Simulating the COVID-19 epidemic event and its prevention measures using python programming

Mustofa Abi Hamid[1], Dimas Aditama[1], Endi Permata[1], Nur Kholifah[2], Muhammad Nurtanto[3], Nuur Wachid Abdul Majid[4]
[1]Department of Electrical Engineering Vocational Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
[2]Department of Clothing and Food Engineering, Faculty of Engineering, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[3]Department of Mechanical Engineering Vocational Education, Faculty of Teacher Training and Education, Universitas Sultan Ageng Tirtayasa, Serang, Indonesia
[4]Department of Information System and Technology Education, Faculty of Technological and Vocational Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

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ABSTRACT

A simulation is needed to observe and indicate how much preventive measures influence the pandemic flow, controlling and stopping it. This study succeeded in making a stochastic susceptible infected recovered deceased (SIRD) simulation using Python programming language to determine the effectiveness of prevention methods such as masks policy, social distancing, vaccination, quarantine, and lockdown. Every preventive measure is modeled based on an equivalent actual event and every essential aspect that affects the course of the pandemic. A person is represented as a circle moving freely in two-dimensional space, and disease spreads through person-to-person contact. This simulator then tested using parameters to simulate COVID-19 and found significant results between communities that implement preventive measures and those that do not. We found that within 106 days, 284 people were infected, but when five preventive methods are applied for a total of 33 days, only 31 people were infected. Adequate to simulate epidemic events and their prevention measures, this simulator can also be used as a learning tool with factors in epidemic events such as population density, mobility, infection rate, disease mortality, and every effect of each preventive measure. Users can change and influence the simulation course using interactive and straightforward software tools.

Corresponding Author:

Mustofa Abi Hamid
Department of Electrical Engineering Vocational Education, Faculty of Teacher Training and Education
Universitas Sultan Ageng Tirtayasa
Ciwaru Raya street No. 25, Serang, Banten, Indonesia
Email: abi.mustofa@untirta.ac.id

1. INTRODUCTION

The high infection rate is determined by the disease's ability and other supporting factors such as regional and population factors [1]. Especially in modern society, interactions can occur in different environments involving many people between groups or communities [2]–[5]. Communities divided into several groups spread infectious diseases from one person to another in a short time. Comprehensive prevention measures are the only way to control, maintain, and suppress the spread in a community group or between communities [6]. For example, the recent rapid spread of COVID-19 is one of the natural transmission forms influenced by area contours, the disease itself, and people's interaction [7]. This

COVID-19 disease has a high infection rate and immediately infected modern society, which has escalated from an epidemic into a pandemic. Every government act by implementing preventive measures to regulate its people, including limiting and other policies tremendously affects this high spread level, thus flattening the graph. In addition, there are several uses of technologies that can help patients who show symptoms to be verified through IoT [8], namely smart knowledge based system (SKBS). The system displays the patient's location, phone number, date and time of examination [8]. In addition, the government also sets learning policies at various levels of education conducted online [4], [9], [10].

In some literature, the prediction of COVID-19 has been done using various ways such as in the paper [11]–[14]. Five prevention methods have been or are being implemented by all countries, including Indonesia to deal with the COVID-19 outbreak, including; masks policy [15], social distancing [16], quarantine [17], vaccination [18] and lockdown [19], [20]. In Indonesia, the health minister’s decision number HK.01.07/MENKES/239/2020 concerning large-scale social restrictions (PSBB) in the DKI Jakarta area [21] in the context of accelerating the prevention of Corona virus disease 2019 [22], which is generally semi-lockdown prevention is implemented. Over time, the development of a vaccine against this disease has successfully been made with a high enough success rate to be applied to the community even though it has not been able to build individual immunity [23]. Indonesia has also implemented vaccinations with the target number of vaccines reaching half of the total population. Looking at each country trying to reduce the infection rate and all the precautions mentioned have the same goal of stopping the disease. So, the question arises, which preventive measure is more effective? How can we find out?

