Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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1. Introduction

The Association of Southeast Asian Nations (ASEAN) is an important trading partner to other global countries, including the United States, China, Japan, the United Kingdom, Australia, and other leading countries. ASEAN has a GDP of 9.7 trillion and a total population of 655 million and a highly strategic territory of the South China Sea. Indonesia is the largest economy in Southeast Asia (SEA), the 16th largest economy in the world and home to the largest Muslim population of 270 million people worldwide. Three of the top 20 busiest ports in the world are located in SEA, with Singapore being the second busiest port globally.\(^1\) Singapore is also the 4th largest exporter of high-tech products, while Brunei is the 4th largest producer of Liquefied Natural Gas (LNG) globally. Malaysia is one of the top exporters of natural rubber and palm oil. In terms of international trade, it is projected that by 2050, the collective economies of ASEAN are expected to grow into the 4th largest economies in the world. Currently, ASEAN represents the 4th largest import market from the United States\(^2\) and continues to show trade growth yearly.
Since the global outbreak of the COVID-19 in Wuhan, China in December 2019, Thailand was the first country in SEA to record its first case. Singapore, Indonesia, and the Philippines have recorded the highest number of cases among ASEAN countries as of 24 June 2020 (global first phase), with Singapore having the highest number of cases, while Brunei, Vietnam, and Laos seem to have fully recovered and are virtually free of the COVID-19 virus.

Throughout the duration of the pandemic, ASEAN nations have received great support in terms of finance and health-related equipment and consumables from organizations and countries around the world, including the United States, China, Japan, South Korea, the World Bank, and the United Nations.3

Layos and Pena,4 in their recent study, reviewed the role of innovation in mitigating the COVID-19 in ASEAN-5 economies. Their study has found a significant relationship between the level of innovation and a country’s ability to respond to a crisis. Abuza’s5 assessment of the COVID-19 spread in Southeast Asia states that no government should be blamed for a pandemic, but they should be scrutinized for how they respond. This chapter further suggests that four interrelated criteria determine the success or disaster of the spread of the COVID-19 in each country, namely, leadership, government transparency, legitimacy, planning and preparedness.

The motivation of this chapter is to compare the assessment of COVID-19 cases within ASEAN countries in the first phase. Evaluating the virus spread in each country, and the outcomes provide insights into the strength and stability of a country’s leadership, politics, and people, thus leading to sustainable cities and communities (SDG 11). This study is a test case to analyze the impact and recovery of COVID-19 cases in each country. So far, there is no article available in the open literature focused on analyzing the spread of COVID-19 in Southeast Asian nations. As the collective economies of ASEAN are projected to grow to the top 5 economies of the world, this study will present the overview of ASEAN countries in terms of controlling pandemics.

2. Methods

2.1 Study area

The research area reviews and analyzes the spread of COVID-19 cases among member countries of the Association of Southeast Asian Nations (ASEAN), namely, Brunei, Cambodia, Indonesia, Laos, Malaysia,
2.2 Data collection

For this research study, the data set for COVID-19 is collected for all the ASEAN countries from the day of the first case to 24 June 2020 (tentative global first phase). Data was extracted from multiple sources of each respective ASEAN country. The sources are as follows:

1. National Ministry of Health websites
2. “Our World in Data” website that helped to provide graphs and charts for analysis
3. Multiple COVID-19 dedicated articles in respective Southeast Asian nations

This data includes relevant information pertaining to the complete timeline of cases recorded, the number of infected cases, deaths, recoveries, active, serious, number of tests conducted, etc.

2.3 Data analysis

The analysis is conducted on available data as of 24 June 2020 derived from the total and daily infected COVID-19 cases of each ASEAN country. To
understand the spread of COVID-19 for the foreseeable future in all Southeast Asian countries and estimate the lasting of the coronavirus pandemic in these countries, the Susceptible-Infected-Recovered (SIR) model, which is a well-known mathematical modeling of infectious diseases, is applied. This model reasonably predicts the spread of contagious diseases transmitted from human to human. This model works as a compartment model, as shown as follows:

The SIR model is expressed as follows:

\[
\begin{align*}
\frac{dS}{dt} &= -\frac{\beta IS}{N} \\
\frac{dI}{dt} &= -\frac{\beta IS}{N} - \gamma I \\
\frac{dR}{dt} &= -\gamma I
\end{align*}
\]

where \( S(t) \), \( I(t) \), and \( R(t) \) are the number of susceptible, infected, and recovered persons expressed as a function of time, \( t \). The important model parameters of this model are the contact rate \( (\beta) \) and the average infectious period \( (1/\gamma) \). The total size \( (N) \) is computed as \( N = S + I + R = \text{constant} \).

