Enhanced Knowledge in Sciences and Technology Vol. 3 No. 2 (2023) 82-90

EKST

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/ekst
e-ISSN : 2773-6385

Simulation of Covid-19 Spread in Malaysia and Italy Using SIR Model

Nur Hidayah Chakngari[1], Norzuria Ibrahim[2]*,

[1]KWSP, 12-16, Bangunan KWSP,
Jalan Dato' Dalam,
80000 Johor Bahru, Johor, MALAYSIA

[2]Department of Mathematics and Statistics,
Faculty of Applied Sciences and Technology,
Universiti Tun Hussein Onn Malaysia (Pagoh Campus),
84600 Pagoh, Muar, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/ekst.2023.03.02.010
Received 15 January 2023; Accepted 19 February 2023; Available online 30 November 2023

Abstract: The spread of the novel coronavirus disease (Covid-19) has created a chaos across the world. The disease continues to spread in all countries. The use of mathematical models in public health plays an important role in many aspects, such as rapidly visualization epidemiological information, monitoring, predicting and estimating the spread of disease, and supporting decision-making to prevent and control the pandemics. The objectives of this study are to simulate the Covid-19 spreading in Malaysia and Italy using Susceptible-Infected-Recovered (SIR) model between 2021 and 2022 and to compare the data spreading of Covid-19 diseases in Malaysia and Italy between 2021 and 2022 using graph descriptions. The simulation of SIR model for Malaysia and Italy built with real data which obtained from Github Repository and Johns Hopkins University, respectively using MATLAB. Then, the simulation of the SIR models is compared to show the trend of the spreading Covid-19 in Malaysia and Italy between the two years. From two years comparison, the number of infections in 2021 is higher for Italy than Malaysia as the vaccination rate in Malaysia is higher compared to Italy. Meanwhile, the number of infections in 2022 for Malaysia is higher than Italy. In conclusion, the awareness of Covid-19 will grow over time, and people's understanding of the disease can be improved, thereby flattening the epidemiological curve in both countries.

Keywords: Covid-19, SIR Model, Epidemiological Information, Comparison, Vaccination Rate

1. Introduction

Since the end of 2019, the world has been dealing with a unique viral infection known as coronavirus disease 2019 (Covid-19), which has a significant impact on human life and the global

**Corresponding author: norzuria@uthm.edu.my*

economy. Covid-19 is a disease caused by the SARS-CoV-2 virus, which is a novel virus (severe acute respiratory syndrome coronavirus 2) [1]. The first case of coronavirus infections 2019 (Covid-19) was reported in mainland China on 31st December 2019, in the city of Wuhan [2]. Since then, the virus has spread around the world, and the number of cases has exploded, with more than 90 million people affected by January 2021[3]. World Health Organization (WHO) declared the outbreak a pandemic on 11th March 2020 [4] making it the largest pandemic of the twenty-first century to date, based on the growing number of confirmed cases of disease by Covid-19 [5] .

The spread of the Covid-19 pandemic has recently been investigated using mathematical models in a number of countries, including China, Italy, and the United Kingdom [6]. The epidemiological Susceptible-Infected-Recovered (SIR) model for Covid-19 spread in Malaysia and Italy is examined in this study. The SIR model is the most basic compartmental model for describing the epidemic pattern of an infectious disease [7]. When modelling using the SIR approach, the population was assumed to be a compartment of interacting individuals in which the disease spreads from the infected to the susceptible and the infected either recover or build immunity against the infectious agent [6]. Therefore, the SIR Model is used to simulate infection magnitude and assess the impact on healthcare resources and the population [8].

Based on the situation today, many countries are still struggling to overcome the spreading of Covid-19. Therefore, each country have to find out the best way to deal with this disease by observing and discussing with experts of other countries handle this disease from high cases to low cases. The SIR model is utilised to examine the spread of Covid-19 in Malaysia and Italy for this study. Malaysia and Italy are very different from one another in terms of climate change, population size, access to healthcare, standard of living and many other aspects. In addition to the restrictions imposed by different weather conditions and a quality of life, this study aims to comprehend the significance of their solution in preventing cases from rising.

