EVALUATING THE IMPACT OF SOCIAL DISTANCING ON COVID-19 SPREAD IN VIETNAM BY USING LOGISTIC GROWTH CURVE MODEL

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Abstract. *The regular increase in COVID-19 cases and deaths has resulted in a worldwide lockdown, quarantine and some restrictions. Due to the lack of a COVID-19 vaccine, it is critical for developing and least developed countries like Vietnam to investigate the efficacy of non-pharmaceutical treatments like social distance or national lockdown in preventing COVID-19 transmission. To address this need, the goal of this study was to develop a clear and reliable model for assessing the impact of social distancing on the spread of coronavirus in Vietnam. For the case study, the Logistic Growth Curve (LGC) model, also known as the Sigmoid model, was chosen to fit COVID-19 infection data from January 23, 2020 to April 30, 2020 in Vietnam. To determine the optimal set of LGC model parameters, we used the gradient descent technique. We were pleasantly surprised to discover that the LGC model accurately predicted COVID-19 community transmission cases over this time period, with very high correlation coefficient value r = 0.993. The results of this study imply that using social distancing technique to flatten the curve of coronavirus disease infections will help minimize the surge in active COVID-19 cases and the spread of COVID-19 infections.*

Keywords

Index Terms*— *COVID-19, social distancing, deep learning, sigmoid model, gradient descent.

1. Introduction

The COVID-19 pandemic was first identified in the Chinese city of Wuhan, Hubei Province [1]. COVID-19's appearance coincided with the Lunar New Year holiday, China's most festive time of year [2]. During this special and long-awaited holiday, a large number of Chinese citizens returned home. Approximately 5 million people left Wuhan, the epicenter of the COVID-19 pandemic, according to [3]. Approximately one-third of those people traveled outside of Hubei province. Because of the global nature of travel, they could have spread the virus inside China and to other countries [2].

Since COVID-19 spreads mainly from person to person who are in close physical contact (less than 6 feet of distance) for an extended period of time [4], social distancing is a measure to minimize pandemic spread by reducing face-to-face contact with others [5].

1.1. Literature review

Researchers have employed a variety of models in order to forecast the COVID-19 outbreak in the short and longer term [6], [7]. Dil and co-workers [8] utilized the Susceptible-Infected-Recovered (SIR) model to project confirmed COVID-19 cases in the Eastern Mediterranean region and forecasted that by June 20, 2020, Pakistan's COVID-19 case count could explode to an estimated half a million.

Using the Susceptible-Exposed-Infectious-Recovered (SEIR) deterministic model, Reno et al. [9] predicted the spread of COVID-19 and its burden on hospital care across several scenarios in Italy. Anastassopoulou and Russo [10] established a strategy for anticipating the spread of the COVID-19 pandemic in China by predicting the reproduction number (R0) using the Susceptible-Infected-Recovered-Deceased (SIRD) model and other critical factors.

Deep learning (DL) techniques play a critical role in the study and prediction of massive outbreak data patterns and aid in the early detection of coronavirus outbreaks [11]. Huang et al. used a convolutional neural network (CNN) model focused on DL to approximate the total reported cases of COVID-19 [12]. Bandyopadhyay et al. suggested the use of a gated recurrent neural network and long short term memory (LSTM) to test predictions using confirmed, negative released, and death cases of COVID-19 [13]. Moftakhar et al. [14] utilized Artificial Neural Network (ANN) and AutoRegressive Integrated Moving Average (ARIMA) model to forecast daily confirmed cases at the nation level in Iran. In [15], ANN-based curve fitting technique was developed for estimating the number of confirmed COIVD-19 cases in India, the United States, France, and the United Kingdom while taking into account the progressive patterns in China and South Korea.

Additionally, Parbat et al. [16] used a Support Vector Regression (SVR) model, a version of Support Vector Machine (SVM), with a Radial Basis Function (RBF) kernel approach to predict daily cases, recovered cases, and death cases. Hao [17] created an ensemble predictor of SVR and Random Forest (RF) to estimate the number of hospitalized patients seven days in advance.