The earlier model equations are solved using the initial conditions: \( S(0) = S_0, I(0) = I_0, R(0) = R_0 \).

The basic reproduction ratio \( (R_0 = \beta/\gamma) \) is an important metric that is derived as the expected number of new infections from a single infection in a population where all subjects are susceptible.

This SIR epidemic model is a data-driven model that assumes a constant population, uniform mixing of the people, and epi-likely infection. The model parameters are obtained by minimizing of the objective function, which is the sum of the square of error (SSE). The schematic diagram of the epidemic evaluation graph is shown in Fig. 2. Here the epidemic evaluation graph regions (colors) are separated as epidemic phases. Here, light red represents the fast growth phase, yellow represents the transition to the steady-state phase, and green represents the pandemic ending phase.
3. Results and discussion

3.1 Analysis of ASEAN countries

SARS-CoV2 (COVID-19) outbreak, which originated in Wuhan, China, has rapidly spread across the nations and devastated the world with human loss and derailed the economy of all nations. COVID-19 spreads from human to human, and the only way to limit the propagation within the community is to identify the people suffering from COVID-19 symptoms and isolate them, as shown in Fig. 3. This isolation is called a chain break, which is being followed by every country on this earth.\(^{12}\)

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**Fig. 2** Schematic representation of the epidemic evaluation graph resulted from the SIR model.

**Fig. 3** Depiction of SARS-CoV2 (COVID-19) spread within the community.
3.2 Overview of present status quo of the pandemic outbreak in ASEAN as of 24 June 2020

The present pandemic outbreak in ASEAN countries, along with population and total tests conducted up to this period are given in Table 1. It can be noticed that as of 24 June 2020, the highest number of cases as well as the highest deaths were recorded in Indonesia. Singapore has reported the 2nd highest number of cases in the ASEAN region. However, it has also reported the least number of deaths among the nations, which reported around 3000 deaths. In terms of total cases reported per 1 million population, Singapore recorded the highest. As per Worldometers, Singapore has done more tests per 1 million people than other ASEAN countries. Interestingly, Laos is the least affected country, among all the ASEAN countries. It can also be observed that Brunei and Laos have zero active cases, and Cambodia has only three active cases. In terms of recovery rate, Laos, Cambodia, Brunei, Malaysia, Thailand, and Vietnam have reported more than 90% recovery rate. There are 136,729 cases reported in ASEAN, and 76,703 cases recovered, meaning which that 56.1% of COVID-19 patients were entirely recovered.

3.3 Overview of the timeline of the pandemic outbreak

A review of the timeline of the first case reported and other vital statistics for ASEAN countries as of 24 June 2020 is presented in Table 2. Among the ASEAN countries, the first case was reported on 13 January 2020 in Thailand, whereas there was a rapid spread in ASEAN countries during the last week of January 2020. In Indonesia, even though the first case was logged on 2 March 2020, it can also be observed that the pandemic has extensively spread among the country within a short span. Cambodia has recorded a higher number of days, with zero cases per day. This number is a great sign to indicate that the pandemic is well in control in this country. Also, the metrics like total cases on day 30, 50, and 100 presented in Table 2 indicates the spread of COVID-19 cases. The number of cases in Singapore, the Philippines, and Indonesia has grown exponentially from day 50 to 100. A lower increase of cases indicates the rapid/controlled spread of infection. It was observed that Vietnam and Cambodia had reported more than 100 days with less than 5 cases reported/day, which indicates that the pandemic is well in control.

The spread of COVID-19 among these countries is shown in Fig. 4. This profile indicates the timelines and the total number of cases reported since
Table 1 Compilation of data for ASEAN countries as of 24 June 2020.