Therefore, this study aim to analyse the pattern of Covid-19 spreading in Malaysia and Italy by year. The epidemic pattern of the Covid-19 will be described using SIR model. There are three objectives for this research.The first is to simulate Covid-19 spreading in Malaysia using SIR model between 2021 and 2022. The second is to simulate Covid-19 spreading in Italy using SIR model between 2021 and 2022 and last objective is to compare the data spreading of Covid-19 diseases in Malaysia and Italy between 2021 and 2022 using graph description.

2. Materials and Methods

2.1 Data Collection

In this study, the data spread of Covid-19 for Malaysia and Italy is obtained from the Github Repository [9] and John Hopkins University [10], respectively. It provides time series data starting on 1st January 2021 until 31st December 2022 with the total number of people infected with the coronavirus, including the number of people who have been confirmed with Covid-19, the number of people who have recovered from infection and the number of people who died as a result of the deadly virus.

2.2 SIR Model Equations

The ordinary differential equations (ODEs) were used in this study to predict and assess the spread of the Covid-19 outbreak in Malaysia using Kermack and McKendrick's Susceptible-Infectious-Recovered (SIR) epidemic disease model. The SIR model of ordinary differential equations [11].

$$\frac{dS}{dt} = -\frac{\beta IS}{N} \quad , \qquad Eq.1$$

$$\frac{dI}{dt} = \frac{\beta IS}{N} - \gamma I \quad , \qquad Eq.2$$

$$\frac{dR}{dt} = \gamma I \quad , \qquad Eq.3$$

where *N* is represents the total population, *S* is the number of susceptible individuals, *I* is the number of infected individuals, *R* is the number of recovered individuals, β is the effective amount of people infects per day and γ is the proportion of infected recovering per day. The basic SIR model is considered in this research and MATLAB code is used to analyze the models. MATLAB is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization, and programming.

2.3 Parameter Values for SIR model

For SIR model *Eq.1* to *Eq.3*, there are several parameters needs to be set. The value of proportion of infected recovering per day, γ is given by [12]

$$\gamma = \frac{1}{D}\,, \qquad Eq.4$$

where *D* is numbers of day an infected person has and can spread the disease. The numbers of D =14 days are assumed for Malaysia and Italy since this value is thought to be the minimum amount of time that Covid-19 patients must spend in a mandatory quarantine [12]. Parameter β is the value of effective amounts of peoples infected recovering per day. This value can be obtained using the following formula given by [13]

$$R_0 = \frac{\beta}{\gamma}, \qquad Eq.5$$

$$\beta = R_0 \times \gamma\,, \qquad Eq.6$$

where β can be obtained from the value of reproduction number and the proportion of infected recovering per day. R_0 is a value that can be calculated for communicable diseases or in general, it represents the number of people that a single infected person can be expected to transmits the disease to. The value of R_0 for Malaysia are takes from the Ministry of Health (MOH) Malaysia official website. The value of R_0 that used for built graph of SIR model for Malaysia is taken on 1st January 2021 and 1st January 2022, respectively.

Table 1 and 2 represents the values of parameters which have been used in the SIR model for 2021 and 2022 Covid-19 cases in Malaysia and Italy. The value of R_0 that been used for Italy is 3.6 [14].

Table 1: Parameter values for Malaysia for year 2021 and 2022

Parameter	Parameters for year 2021	Parameters of year 2022
$\boldsymbol{R_0}$	1.78	0.99
$\boldsymbol{\beta}$	0.13	0.07
$\boldsymbol{D}$	14	14
$\boldsymbol{\gamma}$	0.07	0.07

Table 2: Parameter values for Italy for year 2021 and 2022

Parameter	Parameters for year 2021	Parameters of year 2022
$\boldsymbol{R_0}$	3.6	3.6
$\boldsymbol{\beta}$	0.26	0.26
$\boldsymbol{D}$	14	14
$\boldsymbol{\gamma}$	0.07	0.07

2.4 Comparison of Covid-19 cases in Malaysia and Italy

The spread of Covid-19 in Malaysia and Italy is observed by the graph simulations of SIR model. The plots are for the year 2021 until 2022.