A combined strategy of SVR and Autoregressive Integrated Moving Average (ARIMA) model was proposed to take confirmed cases and forecast the number of infected people across the country [18]. Because the ARIMA model is well-known for prediction, some researchers utilized it to forecast the pandemic's spread. Ahmar and co-workers proposed using ARIMA and the Sutte indicator approach to estimate the confirmed COVID-19 cases in Spain [19]. The authors used a seasonal ARIMA forecasting program with a R statistical model to predict COVID-19 outbreak daily reported and recovered infections [20]. Singh et al. presented an integration of discrete wavelet decomposition and ARIMA to estimate COVID-19-related deaths in France, Spain, Italy, the United Kingdom, and the United States [21].

Several previous studies, as summarized above, simulated and forecast the outbreak's path using models ranging from extremely simple to complex with a large number of variables and parameters. Table 1 summarizes some of the advantages and disadvantages of the aforementioned methods. However, a simple and effective methodology for measuring and evaluating the efficacy of social distancing techniques in preventing the COVID-19 pandemic remains undeveloped.

1.2. Our methodology

Although time-series methods like ARIMA are suitable for real-time applications [22, 23], we prefer the batch-based methods like sigmoid-model in deep learning in this paper because our aim is to design a fitting model for a long-time period of Covid-19. Indeed, since batch-based methods take into account all data in the past, they are more suitable for validating our proposed sigmoid-based model.

Tab. 1: Pros and cons of the above methods.

Algorithms	Advantages	Disadvantages
SIR [8], SEIR [6], [9], SIRD [7, 10]	Predict the spread of COVID-19 and the impact of public health actions on the pandemic outbreak	The models that have been proposed are essentially deterministic and can be used with huge populations
DL [11, 12, 13]	The algorithm's performance is comparable to that of a human expert	In order to train a model, it is necessary to collect enormous volumes of data
ANN [14, 15]	There are various different training methods that the algorithm might access	The characteristics of ANNs include their black box nature, higher computational workload, proclivity to over-fitting and over-training
SVM [16, 17, 18]	The algorithm is particularly useful for avoiding over-fitting and determining the convex optimization problem	Classification has several restrictions, especially during both training and testing phases, as well as limits on the selection of kernel function coefficients
ARIMA [19, 20, 21]	The methodology is applicable to seasonal and nonseasonal models, and outliers can be treated effectively	When there are shifts in observation and modifications in model specification, the model becomes unstable

Sigmoid functions have gained popularity in deep learning as an activation mechanism in an artificial neural network [24]. Sigmoid functions are also useful in a wide variety of machine learning applications that include the conversion of a real number to a probability [25]. When used as the final layer of a machine learning algorithm, the sigmoid function can be used to transform the model's output to a probability score, which is often easier to deal with and interpret. Another use of the sigmoid equation is discussed in this article: population growth modeling.

In general, a novel contagious pathogen to which a population lacks immunity can spread exponentially in the early stages, when the supply of susceptible individuals is abundant. COVID-19 was caused by the SARS-CoV-2 virus, which grew exponentially early in the process of infection in many countries in early 2020 [26]. Due to a variety of causes, including a lack of susceptible (either through continued infection spread before it reaches the threshold for herd immunity or through physical distancing policies), exponential-looking disease curves may first linearize and then reach a maximum limit[27].

A sigmoid function can be used descriptively or phenomenologically since it fits perfectly not just with the initial exponential growth, but even with the pandemic's subsequent leveling off when the populace gains herd immunity. This contrasts with actual pandemic models, which seek to formulate a description based on the pandemic's dynamics (e.g. contact rates, incubation times, social distancing, etc.).