| Country  | Total cases | Total deaths | Total recovered | Active cases | Recovery (%) | Tot cases/1M pop | Deaths/1M pop | Total tests | Tests/1M pop | Population |
|----------|-------------|--------------|-----------------|--------------|--------------|-----------------|---------------|-------------|--------------|------------|
| Indonesia| 49,009      | 2573         | 19,658          | 26,778       | 40.1%        | 179             | 9             | 689,452     | 2521         | 273,468,761 |
| Singapore| 42,736      | 26           | 36,299          | 6411         | 84.9%        | 7306            | 4             | 684,359     | 116,994      | 5,849,533   |
| Philippines| 32,295     | 1204         | 8656            | 22,435       | 26.8%        | 295             | 11            | 631,063     | 5760         | 109,551,348 |
| Malaysia  | 8596        | 121          | 8231            | 244          | 95.8%        | 266             | 4             | 704,336     | 21,767       | 32,357,654  |
| Thailand  | 3158        | 58           | 3038            | 62           | 96.2%        | 45              | 0.8           | 468,175     | 6708         | 69,797,375  |
| Vietnam   | 352         | –            | 329             | 23           | 93.5%        | 4               | 0.1           | 275,000     | 2826         | 97,322,679  |
| Myanmar   | 293         | 6            | 208             | 79           | 71.0%        | 5               | 0.1           | 66,353      | 1220         | 54,403,606  |
| Brunei    | 141         | 3            | 138             | 0            | 97.9%        | 322             | 7            | 27,385      | 62,608       | 437,402     |
| Cambodia  | 130         | –            | 127             | 3            | 97.7%        | 8               | 15           | 33,211      | 1987         | 16,714,185  |
| Laos      | 19          | –            | 19              | 0            | 100.0%       | 3               | 12           | 13,507      | 1857         | 7,273,342   |
| ASEAN     | 136,729     | 3991         | 76,703          | 56,035       | 56.1%        | 8433            | 36           | 3,592,841   | 224,248      | 667,175,885 |

*Extrapolated to 1 million population.

Source: Worldometers, 2020. Covid-19 Coronavirus pandemic. Worldometers.
### Table 2: Review of COVID-19 growth of cases (as of 24 June 2020) in ASEAN, since the first case was reported.

| Country   | First case reported | Time period since first case | Total cases day 30 | Total cases day 50 | Total cases day 100 | Total cases day 24 Jun 2020 |
|-----------|---------------------|------------------------------|--------------------|--------------------|----------------------|-----------------------------|
| Thailand  | 13 Jan 20           | 5M 0W 4D                     | 33 (12 Feb)        | 43 (03 Mar)        | 2811 (22 Apr)        | 3158                        |
| Singapore | 23 Jan 20           | 4M 3W 4D                     | 86 (22 Feb)        | 187 (13 Mar)       | 17,101 (02 May)      | 42,736                      |
| Vietnam   | 23 Jan 20           | 4M 3W 4D                     | 16 (22 Feb)        | 44 (13 Mar)        | 270 (02 May)         | 352                         |
| Malaysia  | 25 Jan 20           | 4M 3W 2D                     | 22 (24 Feb)        | 238 (15 Mar)       | 6298 (04 May)        | 8596                        |
| Cambodia  | 27 Jan 20           | 4M 3W 0D                     | 1 (26 Feb)         | 12 (16 Mar)        | 122 (06 May)         | 130                         |
| Philippines | 30 Jan 20         | 4M 2W 4D                     | 3 (29 Feb)         | 202 (19 Mar)       | 10,463 (09 May)      | 32,295                      |
| Indonesia | 2 Mar 20            | 3M 2W 1D                     | 1528 (01 Apr)      | 6760 (21 Apr)      | 33,076 (10 Jun)      | 49,009                      |
| Brunei    | 9 Mar 20            | 3M 0W 8D                     | 135 (08 Apr)       | 138 (28 Apr)       | 141 (17 Jun)         | 141                         |
| Myanmar   | 24 Mar 20           | 2M 3W 4D                     | 132 (23 Apr)       | 180 (13 May)       | N/A                  | 293                         |
| Laos      | 24 Mar 20           | 2M 3W 3D                     | 2 (24 Apr)         | 19 (14 May)        | N/A                  | 19                          |
the first case. It can be noticed that the spread of the pandemic was relatively low in the initial stages but picked up pace during the first week of March. This is due to the mass religious congregation in Kuala Lumpur, Malaysia, in late February and early March, where over 16,000 people attended, of which approximately 1500 people came from other parts of the world, including Brunei, Singapore, and Indonesia. This gathering has led to massive spikes in Malaysia as well as in neighboring countries.

3.3.1 COVID-19 outbreak doubling rate
The profile showing the COVID-19 outbreak doubling rate among the ASEAN countries is shown in Fig. 5. These profiles are visualized for the days since the 100th confirmed case is reported. The doubling rate was faster in the initial days, but it has slowed down. As per the profile, the highest doubling rate is recorded for countries like Indonesia, Singapore, and the Philippines. Countries like Myanmar and Vietnam have shallow doubling rates, and there were no new cases reported in Brunei and Cambodia for over a month. It indicates that the pandemic is entirely in control in these countries.