3. Results and Discussion

3.1 Application of SIR model using real data in Malaysia and Italy

The analysis for spreading of Covid-19 disease for Malaysia and Italy has been done with the simulation of SIR model using MATLAB. For Malaysia, this phase was applied by data of Covid-19 spread in the interval between 1st January 2021 until 31st December 2021. Figure 1 shows the graph of SIR model that applied to data of spreading of Covid-19 for year 2021.

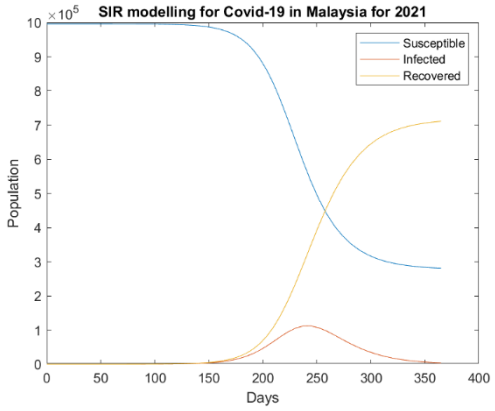

Figure 1: Application of SIR model using data in Malaysia for year 2021 ($\boldsymbol{R_0 = 1.78, \beta = 0.13, D = 14}$)

From Figure 1, the number of people who were susceptible initially remained constant from day 1 before gradually decreasing starting on day 120 and continuing until day 365. The number of infected people started to rise on day 158 and continued to rise until day 244. The number of infected people started to decrease, on day 244 until the end of the year. This is because Malaysia is one the countries that has been the fastest in providing vaccines to Malaysians. In addition, the vaccination rate in Malaysia is increasing. As of 25th December, Malaysia has vaccinated 78.3% of its population, which corresponds to 97.5% of adults and 87.2% of adolescents aged 12 to 17 [15]. Furthermore, starting on day 174, the number of recovered cases keeps growing until the end of the year. With these vaccines, the Malaysian government can prevent the increasing numbers of cases in order to strengthen individual immunization against Covid-19. Therefore, the infections numbers in Malaysia are low. Due to the decrease in the number of susceptible individuals in Malaysia, the number of recovered cases is continuously rising until the end of the year.

Based on the number of infected cases in the community, Malaysia recorded the highest number of cases and recovered cases in 2022. For the year 2022, this phase was applied by data of Covid-19 spread between 1st January 2022 until 31th December 2022. Figure 2 illustrate the graph of SIR model that implemented the data of spreading of Covid-19 spreading for year 2022.

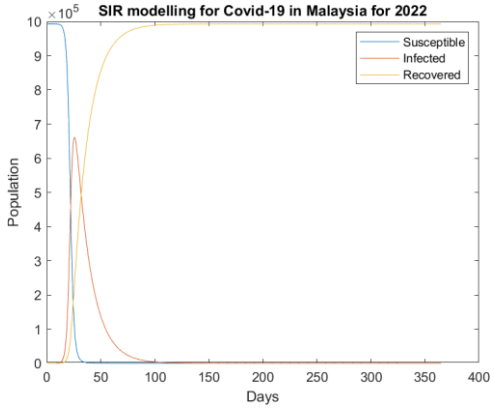

Figure 2: Application of SIR model using data in Malaysia for year 2022
$(R_0 = 0.99, \beta = 0.07, \mathrm{D} = 14)$

From Figure 2, the number of susceptible people began to gradually decrease on the 13th day and continued to do so for the following 33 days, starting with the first day of the year. The number of infected cases in Malaysia for 2022 started increasing on the 12th day, that is, at the beginning of the year. The number of infected cases is higher at the beginning of the year because the arrival of Omicron variants in Malaysia. The number of infected individuals in Malaysia is higher because the Malaysian started neglecting to follow the SOP and restrictions that the government provided to all the community. However, Malaysia started to recover on day 25. The cases of infection gradually decrease until the end of the year because the the vaccination rate is lower, which is 84.1% of Malaysia total population has been vaccinated with at least two doses, and 49.6% completed one booster shot [16].