1.3. Our contribution

The aim of this study is to demonstrate that the Vietnamese government's country social distancing policies would have a crucial and important effect on slowing the spread of the coronavirus and eventually suppressing it. We examine the COVID-19 outbreak's prevalence in Vietnam using real-time occurrence data and a compartmental mathematical model, as well as a logistic growth curve model.

Gradient Descent is a well-known optimization method in Machine Learning and Deep Learning, and it can be used for the majority of learning algorithms [28, 29, 30, 31]. In this work, Gradient Descent is used to estimate the values

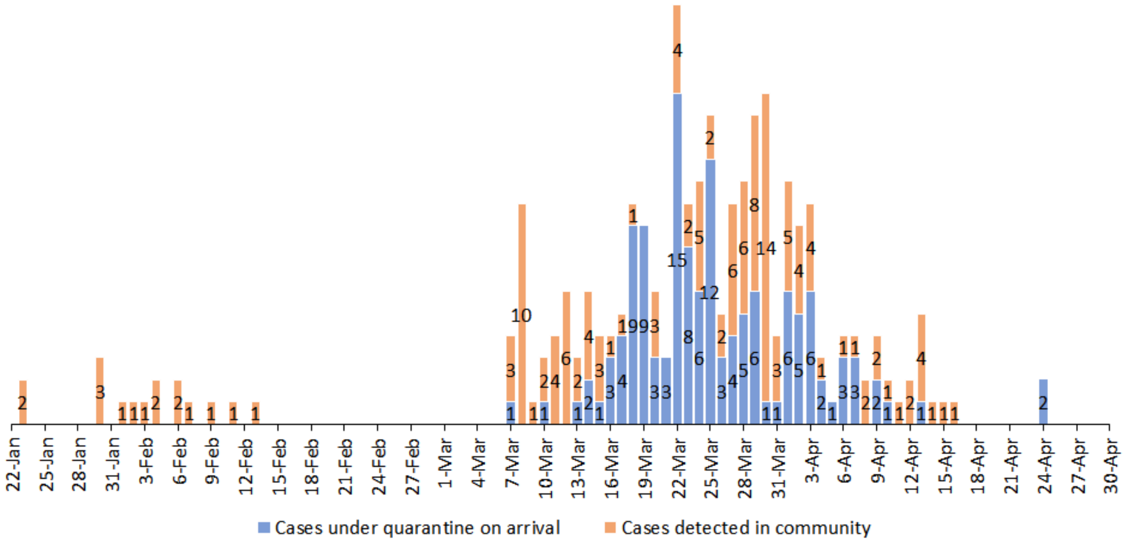

Fig. 1: Progress of the COVID-19 outbreak in Vietnam (from January 23, 2020 to April 30, 2020).

of parameters of the sigmoid function that minimizes a least square cost function. More specifically, we present the findings of an analysis of COVID-19 cases in Vietnam before and after social distancing measures. The data indicate that daily cases declined after the lockdown, implying that the lockdown interventions have been effective in suppressing the disease so far.

1.4. Organization of paper

The following is the organization of the paper. The materials and method are presented in the second section. Section 3 describes the results and discussions. Finally, section 4 gives some conclusions.

2. Material and method

2.1. Material

Vietnam, a neighboring nation of China, recorded the first case of COVID-19 on January 23, 2020 [32]. Two Chinese men were found to be infected with the coronavirus and were treated at the Cho Ray hospital in Ho Chi Minh City, Vietnam. Since then, the government has imposed plenty of public-health measures to combat the outbreak. The data used in this study was obtained from the Vietnamese Government information channel, which was published by Vietnam News Agency (https://baotintuc.vn/) as well as [33]. We created a dataset by combining data from both sources from January 23, 2020 to April 30, 2020. The data used in the modeling is defined in Appendix A. The dataset contains the number of new confirmed COVID-19 imported cases and local transmission cases on a daily basis, as seen in Fig. 1. The COVID-19 case pattern in Vietnam is depicted in Fig. 2. We concentrate on COVID-19 cases reported in the community.