3.3.2 Review of deaths reported due to the COVID-19 outbreak
Since the COVID-19 outbreak, the number of infected cases has increased. Among the primary concern of the epidemic is the number of deaths that
occurred due to COVID-19. The overview of the number of deaths reported so far as of 24 June 2020 is given in Table 1. It can be noticed that among the ASEAN countries, the highest number of fatalities recorded were in Indonesia and the Philippines. Even though Singapore is steadily recording more cases, around 77.5% of infected cases are recovered, the fatality rate is only 0.06%.

The total number of confirmed cases against total confirmed deaths due to COVID-19 among ASEAN countries is shown in Fig. 6. It can be seen that Indonesia and the Philippines reported around 5% deaths out of the total confirmed cases, whereas Malaysia, Thailand, and Myanmar have reported around 2% deaths out of the total confirmed cases. Since there are no confirmed deaths reported yet in Cambodia, Laos, and Vietnam, these countries are not shown in the figure. Interestingly, even though the number of cases is high and increasing every day in Singapore, the number of deaths is very low. This may be due to the Singapore government’s preventive measures and robust medical protocols in increasing the immunity in the infected patients, thus improving the recovery rates.

Case Fatality Rate (CFR) is the ratio between confirmed deaths and confirmed cases and is an essential statistical metric to evaluate the fatality rate. The comparison plot of CFR for ASEAN countries is shown in Fig. 7. The CFR is zero since Cambodia, Laos, and Vietnam have no recorded
COVID-19 deaths. Even though the number of cases is high in Singapore, the number of deaths compared to the total number of cases is low; hence, the CFR is close to zero. Among the ASEAN countries, Indonesia and the Philippines have recorded a higher number of COVID-19 related deaths;
hence their respective CFR profiles are very high. However, thankfully, these profiles are lowering, which is a good sign.

### 3.3.3 Review of confirmed cases against the GDP per capita among ASEAN countries

To understand the relationship between the spread of pandemic (also control of spread) against the GDP per capita, the respective data of ASEAN countries are downloaded from [https://ourworldindata.org](https://ourworldindata.org). The confirmed COVID-19 cases per million people vs GDP per capita among ASEAN countries are shown in Fig. 8. Here the GDP per capita income is based on 2017 statistics. This figure reveals interesting facts like the lower GDP per capita countries like Cambodia, Laos, Myanmar, and Vietnam have reported fewer COVID-19 cases per million people. Countries like Indonesia, Malaysia, and Thailand, with GDP per capita of more than $10,000, have reported a higher number of cases per million people. Singapore has the highest GDP per capita among the ASEAN countries and reported the highest number of cases per million people. Being the 2nd highest GDP per capita country, Brunei has relatively recorded a similar number of cases per million people as nations with $10,000 – $40,000 GDP.

![Scatter plot showing the confirmed COVID-19 cases per million people vs GDP per capita among ASEAN countries.](https://ourworldindata.org/coronavirus-source-data) [Source: https://ourworldindata.org/coronavirus-source-data [Date: 25 June 2020]]
3.4 Analysis of COVID-19 pandemic in Brunei Darussalam

3.4.1 The sequence of cases originated and government actions

The first COVID-19 case in Brunei was recorded on 9 March 2020, of a man who had returned to Brunei after attending a religious congregation with a group of other Bruneians in Kuala Lumpur, Malaysia. Of the 81 Bruneians who had attended, 19 Bruneians were found to be infected. This event eventually led to the infection of a total of 71 cases, which represents more than 50% of total cases in Brunei.

As of 24 June 2020, Brunei has recorded 141 confirmed cases, 138 recovered cases, and conducted 16,751 tests in the country.14 There have been three deaths in total so far. The Brunei government has imposed numerous preventive measures including suspending public gatherings and events such as weddings and sporting events. Additionally, the government has restricted air travel, shut down public facilities such as mosques, and even closed all schools resorting to work and study from home measures. Brunei has not seen a case in the last 6 weeks.

3.4.2 Forecasting of COVID-19 outbreak using the SIR model

The growth of infections in Brunei has increased rapidly after the onset of the first case; after a month, the spread of infections has completely been arrested due to government preventive measures. The SIR model is simulated to forecast the outbreak spread, and the predicted profile is compared with the actual recorded cases, as shown in Fig. 9. The pandemic outbreak spread initially with a doubling time of 5.2 days. The estimated SIR model parameters are given in Table 3. The predicted total epidemic duration is 39 days, and the total growth phase duration is 18 days.