Epidemic events have a complicated and complex flow of events, but this event can be generally simplified into a mathematical model. We are using the susceptible infected recovered (SIR) model widely used for modeling infectious diseases. Starting from disease prediction [24] to include some preventive measures into the model, such as vaccination [25], investigating the effectiveness of social distancing [26], and during the lockdown period [27]. This model is the simplest epidemic model, and can be developed further according to the needs and understanding of the researcher’s analysis into other models such as susceptible-exposed-infectious-recovered (SEIR) [28], [29], susceptible exposed quarantined infected recovered (SEIQR) [30] to other models such as auto-regressive integrated moving average (ARIMA) [31], [32], and the latest susceptible infected diagnosed ailing recognized threatened healed extinct (SIDARTHE) model [33], and others. For convenience and simplification of the epidemic model in this study, the SIRD model will be used by adding the deceased population into the mathematical model. The complex nature of society and the transmission of the disease have many interrelated factors making it difficult to understand as it’s spread along with the population. We can solve this problem by creating epidemic simulations that represent actual events by simplifying things and taking the epidemic’s main factors for better observability. The simulation results, which is a detailed description of this actual event, can predict epidemic events. This prediction then can help the authorities to make more informed decisions to control the epidemic.

In this study, a computer simulation will modulate various preventive measures applied to the COVID-19 pandemic. This simulation is designed to understand and prove how much influence prevention measures have on the rate of disease in modern society. Also, to adequately observed the complexity of the disease’s transmission. The modeled preventive measures include masks policy, social distancing, quarantine, vaccination, and lockdown. Armed with a disease spread model, this simulation itself can be used as a pedagogical learning medium. The simulation is intended to demonstrate how disease spreads with the various variables followed.

2. RESEARCH METHOD

2.1. Mathematical models and simulation modeling

This model is the addition of the deceased population variable from the SIR model. A more specific model for finding and predicting epidemic events is obtained by separating the deceased and recovered. This addition has also been rendered in [34], [35] with similar purposes. The following is the SIR flow after becoming a SIRD, see Figure 1.

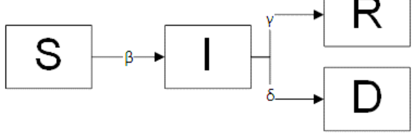


Figure 1. Flowchart of modified SIRD model from SIR model

Where as β is the infection rate, the shift from Susceptible to Infected, γ is the healing rate, the shift from Infected to Recovered, δ is the death rate, the shift from Infected to Deceased. The simulation program based on the diagram flow above with each item represents a programming subject using a stochastic approach. Simulation is created on a 2D screen that represents the environment, and 2D circles represent people. This 2D screen is a square or rectangle whose value can be arranged by the user with the formula Lp×l. The values of p and l are in pixel used to initiate the simulation screen where people interact. To distinguish each person based on their condition in an epidemic, we will indicate it based on color see Figure 2. Figure 2(a) is a simulation design for person susceptible with white visualization, Figure 2(b) is a simulation design for people infected with COVID-19. While the simulation of people recovering from COVID-19 is visualized with blue as in Figure 2(c) and green color for people who are deceased due to COVID-19 as in Figure 2(d).

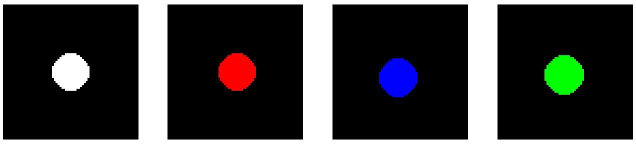


Figure 2. Design of each person: (a) person susceptible, (b) infected, (c) people recovered, and (d) deceased

The entire program script is written in Python using several libraries including, pymunk, pygame, random, deque, pandas, and matplotlib. The program comprises seven main classes: global variable, person, city, gate, data, timer, and simulation. The global variable class is the program's head, which contains the main parts that manage the simulation, such as epidemic elements and preventive measures. The person class comprises functions that regulate the state of a person in the simulation. The city class comprises functions that control the simulation area screen where the epidemic is simulated. The gate class comprises functions that govern the lock gate during the lockdown period. The data class comprises functions that capture, store, display, and manipulate event data from the simulation. The timer class comprises functions that regulate everything related to time in the simulation. The simulation class is the main program class with all the called classes on which the simulation is molded.

This simulation program is designed for anyone with a basic knowledge of Python language and epidemic events. Simple, modular, and straightforward design in easy-to-understand Python language lets users utilize this software efficiently and understand epidemic events clearly and educatively. The simulation results provide a visual description of how the epidemic occurs, when it will end, the effects of preventive measures, and how to control the disease's infection rate. Each of these circles has a set of state settings to represent a person in motion. The first is the diameter value which is not equal to zero (d≠0) as a person's body value, and this d value is in pixel. The second is the direction and speed of a person moving, which will be arranged randomly with a maximum value limit representing the random movement of people to create homogeneous mobility. This direction and velocity are written in a coordinate system: $\vec{J} = J\ (m, -m)$, where J is the speed in pixel/second and is given randomly. The direction is determined based on the two values of m, which represent the coordinates system. Because the value of m is only one with two notations and is given randomly, the direction and speed of a moving person will be according to the model and evenly distributed as desired.