In Italy, this first phase was applied by data of Covid-19 spread in the interval between 1st January 2021 until 31th December 2021. Figure 3 shows the graph of the SIR model that applied to data of spreading of Covid-19 for the year 2021.

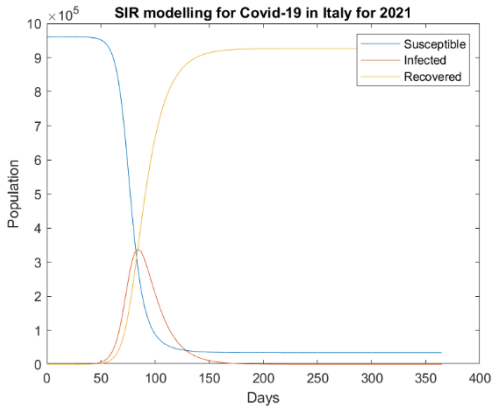

Figure 3: Application of SIR model using data in Italy for year 2021
$(R_0 = 3.6, \beta = 0.26, \mathrm{D} = 14)$

Based on Figure 3, the number of susceptible individuals slowly decreased from day 50 to day 166 and began to remain constant at day 150 through the end of the year. At the same time, the number of infected increased on day 50 and clasted until day 84. The number of infections in Italy is higher due to the Covid-19 delta variant that arrived in June 2021. This variant has become predominant and there is

an increase in the number of cases of infection. The Delta variant is more contagious and is just as risky for those who have not received the Covid-19 vaccine or have only taken the first dose. As of 3th September 2021, Italy has administered a total of 78,798,299 doses of Covid vaccine. As each person requires two doses of the Covid vaccine for full effectiveness, the total number administered is sufficient to cover approximately 65.1% of the country's population [17]. In August 2021, hackers blocked an Italian vaccination booking system [18]. This results in the vaccination service to the Italian people being slow and delayed. In addition, the number of recovered people in Italy is higher than in Malaysia. The number of infected gradually decreased until day 150. After that, the number of infections remained stable until the end of the year. The peak of the highest infection number comes on day 84. The number of recovered cases started to increase from day 50 util day 365.

For the year 2022, this phase was applied by data of Covid-19 spread in the interval between 1st January 2022 until 31st December 2022. Figure 4 shows the SIR graph that applied to the data of spreading of Covid-19 for the year 2022.

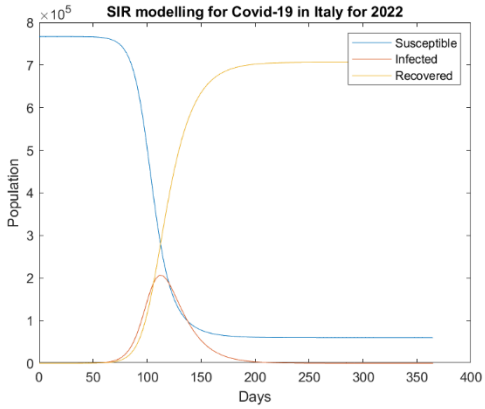

Figure 4: Application of SIR model using data in Italy for year 2022 ($\boldsymbol{R_0 = 3.6, \beta = 0.26, D = 14}$)

Based on Figure 4, the number of susceptible people slowly decreased from day 61 to day 136. After a sharp decline, the number of susceptible people remained stable until day 365. Also, the number of infected cases started to increases on day 68 and reached the highest peak on day 111. The number of cases is decrease through day 196 before remaining stable through the end of the year. In addition, the number of recovered cases is higher than the number of infections in Italy. The number of recovered cases began to rise. The number of infected cases is high at the beginning of the year because of the arrival of the Omicron variants. In addition, in Italy, around 90% of the adult population has been fully vaccinated [20].