The SIR model simulation predicted that the end of the epidemic (5 cases) is estimated to be 9 April 2020, which is close to 30 March 2020 (real-time data). Similarly, the model predicted that the end of the epidemic (1 case) is 21 April 2020, which is very close to 20 April, when there were no cases reported for two weeks. However, there was one case on 7 May and 2 cases on 8 May, which was the last case in Brunei. Root mean square error (RMSE) of the model prediction is 2.198 with an $R^2$ of 0.994. According to Hamid,15 there is unlikely to be a second local outbreak in the country unless the Brunei government is lax with air travel restrictions causing a resurgence in imported cases.
3.5 Analysis of COVID-19 pandemic in Cambodia

3.5.1 The sequence of cases originated and government actions

Cambodia saw the first COVID-19 case on 28 January 2020. Specifically, the first case was a man who was reported to have returned from Wuhan, China, with his family. In terms of COVID-19 cases, Cambodia has seen a total of 130 confirmed cases, 128 recovered cases, and no deaths as of 24 June 2020. In its efforts to combat the spread of COVID-19 in the country, the Cambodian government established a dedicated national committee and took measures including the closure of educational institutions nationwide, restriction of air travel, closing down border crossings with Vietnam, and introduced monthly allowances to unemployed workers caused by the virus.

Fig. 9 Forecasting of COVID-19 outbreak using the SIR model for Brunei.
Table 3  Epidemic modeling by susceptible-infected-recovered (SIR) model for ASEAN countries.

| Country   | Acceleration phase (days) | Deceleration phase (days) | Contact frequency (Beta) (/day) | Removal frequency (gamma) (/day) | Predicted total epidemic duration (days) | Root mean squared error | P-value       | $R^2$  |
|-----------|---------------------------|---------------------------|---------------------------------|----------------------------------|-----------------------------------------|------------------------|--------------|-------|
| Brunei    | 6                         | 12                        | 0.437                           | 0.304                            | 39                                      | 2.2                    | 9.137e − 113 | 0.994 |
| Cambodia  | 5                         | 6                         | 0.513                           | 0.142                            | 32                                      | 3.5                    | 4.489e − 82  | 0.986 |
| Indonesia | 57                        | 66                        | 0.097                           | 0.062                            | 568                                     | 125.0                  | 5.512e − 129 | 0.997 |
| Myanmar   | 9                         | 11                        | 0.301                           | 0.08                             | 63                                      | 47.8                   | 5.340e − 21  | 0.701 |
| Malaysia  | 21                        | 25                        | 0.159                           | 0.059                            | 236                                     | 435.3                  | 2.037e − 112 | 0.981 |
| Philippines | 74                       | 83                        | 0.131                           | 0.104                            | 666                                     | 741.6                  | 1.369e − 114 | 0.993 |
| Singapore | 23                        | 28                        | 0.163                           | 0.075                            | 305                                     | 861.6                  | 4.937e − 182 | 0.997 |
| Thailand  | 11                        | 14                        | 0.306                           | 0.123                            | 143                                     | 56.6                   | 5.648e − 194 | 0.998 |
| Vietnam   | 18                        | 21                        | 0.171                           | 0.056                            | 147                                     | 3.943                  | 2.397e − 11  | 0.983 |
3.5.2 Forecasting of COVID-19 outbreak using the SIR model
Using the SIR model, the outbreak’s spread in Cambodia is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 10. The pandemic outbreak spread initially with a doubling time of 1.9 days. The estimated SIR model parameters are given in Table 3. The predicted total epidemic duration is 32 days, in which the total growth phase duration is 12 days.

The SIR model simulation predicted that the end of the epidemic (5 cases) is estimated to be 04 April 2020, which is close to 26 March 2020 (real-time data). Similarly, the model predicted that the end of the epidemic (1 case) is 14 April 2020, which is very close to 12 April, when there were no cases reported for 4 weeks. However, there were few cases (one per week) reported later. RMSE of the model prediction is 3.5, with $R^2$ of 0.986.

3.6 Analysis of COVID-19 pandemic in Indonesia
3.6.1 The sequence of cases originated and government actions
The first two COVID-19 cases in Indonesia were reported on 2 March 2020. These two cases were a dance instructor and her mother, who were
suspected to be infected by a Japanese national. On 9 April 2020, the virus had spread to all 34 provinces of Indonesia, in which at least 500 cases were present in half of the provinces.

As of 24 June 2020, there have been a total of 49,009 confirmed cases in Indonesia, followed by 19,658 recovered cases and 2573 deaths. Additionally, there have also been 689,452 tests conducted. Indonesia has the highest number of COVID-19 cases among Southeast Asian countries.

Indonesia implemented a local lockdown as opposed to a national lockdown. Further, it introduced a national COVID-19 initiative called the “Large Scale Social Restriction” (LSSR), which includes the closure of public schools and facilities, restriction of public transport, and the control of public movement between provinces.

### 3.6.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the outbreak’s spread in Indonesia is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 11. The estimated SIR model parameters are given in Table 3.