To simulate the SIRD epidemic model, we will represent these conditions in the circles we have created. In this epidemic model, a person experiences four states of conditions: susceptible-infected-recovered-deceased, with the recovered and deceased states being separate states. This state is established using a True or False value statement in the person class for each item. For example, the normal state at the beginning of the simulation is susceptible, so we set susceptible=true and infected=false. When a person is infected, the program automatically will change to susceptible=false infected=true, and so on. Furthermore, we only need to determine the aspects that the situation has in someone who experiences it. The susceptible state is described as the initial state of a person who becomes infected if he comes into contact with an infected person. An infected state is a person who has/carries a disease and is able to infect other people who come into contact with him. Contact itself is a form of direct touch from person to person. We certainly realize the COVID-19 can spread through the air medium via water droplets, and for modeling and simplification, we represent this in the form of contact mentions before. The recovered state is the state of a person who has recovered from the disease and is immune to the disease in the sense that if he makes contact with an infected person, he will not be reinfected. The deceased state is the state of a person who died due to illness. People who are declared deceased will not be able to move in simulation to represent their state.

The values of β, γ, and δ from Figure 1. are described as separate and independent parameters. The value of β is determined by the number of contacts that occur in one day between susceptible and infected people, which is influenced by the number of populations, the area size, and the speed of people moving or mobility. The values of γ and δ are determined by one value each in the program script. The value of γ is a value that states how long a person will recover from being infected in seconds. The value of δ is a percentage value that expresses the probability that people will die after being infected. After successfully modeling the initial equation, the next step is to model each precaution [36]. We model each prevention measure based on actual events and by definitions that best describe it. Keep in mind some of the descriptions below are operational definitions used in this simulation that are slightly different because of the simulation modeling process.

2.2. Testing scenario

We will be applying two scenarios in this study to determine the program's success in simulating and predicting the COVID-19 pandemic based on the model that has been designed. The test is divided into two tests: simulation without preventive measures and simulation with preventive measures to analyze their differences. Several interrelated parameters to complete the initial conditions of the simulation are established to represent the natural environment. A person is described as a circle with a diameter of 10 pixels in a ratio equivalent to 50 cm. So, 1 meter in the simulation is two times the diameter of a person. The meter unit in the simulation is defined as (1):

$$N_S = d_O \times 2$$
$$N_S = 10 \times 2$$
$$N_S = 20 \textit{ pixels} \quad (1)$$

where, N_S = Pixel value equivalent to 1 meter; d_O = Diameter of a person.

The simulation screen as an epidemic simulation space will have a length of 1000 pixels and a width of 710 pixels. These values are pure experimental values as the screen area follows the size of the computer screen used. The simulated screen area will be as such in meters:

$$L_S = \frac{p_S - \mathrm{M}}{N_S} \times \frac{l_S - \mathrm{M}}{N_S}$$
$$L_S = \frac{1000 - 20}{20} \times \frac{710 - 20}{20}$$
$$L_S = 1690{,}5 \text{ m}^2 \quad (2)$$

where: L_S = Simulation screen area (in square meters); p_S = Simulation screen length; l_S = Simulation screen width; M = Screen margin.

The community population is set at 300 people. This number is purely an experiment to create population density in simulation. So, there are approximately two people in 10 m^2. Each person will appear on the simulation screen evenly distributed by random placement and then move at a random speed and direction. Within the problem constraints, one day is equal to one second. The speed in the simulation is a pure experimental value entered to create population mobility, which is 0.5 meters/day. Based on (1) the value entered into the program becomes 10 pixels. Each person's direction and speed will be set randomly with speed values between 0 meters/day to 0.5 meters/day. Why is this speed value so low? This is because to create a relatively stable movement of people. A crash will occur if this value is too high and outnumber the simulation screen's value. In addition, the movement of people who are too quick will complicate observing events during the simulation. Based on these fixed variables, the simulation will be executed. Based on previous research [37], population density and mobility significantly affect the infection rate.