3.2 Comparison of the simulation of SIR model in Malaysia and Italy

Based on Figures 1 and 3, the SIR graph simulation for Malaysia and Italy for 2021 would be compared. It turned out that the number of infected cases in Italy is higher than in Malaysia and the number of recovered cases in Italy is also higher than in Malaysia. This is because Malaysia is one of the countries that has been the fastest in getting vaccines to Malaysians. As of 25th December 2021, Malaysia has vaccinated 78.3% of its population, which corresponds to 97.5% of adults and 87.2% of adolescents aged 12 to 17 [15]. The number of infections in Italy is higher due to the Covid-19 delta variant that arrived in June 2021. This variant has become dominant and there is an increase in the number of cases of infection. Malaysia is also affected by the delta variant, but the number of cases due to the variant is not as high as in Italy. In Malaysia, the total number of Covid-19 cases caused by the delta variant is 3,570 [25] while Italy recorded nearly 17% of total Covid-19 cases that due to the delta variant as of 26th June 2021 [26]. The Delta variant is more contagious and is just as risky for those who have not received the Covid-19 vaccine or have only taken the first dose. Delta is considered a "variant of concern' by WHO [26]. As of 3th September 2021, total of 78,798,299 doses of Covid

vaccine have now been administered in Italy. Since each person needs 2 doses of the Covid vaccine for full effectiveness, the total number administered enough to cover approximately 65.1% of the country's population [17]. Therefore, the high percentage of vaccination in Malaysia can prevent the rising numbers of cases, strengthen individual immunization against Covid-19 and keep the infections numbers in Malaysia low. Meanwhile, in Italy, where vaccination coverage is low, nationwide lockdowns, quarantines, social distancing and the use of face masks have been successfully applied to reduce the spread of the virus and the strain on the country's healthcare system [27]. Both countries were able to contain the damage brought on by the emergence of the Delta variant thanks to the high efficacy and effectiveness of the licensed vaccines against this infection, severe disease, and death, as well as to the prioritization of the highest risk categories [28].

According to Figures 2 and 4, the SIR graph simulation for Malaysia and Italy for 2022 would be compared. Authors finds out that the number of infections in Malaysia is higher than Italy and the number of recovered cases in Malaysia is also higher than Italy. Italy has managed to reduce the number of Covid-19 cases from a high number of cases to a low number compared to previous year. Italy has had some of the toughest restrictions in the world during the pandemic and, despite a relaxation of most rules, is still one of the most cautious countries in Europe [19]. For both countries, the number of infections had increases at the beginning of the year due to the emergence of Omicron variants. With the emergence of variants of Omicron, the number of cases increased exponentially. Italy reported its first case of Omicron on 28th November 2021, while Malaysia reported its first case of Omicron on 2th December 2021. Italy took early precautionary measures with a travel ban imposed on seven southern African countries: South Africa, Lesotho, Botswana, Zimbabwe, Mozambique, Namibia and Swaziland to avoid an increase in the number of infected cases [21].

The precautionary take by Italy managed to reduces the number of cases at the beginning of the year 2022. The vaccination percentage in Italy is around 90% of the adult population had been fully vaccinated [19] while the vaccination percentages in Malaysia is around 84.1% that had been fully vaccinated in 2022 [16]. The high vaccination rate contributes to the low number cases of Covid-19. In order to reduced number of cases in Italy, Italy government has ordered the closure of public facilities in Italy, including schools, restaurants, shops and museum [23] and Italy extends the lockdown until March 2022 and masks are mandatory outdoors for any public activities to maintain the latest restrictions to implemented to contain the fourth wave of the pandemic over the Christmas and New Year holidays [24]. In addition, the Italian government is making mandatory for people aged 50 and over to get vaccinated under strict new rules to control the country's rising number of Covid-19 cases and failure to receive vaccination will result in fines of between RM2,857 and RM7,142 [22]. Also, Italian requires a "special green pass" to enter public places such as restaurants and bars, cinemas, gyms, nightclubs and stadium to ensure that the person has been vaccinated and negative Covid-19 [24].

