the country, along with an increasing number of local cases and subsequently being isolated in the designated hospitals.

Table 4.1 below showed a steady increment in new cases in all states and Federal Territories reporting in the first two months. However, in April, Kuala Lumpur recorded the highest monthly incidence case of 803, accounting for 25% of the national figure, followed by Selangor, 727 cases, and Sarawak in the third place, with monthly cases of 351. This has been reflected in the first peak of national incidence of 3236 cases in a month. As time progressed, the recently introduced Movement Control Order (MCO) has started to impose a positive effect less than one month ago. All states dan Federal Territories registered a declining number of monthly incidence cases, especially those states and Federal Territories within Klang valley areas. The statistic continued to please all the Malaysians with the concordant introduction of Recovery MCO (RMCO) in mid-June 2020. However, this situation remained calm until early September 2020 where the cases started to climb up again, as shown in Table 4.1