Next are the parameters related to the disease. Taking from COVID-19 disease, we model the transmission chance value to represent the disease's spreadability. The higher the value, the more likely people will acquire the disease in a single contact with an infected person-conversely, the lower this value, the lower the disease probability to transmit. The transmission chance will be at 100%. In other words, the disease will be transmitted in one contact between a susceptible person and an infected person. The value of 100% is taken purely as an experimental value to illustrate that the COVID-19 disease spreads from one person to another so easily and quickly with the initial assumption that there is no protection between the involved people.

The recovery time value represents the length of time a person is in an infected condition to recover. In this research experiment, the recovery time is 14 days as the average time for someone infected with COVID-19 to recover based on many circulating sources such as the centers for disease control and prevention (CDC) [38], Bappenas [39], news articles from the conversation [40], and health [41]. This value is fixed for all infected persons, there is no incubation period based on the designed SIRD model, as well as other considerations based on the limitations in this study. The mortality rate is a percentage value of a person dying from the disease they are suffering from. Based on the Kompas article by Dian [42] and other data on COVID-19 cases in Indonesia dated May 23, 2021, the mortality rate in Indonesia is around 2.7%. This value is rounded to 3% so that there is a 97% chance of an infected person recovering from the disease. This is because the simulation requires an integer value to function optimally. So, the following are fixed variables that will be used in each simulation scenario, see Table 1. Two simulation tests will be performed using the fixed variables above to compare the results. The following are individual scenarios.

Table 1. Fixed variable testing

Parameter	Mark
Total population	300 people
Simulation screen area	1000×710 pixels
Person size/diameter	10 pixels
The maximum speed of people	10 pixels
Transmission chance	100%
Recovery time	14 days
Mortality rate	3%

2.2.1. Epidemic with precautions

Patient zero or the first case infected at the start of the simulation will initiate by 1 person with a random appearance location on the simulation screen. Simultaneously, the day in the simulation starts from 0. Then mask policy from the 14th day until the number of infected people is 0 or the epidemic's end. In the program, we can fill this mask policy end value with an immense value (such as the 1000th day because the end of the simulation is unknown). On the same day, people began to practice social distancing and continued until the number of infected people was 0 or the epidemic's end.

Furthermore, the quarantine of infected people is implemented from the 17th day. Then the lockdown began to be implemented from the 40th day to the 95th day. All values above are taken based on the sequence of events in Indonesia recorded by [39] from 2020. The value of the effectiveness of the mask in capturing disease particles is 50%. This value is taken based on the article [43] with the assumptions mentioned above and limitations. In the program, the mask policy decreases the transmission chance value by as much as the effective percentage value of the mask. This is based on evidence that the mask policy can reduce the possibility of people who wear them contracting the disease and vice versa when sick people wear them [15]. Then the number of people who practice social distancing in this experiment is 50% of the total population. This value is purely an experiment based on the article's reference [44]. In quarantine prevention measures, we will quarantine people once a day by assigning a value of the initialized quarantine schedule (day scheduled quarantine) 1. The number to be quarantined (quarantine rate) is 20% of the total infected each day. Then for people who do not have symptoms, it is represented as the residual value of the quarantine chance, which is 50% of the total infection [45].

During a lockdown, this activity is assumed to execute exquisitely and fully implemented the contaminated area is completely closed from the outside world. The lockdown value to represent such a situation is 100% in the program. This value is based on [18] the lockdown regulation in Indonesia. We find it difficult to simulate vaccination based on actual events as the Covid vaccine fully developed after 1 year of the pandemic. While in simulation, it is questionable the disease still infects after a count of more than 365 days. Then vaccination in the simulation experiment will be implemented 10 days before the lockdown measures are completed with a schedule of once every 3 days.

The number of people vaccinated every period is 30% of the total susceptible population. This value is purely experimental. The vaccination chance value is at 90% to represent vaccines successfully build a person's immune system [46]. Because this epidemic simulation program employs a stochastic approach, the simulation will execute 10 times to get the average results from the simulation. The following is a summary of the values of each parameter needed for an epidemic simulation scenario with preventive measures to execute flawlessly, see Table 2.