4. Conclusion

In conclusion, the SIR model is a useful method for evaluating and controlling the Covid-19 epidemic. SIR model can be used to analyse the dynamics of Covid-19 spreading in Malaysia and Italy in more detail. The outcomes of the SIR model have been validated using actual data of the spread of Covid-19 in Malaysia. The verification process was divided into two stages for the years 2021 and 2022. According to the SIR graph simulation built in MATLAB for Malaysia, the number of infections peaked in 2022 at a higher rate than it did in 2021. Additionally, Italy experienced the opposite outcome from Malaysia, with a higher peak in infection rates in 2021 than in 2022. The results of the SIR model based on actual Covid-19 spread data in Malaysia and Italy are compared based on graph descriptions refer to figure 1 to 4. In fact, Malaysia is better positioned for responding to the current outbreak than Italy [20]. In order to reduce the risk of Covid-19 transmission in the public, this study advises Malaysia and Italy to strengthen their public health measures and surveillance by providing adequate education on Covid-19 prevention and control [20].

Acknowledgement

The authors would also like to thank the Faculty of Applied Sciences and Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Jakhar, M., Ahluwalia, P., & Kumar, A. (2020). Covid-19 Epidemic Forecast in Different States of India using SIR Model. *medRxiv 2020:https://doi.org/10/1101/2020.05.14.20101725*.

[2] Ariffin, M. R., Gopal, K., Krishnarajah, I., Che Ilias, I. S., Adam, M. B., Sham, N. M., . . . Mohd Dom, N. S. (2020). Coronavirus disease 2019 (COVID-19) infectious trend simulation in Malaysia: a mathematical epidemiologic modelling study. *SSRN*, 1-17.

[3] Wong, W., Juwono, F. H., & Chua, T. H. (2021). SIR Simulation of Covid-19 Pandemic in Malaysia: Will the Vaccination Program be Effective? *arXiv preprint arXiv:2101.07494v1*. 1-19.

[4] Thapa, P. (2021). Predicating COVID-19 Epidemic in Nepal using the SIR Model. *Artificial Intelligence for Covid-19*, 229-237.

[5] Layati, E., Ouigmane, A., Ouhsine, O., Moujane, A., Alves, M. d., Murugesan, B., . . . Ghachi, M. E. (2021). Modeling of Coronavirus Spread in Morocco using Statistical Approach: SIR Model. *Journal of Environmental Treatment Techniques*, 594-600.

[6] Sinkala, M., Nkhoma, P., Zulu, M., Kafita, D., Tembo, R., & Daka, V. (2020). The COVID-19 Pandemic in Africa: Predictions using the SIR Model. *medRxiv preprint doi: https://doi.org/10.1101/2020/06.01.20118893*.

[7] Law, K. B., Peariasamy, K. M., Gill, B. S., Singh, S., Sundram, B. M., Rajendran, K., . . . Abdullah, N. H. (2020). Predicting the early depleting transmission dynamics of COVID-19: A time-varying SIR Model. *Scientific Reports*, 1-11.

[8] Aik, L. E., Choon, T. W., & Hong, T. W. (2021). An Improved SIR Model for Covid-19 Epidemic in Malaysia. *ARPN Journak of Engineering and Applied Sciences*, 1793-1797.

[9] MOH, M. (2023, February 12). *COVIDNow in Malaysia*. Retrieved from Ministry of Health Malaysia: https://covidnow.moh.gov.my/

[10] Moss, D. B., Watson, D. C., Rutkow, D. L., Garibaldi, D. B., Blauer, B., Gardner, D. L., & Nuzzo, D. J. (2022, June 28). *Covid-19 Dashboards*. Retrieved from John Hopkins University and medicine: https://coronavirus.jhu.edu/map.html

[11] Quoc, P. B., On, V. V., Khanh, N. D., Thuong, N. T., Thuy, H. T., Ngoc, H. V., . . . An, V. H. (2021). Prediction of COVID-19 evolution in Binh Duong province using SIR Model. *Thu Dau Mot University Journal of Science*, 415-421.

[12] Yunus, A. M., Ibrahim, M. S., Ismail, S., & Mohd Yunus, A. A. (2021). Future of Mathematical Modelling: A Review of COVID-19 Infected Cases Using SIR Model. *Baghdad Science Journal*, 824-829.

[13] Ching, L. T. (2020). Comparing the change of R0 for the Covid-19 pandemic in 8 countries using SIR Model for specific periods. 2-14.