2.2. Method

An Logistic Growth Curve (LGC) was used in our research to analyze and model the growth of COVID-19 infections in Vietnam [34]. LGC is an S-shaped sigmoidal curve that increases growth in the beginning period, but reduces growth later on. In logistic growth, a population's per capita growth rate decreases as population size reaches a threshold imposed by scarce

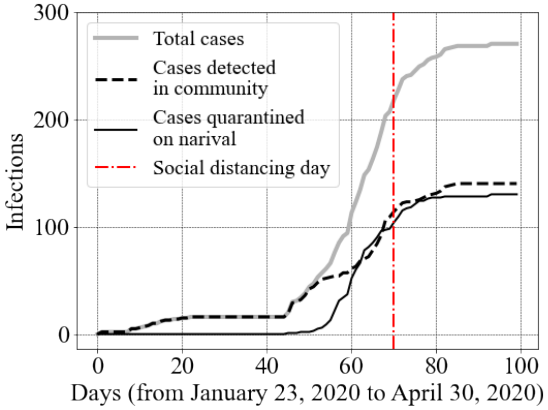

Fig. 2: Cumulative number of actual COVID-19 cases in Vietnam (from January 23, 2020 to April 30, 2020).

environmental resources. LGC is defined by the following equation:

$$y(t) = \frac{K}{1 + ae^{-bt}} \tag{1}$$

wherein:

y is the cumulative number of infections occurring at a certain time t;

K is referred to as the "Carrying Capacity";

a, b are the parameters that determine the form of the curve;

The least square error (LSE) [35] was used in this study, which defined the cost function as:

$$J(\theta) = \frac{1}{n}\sum_{i=1}^{n}[h_\theta(t^{(i)}) - y^{(i)}]^2 \tag{2}$$

where θ is a parameter vector (a, b) to optimize; $y^{(i)}$ is the cumulative number of confirmed cases at a particular point in time $t^{(i)}$; n is the number of data points; and $h_\theta(t^{(i)})$ is the projected total number of confirmed cases at a certain time $t^{(i)}$ for a particular θ based on Eq. (1). The goal is to discover values that gives minimum cost value when the predicted value and the actual data are close to each other, as determined in Eq. (2).

To achieve the objective, we employ a gradient descent-based iterative method. (i.e. Python's Trusted Region algorithm is used in this case) to determine the appropriate value θ to achieve LSE in Eq. (2) for data fitting [36]. Also, the gradient descent is a computationally efficient method. It is well-known that the gradient descent algorithm for univariate function only needs a linear computational complexity $O(kn)$, where k is the number of iteration and n is the number of data.

Regularly, when the date is determined, K is used as the total population. Alternatively, the value of K is not constant in the COVID situation and continues to grow larger day by day. To determine an acceptable value for K, we follow Meyer and Ausube's procedure [37] in the process of optimization/iteration. If a sequence of data is provided, estimating the value of K is also straightforward since the model can forecast the growth rate.

A drawback of the gradient descent is that it is an iterative approach for seeking function's local minima. It does not always find the global minimum and may become trapped at a local minimum. Nonetheless, we found that the numerous alternative sets of parameters in our gradient descent method of LGC model all provided a good fit of the data and their differences were neglectable. We speculate that for a simplistic univariate model like LGC, our local minima of gradient descent may be very close to the global minimum.

3. Results and discussions

3.1. Results

The LGC model was fitted to the available data in this study to determine the efficacy of social distancing policies in containing the spread of COVID-19 in Vietnam.