![Fig. 11 Forecasting of COVID-19 outbreak using the SIR model for Indonesia.](image-url)
The pandemic outbreak spread initially with a doubling time of 1.9 days. The estimated SIR model parameters are given in Table 3. With rising cases, the predicted total epidemic duration may last for 568 days, in which the total growth phase duration is 123 days. The SIR model simulation predicted that the end of the epidemic (5 cases) is estimated to be 11 February 2021, and the end of the pandemic (1 case) is 24 March 2021 as the cases increase. RMSE of the SIR model prediction is 125.0 with $R^2$ of 0.997.

3.7 Analysis of COVID-19 pandemic in Laos

3.7.1 The sequence of cases originated and government actions
On 24 March 2020, the first two cases of COVID-19 were reported in Laos. These two initial cases represented a man who had returned from Thailand and a female tour guide who was infected by a Cambodian tourist who tested positive. It should be noted that Laos was also the last country in Southeast Asia to have caught the spread of the virus.

On 29 March 2020, the Laos government imposed a national lockdown that effectively closed all country land borders in addition to air travel. By 18 May 2020, after many improvements in the daily number of cases in the country, the Laos government loosened its restrictions.

3.7.2 Forecasting of COVID-19 outbreak using the SIR model
Using the SIR model, the outbreak’s spread in Laos is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 12. Due to the low number of cases, the SIR model could not have enough data to train and forecast. Also, the growth rate and ending phase are close to each other.

3.8 Analysis of COVID-19 pandemic in Malaysia

3.8.1 The sequence of cases originated and government actions
The first case of COVID-19 in Malaysia was reported on 25 January 2020. The first case was reportedly infected by travelers coming from China. In late February 2020, a religious congregation took place at the Jamek Mosque, attended by over 16,000 people worldwide. This mass gathering led to one of the largest initial outbreaks in the country and infected other attendees from other countries, including Brunei, Singapore, and Indonesia.

The actions of containing the outbreak in Malaysia occurred during a change in government leadership. In its efforts to combat the outbreak, the new Malaysian government had imposed the “Movement Control
Order” throughout the country. This included prohibiting of mass gatherings of events and activities such as sports, and cultural and religious activities, including attending Friday prayers at mosques and weddings. The government also restricted travel into the country and imposed mandatory quarantines for travelers who were allowed into the country. Other actions taken were the temporary closure of educational institutions nationwide and nonessential government offices and services. Though the Movement Control Order was a temporary periodical directive across the country, it had been extended four times. Other notable efforts taken by the government were the introduction of special allowances to be provided to low-income households during the pandemic. Despite that Malaysia initially had the highest number of cases in Southeast Asia, the growth of cases had significantly dropped due to the strong measures taken by the government. Malaysia currently stands as the 4th highest in cases within Southeast Asia with an outlook of recovery in the near future. As of 24 June 2020, Malaysia has confirmed a total of 8596 cases, 8231 recovered cases, 121 deaths, and has conducted 704,336 tests throughout the country.
3.8.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the outbreak’s spread in Malaysia is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 13. The pandemic outbreak spread initially with a doubling time of 6.9 days. The estimated SIR model parameters are given in Table 3. With a growing number of cases, the predicted total epidemic duration may last for 236 days, in which the total growth phase duration is 46 days.

Based on the available data, the SIR model predicts that the end of the epidemic (5 cases) is estimated to be 18 August 2020, and the end of the epidemic (1 case) is 22 September 2020, as the cases are increasing. So far, the model predictions are perfect, resulting in an RMSE of 435.3 with an $R^2$ of 0.981.

3.9 Analysis of COVID-19 pandemic in Myanmar

3.9.1 The sequence of cases originated and government actions

In Myanmar, the first and second two cases were reported on 23 March 2020. As of 24 June 2020, there have been a total of 290 confirmed cases
in Myanmar, 200 recovered cases, and 6 deaths. About 22,077 tests have been conducted.

Myanmar announced a community lockdown in one village in China state to combat the spread of the virus. On 30 January 2020, Myanmar formed a special committee to tackle the pandemic. On 1 February 2020, Myanmar suspended Chinese visas from entering the country and evacuated 59 students in Wuhan. By 14 March 2020, Myanmar set new bans and restricted travelers from China, South Korea, and parts of Europe, and by 21 March 2020, new restrictions were further imposed on all foreign nationals, including requirements of presentations of medical certificate and 14-day quarantine. Air travel is put on hold on 13 April 2020.