[14] Marino Gatto, E. B. (2020). Spread and Dynamics of the COVID-19 epidemic in Italy : Effects of emergency containment measures. *PNAS Journal*, 10484-10491.

[15] Ayamany, K. (2021, December 26). *Malaymail*. Retrieved from A look back at 2021: The year of the vaccine: https://www.malaymail.com/news/malaysia/2021/12/26/a-look-back-at-2021-the-year-of-the-vaccine/2031098

[16] Aanmelden. (2022, August 10). *Flanders Trade*. Retrieved from flandersinvestmentandtrade.com: https://www.flandersinvestmentandtrade.com/export/nieuws/coronavirus-%E2%80%93-situation-malaysia

[17] Bhatia, G., Dutta, P. K., Canipe, C., & McClure, J. (2022, June 28). *Covid-19 Trackers*. Retrieved from Reuters: https://graphics.reuters.com/world-coronavirus-tracker-and-maps/countries-and-territories/malaysia/

[18] Borghese, L., & Braithwaite, S. (2021, August 2). *CNN Business*. Retrieved from Edition CNN: https://edition.cnn.com/2021/08/02/business/italy-hackers-covid-vaccine-intl/index.html

[19] Staff, C. (2022, October 7). *Transforming Africa's Arcade*. Retrieved from CNN Travel: https://edition.cnn.com/travel/article/italy-travel-covid-19/index.html

[20] Wan Ahmad, W. A., Ibrahim, N. A., Awang Nawi, M. A., Mohd Noor, N. F., Mohamad, N., Aleng, N. A., . . . Min Allah, N. U. (2021). Malaysian and Italian trend line for Covid-19: A study on trend analysis. *Bulletin of Applied Mathematics and Mathematics Education*, 61-74.

[21] CGTN. (2021, November 28). *Italy announced first detected case of Omicron COVID-19 variant*. Retrieved from Newsaf.cgtn: https://newsaf.cgtn.com/news/2021-11-28/Italy-announces-first-detected-case-of-omicron-COVID-19-variant-15xI1h5Zk2I/index.html

[22] KOSMO. (2022, Januari 7). *Itali mewajibkan vaksinasi penduduk 50 tahun ke atas*. Retrieved from Kosmo: https://www.kosmo.com.my/2022/01/07/itali-wajibkan-vaksinasi-penduduk-50-tahun-ke-atas/

[23] Harian, B. (2021, March 13). *Itali kembali kepada perintah sekatan*. Retrieved from bharian.com: https://www.bharian.com.my/dunia/eropah/2021/03/795673/itali-kembali-kepada-perintah-sekatan

[24] Bernama. (2021, December 15). *Itali lanjut lagi tempoh darurat Covid-19 hingga Mac tahun depan*. Retrieved from freemalaysiatoday.com: https://www.freemalaysiatoday.com/category/bahasa/dunia/2021/12/15/itali-lanjut-lagi-tempoh-darurat-covid-19-hingga-mac-tahun-depan/

[25] Xian, L. J. (2021, November 11). *Nearly 50 cases of th Delta variant detected in Malaysia as of Thursday (Nov 11)*. Retrieved from The Star: https://www.thestar.com.my/news/nation/2021/11/11/nearly-50-cases-of-the-delta-variant-detected-in-malaysia-as-of-thursday-nov-11

[26] Reuters. (2021, June 26). *Delta, Kappa variants surge in Italy to nearly 17% of cases, health institute says*. Didapatkan dari REUTERS: https://www.reuters.com/world/europe/delta-kappa-variants-surge-italy-nearly-17-cases-health-institute-says-2021-06-25/

[27] Daiana Bezzini, I. S. (2021). First Wave of Covid-19 Pandemic in Italy: Data and Evidence. *National Library of Medicine*, 91-113.

[28] Marziano, V., Guzetta, G., Mammone, A., Riccardo, F., Poletti, P., Trentini, F., Merler, S. (2021). The effect of COVID-19 vaccination in Italy and perspectives for living with the virus. *Nature Communications*, 1-8.