To assess the impact of social distancing on disease prevention, we collected data over a 99-day period beginning with the outbreak of the epidemic in Vietnam. This data is used to approximate the parameters of the logistic model. The total number of actual and expected cases overlapping is shown in Fig. 3. Our fitted infections in Fig. 3 were very close to the observed data of infections. They have a very strong

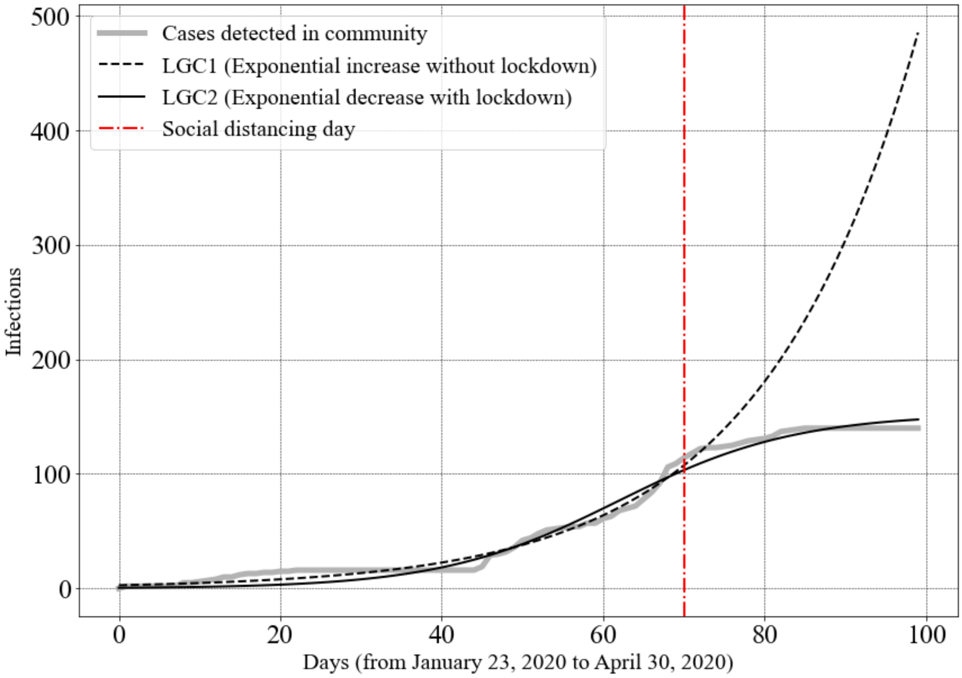

Fig. 3: The actual and logistic model fitted results of COVID-19 infection in Vietnam based on data from January 23, 2020 to April 30, 2020. (Notes: LGC1 estimated with data before social distancing day, parameters $a = 23163220.203$, $b = 0.052$, $c = 65345425.117$ and LGC2 estimated with data before and after social distancing day, parameters $a = 278.347$, $b = 0.091$, $c = 152.582$).

Pearson's correlation coefficient ($r = 0.993$) [38] when plotted against each other, as shown in Fig. 4. This demonstrates the importance of social distancing interventions in reducing the overall number of infections in the community exponentially.

Figure 5 depicts the progression of the epidemic in Vietnam, as well as the effects of the logistic model, from its inception to the day when the government implemented social distancing policies. The figure represents the number of COVID-19 infections in the community and the estimated number of confirmed cases based on the logistic model being similar to each other. This demonstrates the pandemic's risk, as the number of confirmed COVID-19 cases in the population grows exponentially.

Finally, as shown in Fig. 6, the total number of actual infections increased gradually over 120

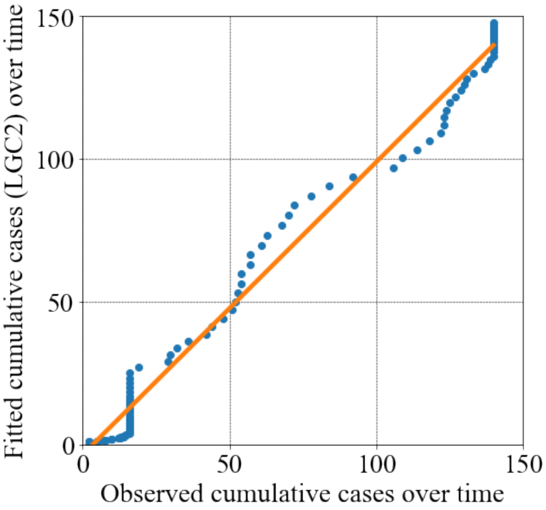

Fig. 4: Goodness-of-fit of LGC2 model, with Pearson's correlation coefficient $r = 0.993$. The closer to the 45-degree line, the better the fitting curve.