### 3.9.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the outbreak’s spread in Myanmar is forecasted. The SIR model–predicted profile is compared with the actual recorded cases, as shown in Fig. 14. The pandemic outbreak spread initially with a doubling time of 2.6 days. The estimated SIR model parameters are given in Table 3.

![Forecasting of COVID-19 outbreak using the SIR model for Myanmar](image)

*Fig. 14* Forecasting of COVID-19 outbreak using the SIR model for Myanmar.
The predicted total epidemic duration may last for 63 days, in which the total growth phase duration is 20 days. Based on the data available so far, the SIR model predicts that the end of the epidemic (5 cases) is estimated to be 7 May 2020, and the end of the epidemic (1 case) is 22 May 2020. So far, the model predictions are moderately good, resulting in an RMSE of 47.8 with $R^2$ of 0.701. SIR model predictions are not as good as for other ASEAN countries.

3.10 Analysis of COVID-19 pandemic in the Philippines

3.10.1 The sequence of cases originated and government actions

The first case confirmed in the Philippines was reported on 30 January 2020, involving a 38 year-old Chinese woman from Wuhan who arrived from Manila from Hong Kong while the second case was a 44 year-old Chinese man, reported on 2 February 2020, who had died 1 day earlier. As of 24 June 2020, there have been a total of 32,295 confirmed cases, 22,435 active cases, 8656 recovered cases, and 1204 deaths. About 631,063 tests have been conducted.

The Philippines recorded the highest number of cases in Southeast Asia, in which the largest single case increase in cases was reported on 23 June 2020 and had recorded 1186 new cases. The Philippines government has imposed travel bans on countries including mainland China, Macau, Hong Kong, and South Korea in terms of measures. On 7 March 2020, the president of the Philippines issued the “Code Red Sub Level 1,” including procuring of safety gear and other preventive measures. By 12 March 2020, the country was announced to have reached “Code Red Sub Level 2,” which including a partial lockdown from Metro Manila, which expanded to Luzon by 16 March 2020. On 17 March, the president announced a state of calamity and was under probation for 6 months. On 17 April, the Philippines was reported to have reduced the virus reproduction number from 1.5 to 0.65. In late April 2020, the local government units were not allowed to authorize quarantine measures without proper consent.

3.10.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the spread of the outbreak in the Philippines is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 15. The pandemic outbreak spread initially with a doubling time of 29.2 days. The estimated SIR model parameters are given in Table 3. With a growing number of cases, the predicted total epidemic duration may last for 666 days, in which the total growth phase duration is 157 days.
3.11 Analysis of COVID-19 pandemic in Singapore

3.11.1 The sequence of cases originated and government actions

On 23 January, Singapore became the second country, along with Vietnam, to confirm its first COVID-19 case in Southeast Asia. Singapore has experienced up to 4 waves of recurring outbreaks. The first wave was described as early imported cases from China in January 2020, while the second wave was a growth of local clusters within Singapore from February 2020. The third wave came from Singapore citizens and permanent residents who had returned from abroad in March 2020, while the latest and fourth wave in Singapore was due to the spread of COVID-19 among migrant workers living in close quarters.

To control the spread, the Singapore government introduced the COVID-19 (Temporary Measures) Act 2020 and Control Order...
Regulations 2020. Singapore restricted travel into the country as early as January 2020 and banned all short-term travel from 23 March 2020. Other actions taken involved the closure of schools and nonessential workplaces. As of 24 June 2020, Singapore has confirmed at least 42,623 COVID-19 confirmed cases, 36,299 recovered cases, conducted 684,359 tests, and 26 death cases. At present, Singapore has the second-highest number of cases in Southeast Asia.

3.11.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the outbreak’s spread in Singapore is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 16. The pandemic outbreak spread initially with a doubling time of 7.2 days. The estimated SIR model parameters are given in Table 3. With a growing number of cases, the predicted total epidemic duration may last for 305 days, in which the total growth phase duration is 52 days. Based on the available data, the SIR model predicts that the end of the epidemic (5 cases) is estimated to be 8 October 2020, and the end of the epidemic (1 case)
is 7 November 2020. So far, the model predictions are perfect, and it has resulted in RMSE of 861.6 with $R^2$ of 0.997. Therefore it indicates that the SIR model predictions are good enough, but with the government taking more preventive measures, the epidemic may end much earlier than the model predicted.

3.12 Analysis of COVID-19 pandemic in Thailand

3.12.1 The sequence of cases originated and government actions

In Thailand, the first case of COVID-19 cases was reported on 13 January 2020, with its first local transmission on 31 March 2020. One of its highest transmissions occurred in mid-March through a Muay Thai fight at the Boxing Stadium, and cases rose by over a hundred each day over the weeks. As of 24 June 2020, there have been a total of 3156 confirmed cases in Thailand, with 3023 recovered cases and 58 deaths. A total of 468,175 tests have been conducted.