Table 2. Independent variable tests with precautions

Mask			Quarantine			Lockdown		
Mask Policy	:	50%	Day Start Quarantine	:	17^{th} day	Day start Lockdown	:	40^{th} day
Day Start Using Mask	:	14^{th} day	Day Scheduled Quarantine	:	once a day	Lockdown	:	100%
Day End Using Mask	:	1000^{th} day	Quarantine Rate	:	20%	Day End Lockdown	:	95^{th} day
			Quarantine Chance	:	50%			
Social Distancing			Vaccination					
Day Start Social Distancing	:	14^{th} day	Day Start Vaccine	:	85^{th} day			
Day End Social Distancing	:	1000th day	Day Scheduled Vaccine	:	every 3 days			
Social Distancing Rate	:	50%	Vaccination Rate	:	30%			
			Vaccination Chance	:	90%			

2.2.1. Epidemic without precautions

Simulation of an epidemic without preventive measures can be achieved by setting all parameter values related to preventive measures to zero utilizing only the fixed variables from Table 1 and the independent variables as in Table 2. The difference is that all values listed in Table 2 must be 0 then the simulation can be executed. This scenario is designed as a point reference and comparison with the previous scenario. This simulation will also perform 10 times, see Table 3.

Table 3. Independent variable tests without precautions

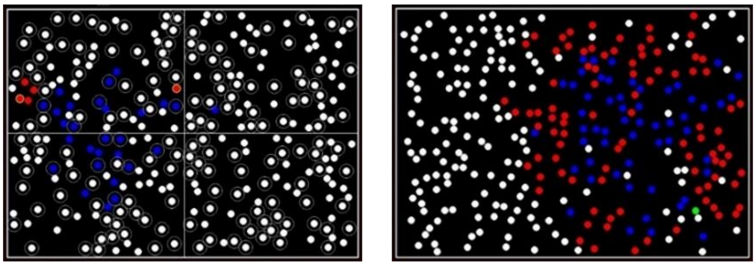
Mask			Quarantine			Lockdown		
Mask Policy	:	0	Day Start Quarantine	:	0	Day start Lockdown	:	0
Day Start Using Mask	:	0	Day Scheduled Quarantine	:	0	Lockdown	:	0
Day End Using Mask	:	0	Quarantine Rate	:	0	Day End Lockdown	:	0
			Quarantine Chance	:	0			
Social Distancing			Vaccination					
Day Start Social Distancing	:	0	Day Start Vaccine	:	0			
Day End Social Distancing	:	0	Day Scheduled Vaccine	:	0			
Social Distancing Rate	:	0	Vaccination Rate	:	0			
			Vaccination Chance	:	0			

3. RESULTS AND DISCUSSION

After applying the value of the parameters based on the two existing scenarios into the simulation program, it can be executed to simulate COVID-19. The epidemic simulation program that has been made runs without any significant problems. As already mentioned, the simulation scenario with preventive measures was performed 10 times. We observed the simulation visually, and the data result is recorded in .xlsx format files. Then we execute the scenario without prevention 10 times. The data from these two simulations can then be observed and analyzed to differentiate and examine the ongoing epidemic. The following is screenshots while the simulation ran respectively.

Figure 3 is captured from the Pygame window, and the results run according to the model. The program that has been made has succeeded in simulating epidemic events. For a short explanation, a white color depicting the susceptible person will appear on the screen, moving with varying directions and speeds. An infected person will appear in a random place on the screen. When a susceptible person comes into contact with an infected person, the susceptible person will become infected based on the value of the transmission chance (100%). People who have been infected will gradually get better within 14 days. During those 14 days, every contact with other susceptible people will turn them into infected people, and so on. People who have recovered, according to the model, will be immune to disease. Additionally, up to 3% of people who have been infected will experience severe complications due to the illness. As a result, after 14 days of suffering from disease, the person is declared dead/deceased. This simple schematic represents the epidemic events, and this simulation program successfully simulates it properly.

Figure 3(a) and (b) can represent another experiment in the same category. In short, at the beginning of the epidemic, 300 people will be randomly placed on the simulation screen with the susceptible status, and one of them will have the infected status so that the epidemic simulation can be started. Each person moves at a speed that varies from 0 to 10 pixels per second in various directions. Thus, contact occurs when people (circles) collide with other people, and the disease spreads. The data captured from the identified events during the simulation resulted in a variety of data. When the preventive measures are applied, contact between people decreases according to the ongoing preventative measures. The act of wearing a mask reduces the percentage of transmission by 50% when contact occurs. People who practice social distancing will be protected from being infected because direct contact does not happen with other people. This act will also shield other people from being infected when an infected person performs this activity. Quarantined people will stay in isolation and not transmit the disease if contact occurs with susceptible people. People who have been vaccinated will not be infected if they come into contact with infected people. Lockdown separating territory into 4 parts isolating people into 4 separate populations reduces mobility, as shown in Table 4 and Table 5 are a cumulative data table of cases S=Susceptible, I=Infected, R=Recovered, D=Deceased, Q=Quarantined, V=Vaccinated, SD=Social Distancing from each test scenario, as well as the maximum days achieved when the epidemic ends.