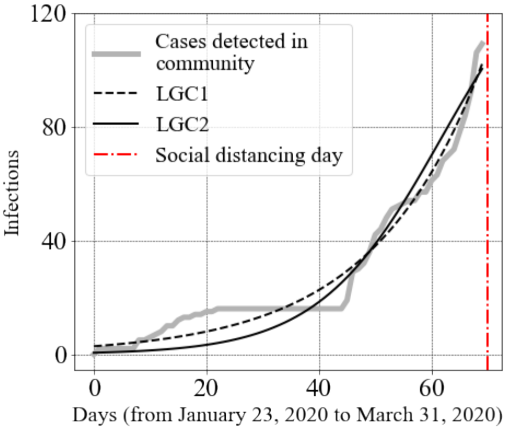

Fig. 5: The actual and predicted growth of COVID-19 infection in Vietnam from the beginning of the outbreak to the day before national social distancing. (Notes: LGC1 estimated with data before social distancing day, parameters $a = 23163220.203$, $b = 0.052$, $c = 65345425.117$ and LGC2 estimated with data before and after social distancing day, parameters $a = 278.347$, $b = 0.091$, $c = 152.582$).

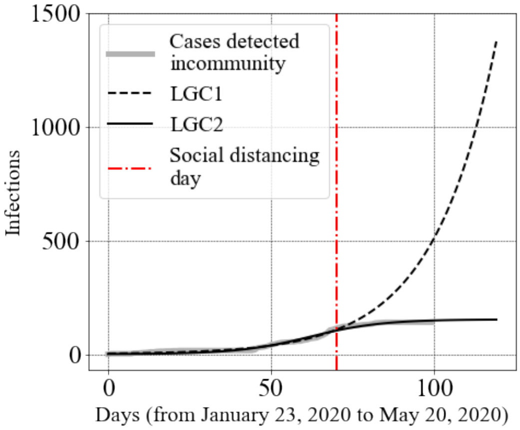

Fig. 6: The actual data in the period of 120 days from the beginning of the outbreak and the predicted growth of COVID-19 infection in Vietnam. (Notes: LGC1 estimated with data before social distancing day, parameters $a = 23163220.203$, $b = 0.052$, $c = 65345425.117$ and LGC2 estimated with data before and after social distancing day, parameters $a = 278.347$, $b = 0.091$, $c = 152.582$).

days and then remained constant at 140; however, the algorithm predicts that the total number of infections would exceed 1300. This finding demonstrates the COVID-19 infection pattern in Vietnam in the absence of social distancing measures and demonstrates the efficacy of nationwide social distancing regulations.

3.2. Discussions

Vietnam slowly lifted social distancing policies and movement restrictions on May 8, 2020, after being closed for nearly a month [39]. On 19th May 2020, Vietnam was one of the few countries to enter the normal situation at the earliest [40]. As shown in Fig. 7, several international media organizations praised Vietnam for its exceptional performance in combating the COVID-19 pandemic at the time. The Financial Times, one of the world's leading newspapers, published an article on March 24, 2020, highlighting that Vietnam's coronavirus defense deserves praise for a low-cost model [41]. Social distancing appears to have been a factor in limiting the mass spread of COVID-19 infection in Vietnam, as shown by this research. The imposition of social distancing had averted the worst-case scenario of the pandemic. It has aided the Vietnamese government in flattening the infection curve through the collaboration of various agencies and the general public. It is important to understand that social distancing is not intended to eradicate COVID-19 entirely; rather, it is intended to flatten the curve, minimize an increase (or tall curve) in infections or the number of reported active COVID-19 cases. This is to ensure that a country's health systems are safe and prepared to deal with a pandemic.