Thailand’s response to the pandemic included surveillance and contract tracing, screening at international airports and hospitals, as well as investigations in outbreak clusters with returning residents to undergo self-quarantine. On 5 March 2020, travel restrictions were announced; by 19 March 2020, medical certificates were required for international arrivals to the country. A curfew was ordered, which took effect on 3 April from 10pm to 4am to curb the spread of the virus, combined with the travel ban preventing foreigners from entering the country. The transmission rate has fallen to near zero by mid-May, so there has been a gradual easing of restrictions in the country.

3.12.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the outbreak’s spread in Thailand is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 17. The pandemic outbreak spread initially with a doubling time of 4 days. The estimated SIR model parameters are given in Table 3. The predicted total epidemic duration may last for 143 days, in which the total growth phase duration is 25 days. Based on the available data, the SIR model predicts that the end of the epidemic (5 cases) is estimated to be 11 June 2020, and the end of the epidemic (1 case) is 5 July 2020. So far, the model predictions are perfect, and it has resulted in RMSE of 56.6 with $R^2$ of 0.998. Therefore the SIR model predictions are good enough.
3.13 Analysis of COVID-19 pandemic in Vietnam

3.13.1 The sequence of cases originated and government actions

The first two COVID-19 cases in Vietnam were first reported on 23 January 2020, a father who had traveled from Wuhan, China, and supposedly infected his son whom he was visiting in Vietnam. As of 24 June 2020, there are 349 infected cases, 329 recovered cases, and 275,000 tests that have been conducted in the country. Vietnam is one of the few countries not to have any COVID-19 related deaths. The capital of Vietnam, Hanoi, is the worst affected area with 121 cases or 35% of total cases in the country.

Vietnam is recognized as having one of the best epidemic control programs in the world. On 22 March 2020, Vietnam took preventive measures to halt imported cases by suspending general flights into the country and only allowed controlled air travel subject to official approval. In contrast to its regional neighbors and other countries such as the United States, China, and the United Kingdom, the total number of cases in Vietnam is relatively low. Despite this, Vietnam is regarded to have experienced two waves of the COVID-19 spread in the country.
3.13.2 Forecasting of COVID-19 outbreak using the SIR model

Using the SIR model, the outbreak’s spread in Vietnam is forecasted. The SIR model-predicted profile is compared with the actual recorded cases, as shown in Fig. 18. The pandemic outbreak spread initially with a doubling time of 5.5 days. The estimated SIR model parameters are given in Table 3. The predicted total epidemic duration may last for 147 days, in which the total growth phase duration is 39 days.

Based on the data available so far, the SIR model predicts that the end of the epidemic (5 cases) is estimated to be 19 May 2020, and the end of the epidemic (1 case) is 19 June 2020. So far, the model predictions are perfect, and it has resulted in RMSE of 15.8 with $R^2$ of 0.985. Therefore the SIR model predictions are good enough.

4. Conclusions

The top 5 largest economies (Indonesia, Thailand, Singapore, Malaysia, and the Philippines) in Southeast Asia also represent the top 5 most...
significant number of COVID-19 cases in Southeast Asia. While Indonesia represents the largest economy, it also has the largest number of cases. In contrast, despite Thailand having the second-largest economy in Southeast Asia, it has the lowest number of cases among the top 5 largest economies. Also shown the fastest recovery, with most cases ranging between only 0 and 5 cases per day while Indonesia has averaged approximately 1000 cases per day.

When considering the economic and commercial features, Thailand has shown the best performance among all countries in controlling the pandemic. At the same time, Laos registered the lowest number of cases in Southeast Asia despite having a population of 7 million and the 9th largest economy in Southeast Asia. In this regard, Laos is arguably the safest country in Southeast Asia in terms of any potential future viral outbreaks.

As the collective economies of ASEAN are projected to grow to the top 5 economies of the world, this study will present the view of these ASEAN countries in terms of controlling pandemics.

Even though down the line, the policies of each country may change over the time and be in a better position, this study provides present insight into the strength and vulnerability of a country’s infrastructure, policies, people’s preparedness and country’s ability to respond to a crisis. The results presented in this study facilitate a benchmark for the governments, corporations, and individuals to understand the lacking infrastructure and medical facilities and develop better systems for potential future disease outbreaks.

**Contribution**

RRK (Conceptualization, modeling, editing, visual graphics); MZSAH (Data analysis, editing); YK (Data downloading, editing).

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