4. Conclusions

COVID-19 vaccines are rare, hence it is vital for underdeveloped nations like Vietnam to study other means of avoiding COVID-19 spread, such as social distance or national lockdown. This paper has presented a reliable model representing the impact of social distancing on the spread of coronavirus in Vietnam.

Our data analysis revealed that there was an exponential rise in the number of coronavirus cases in the population, then the growth was

PRAISE OF INTERNATIONAL MEDIA

Vietnam's success in COVID-19 lockdown

Suffering no deaths from the virus and had limited total infections to just 288, despite being next door to China. Vietnam has been widely praised for its success in tackling COVID-19.

Despite its border with China, low income and population of 95 million, Vietnam is an outlier success story in the pandemic. It has 270 confirmed cases of the virus and no deaths.

When the health care systems of most powerful countries in the world have failed to curb the spread of COVID-19, Vietnam performed an outstanding work against the pandemic.

International media has praised Vietnam's handling of the crisis, which has resulted in relatively few cases and not on death, considering Vietnam neighbors China.

Vietnam chose to prevent rather than fight Covid-19, a strategy which means it has had no virus deaths.

Even if we consider these numbers with a dose of caution, one thing is clear: Vietnam has a done a good job thus far in fighting the coronavirus.

Vietnam is a lower-income, densely populated country that shares a large land border with China, where the outbreak first began.

The particularities of domestic politics in Vietnam that have led to such surprisingly effective responses from the government and its people against the pandemic.

Fig. 7: Global media attention was drawn to Vietnam's outstanding successes in combating the COVID-19 pandemic. [42, 43, 44, 45, 46, 47, 48, 49, 50].

slowed down to linear, and eventually the growth fell exponentially after the government implemented social distancing steps. Owing to this exponential phenomenon, we found that the Logistic Growth Curve (LGC) model, also known as Sigmoid model, is a suitable model for fitting COVID-19 infection results. In this study, the LGC adequately fit Vietnam COVID-19 community transmission data before and after the social distancing day. Furthermore, the LGC model calculated with data prior to social distancing suggested that if physical distancing actions were not undertaken, the number of COVID-19 cases predicted would grow dramatically.

The results show that social distance may have aided in the containment of COVID-19 infection in Vietnam and other nations around the world. This findings could help future study into preventing and controlling COVID-19 infection spread.

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Appendix A: Dataset

Days	Date	A	B	C	D	E	Days	Date	A	B	C	D	E	Days	Date	A	B	C	D	E
1	23-Jan-20	0	2	0	2	2	34	25-Feb-20	0	0	0	16	16	67	29-Mar-20	6	8	96	92	188
2	24-Jan-20	0	0	0	2	2	35	26-Feb-20	0	0	0	16	16	68	30-Mar-20	1	14	97	106	203
3	25-Jan-20	0	0	0	2	2	36	27-Feb-20	0	0	0	16	16	69	31-Mar-20	1	3	98	109	207
4	26-Jan-20	0	0	0	2	2	37	28-Feb-20	0	0	0	16	16	70	01-Apr-20	6	5	104	114	218
5	27-Jan-20	0	0	0	2	2	38	29-Feb-20	0	0	0	16	16	71	02-Apr-20	5	4	109	118	227
6	28-Jan-20	0	0	0	2	2	39	01-Mar-20	0	0	0	16	16	72	03-Apr-20	6	4	115	122	237
7	29-Jan-20	0	0	0	2	2	40	02-Mar-20	0	0	0	16	16	73	04-Apr-20	2	1	117	123	240
8	30-Jan-20	0	3	0	5	5	41	03-Mar-20	0	0	0	16	16	74	05-Apr-20	1	0	118	123	241
9	31-Jan-20	0	0	0	5	5	42	04-Mar-20	0	0	0	16	16	75	06-Apr-20	3	1	121	124	245
10	01-Feb-20	0	1	0	6	6	43	05-Mar-20	0	0	0	16	16	76	07-Apr-20	3	1	124	125	249
11	02-Feb-20	0	1	0	7	7	44	06-Mar-20	0	0	0	16	16	77	08-Apr-20	0	2	124	127	251
12	03-Feb-20	0	1	0	8	8	45	07-Mar-20	1	3	1	19	20	78	09-Apr-20	2	2	126	129	255
13	04-Feb-20	0	2	0	10	10	46	08-Mar-20	0	10	1	29	30	79	10-Apr-20	1	1	127	130	257
14	05-Feb-20	0	0	0	10	10	47	09-Mar-20	0	1	1	30	31	80	11-Apr-20	0	1	127	131	258
15	06-Feb-20	0	2	0	12	12	48	10-Mar-20	1	2	2	32	34	81	12-Apr-20	0	2	127	133	260
16	07-Feb-20	0	1	0	13	13	49	11-Mar-20	0	4	2	36	38	82	13-Apr-20	1	4	128	137	265
17	08-Feb-20	0	0	0	13	13	50	12-Mar-20	0	6	2	42	44	83	14-Apr-20	0	1	128	138	266
18	09-Feb-20	0	1	0	14	14	51	13-Mar-20	1	2	3	44	47	84	15-Apr-20	0	1	128	139	267
19	10-Feb-20	0	0	0	14	14	52	14-Mar-20	2	4	5	48	53	85	16-Apr-20	0	1	128	140	268
20	11-Feb-20	0	1	0	15	15	53	15-Mar-20	1	3	6	51	57	86	17-Apr-20	0	0	128	140	268
21	12-Feb-20	0	0	0	15	15	54	16-Mar-20	3	1	9	52	61	87	18-Apr-20	0	0	128	140	268
22	13-Feb-20	0	1	0	16	16	55	17-Mar-20	4	1	13	53	66	88	19-Apr-20	0	0	128	140	268
23	14-Feb-20	0	0	0	16	16	56	18-Mar-20	9	1	22	54	76	89	20-Apr-20	0	0	128	140	268
24	15-Feb-20	0	0	0	16	16	57	19-Mar-20	9	0	31	54	85	90	21-Apr-20	0	0	128	140	268
25	16-Feb-20	0	0	0	16	16	58	20-Mar-20	3	3	34	57	91	91	22-Apr-20	0	0	128	140	268
26	17-Feb-20	0	0	0	16	16	59	21-Mar-20	3	0	37	57	94	92	23-Apr-20	0	0	128	140	268
27	18-Feb-20	0	0	0	16	16	60	22-Mar-20	15	4	52	61	113	93	24-Apr-20	2	0	130	140	270
28	19-Feb-20	0	0	0	16	16	61	23-Mar-20	8	2	60	63	123	94	25-Apr-20	0	0	130	140	270
29	20-Feb-20	0	0	0	16	16	62	24-Mar-20	6	5	66	68	134	95	26-Apr-20	0	0	130	140	270
30	21-Feb-20	0	0	0	16	16	63	25-Mar-20	12	2	78	70	148	96	27-Apr-20	0	0	130	140	270
31	22-Feb-20	0	0	0	16	16	64	26-Mar-20	3	2	81	72	153	97	28-Apr-20	0	0	130	140	270
32	23-Feb-20	0	0	0	16	16	65	27-Mar-20	4	6	85	78	163	98	29-Apr-20	0	0	130	140	270
33	24-Feb-20	0	0	0	16	16	66	28-Mar-20	5	6	90	84	174	99	30-Apr-20	0	0	130	140	270

Notes:
A: Cases under quarantine on arrival
B: Cases detected in community
C: Total cases under quarantine on arrival
D: Total cases detected in community
E: Total cases