(a) (b)

Figure 3. Screenshot of test 1: (a) with precautions and (b) without precautions

Table 4. Cumulative simulation experiments tests with precautions

Name	S	I	R	D	Q	V	SD	Day
Test 1	269	31	31	0	13	0	145	33
Test 2	276	24	24	0	14	0	144	41
Test 3	276	24	24	0	9	0	155	44
Test 4	276	24	23	1	9	0	154	28
Test 5	276	24	24	0	15	0	149	31
Test 6	285	15	14	1	6	0	155	42
Test 7	272	28	28	0	9	0	147	28
Test 8	294	6	6	0	4	0	151	27
Test 9	287	13	13	0	6	0	167	30
Test 10	266	34	34	0	18	0	164	57

Table 5. Tests without precautions

Name	S	I	R	D	Day
Test 1	16	284	273	11	106
Test 2	19	281	274	7	107
Test 3	20	280	268	12	89
Test 4	17	283	273	10	91
Test 5	18	282	274	8	86
Test 6	29	271	262	9	120
Test 7	15	285	282	3	123
Test 8	25	275	267	8	93
Test 9	20	280	273	7	99
Test 10	26	274	266	8	97

The two image clusters above are the result of the two COVID-19 simulation scenarios that have been performed. It runs on the same program and the same simulation model. In general, we can say that the simulation results are similar. But, if we look in detail at the epidemic simulation course, differences can be found between each other even in the same experiment scenario. These differences appear because the simulation employs a stochastic approach. The main things that are preset to random are where people appear at the start of the simulation and their movements throughout the simulation. However, we can draw a line of understanding from the collected data and observations during the simulation from these two scenarios, 20 experiments. This simulation program tries to prove that the epidemic course between societies is different from one another with the same type of disease, which depends on many factors. It will be discussed in more detail in the next section. From the 10 trials of each test implemented, we will draw a line of understanding from the simulated epidemic events. From Tables 4 and 5, the following are the averages for each case.

Within 36.1 days, the disease managed to infect 22.3 people, with 0.2 people died while 22.1 people managed to recover, and 277.7 people still in a vulnerable condition, 10.3 people were quarantined, 0 people were vaccinated, and 153.1 people were doing social distancing. The average peak of infection occurred in the range of day 10 to day 20. Meanwhile, within 101.1 days, the disease managed to infect 279.5 people, with 8.3 people died while 271.2 people managed to recover, leaving 20.5 people to remain susceptible. The first peak of infection occurred in the range of day 40 to day 50 except in the 4th experiment, the peak occurred on the 30th day. In Experiment 1, there was a second wave of disease spread as can we observe. These various forms of epidemic graphs result from mobility, which is arranged randomly as each person moves independently, the disease spread. Comparing these two test scenarios from the results at first glance, we can prove that preventive measures are very effective. From the 10 trials, all actions do not even need to be performed. The mask policy, social distancing, and quarantine are enough to stop the spread. The disease spread pass through the 40th day and the lockdown measures were implemented. Because epidemic events stopped so quickly, vaccination is not implemented. Why do the simulation results show the outbreak stopped rather quickly compared to the COVID-19 pandemic? For a short answer, many things influence it. First is the limiting factor in modeling the outbreak in this simulation, and second is the factor of COVID-19 pandemic occurrence itself [47].

The first factor is the problem scope taken in this study. In actual events, a disease spreads from person to person, this event is called an epidemic. If an epidemic event spreads widely to other regions and even countries, it is called a pandemic. This dissemination process is undoubtedly influenced by individual and environmental factors [48]. The disease can take longer or faster to infect and spread, depending on the factors in a person [49]. For example, take a person who is 20 years old in a healthy condition, if he is infected, this person will recover relatively quickly [50]. In contrast to people aged 40 or 50 years and over, the time to recover from an infection will be relatively longer. This happened in the COVID-19 pandemic, where the recovery time varied between 14 days to 21 days. The second factor is the COVID-19 disease itself. What is meant here is the possibility that this disease has a higher transmission rate compared to known results. Based on those results, the death rate in Indonesia caused by COVID-19 is only about 3% of the total number of people who have been infected. However, this disease continues to spread even though various handling measures have been initiated. But if we compare the results of this simulation with the actual situation. Even with the existing bias, the results can be said to be feasible and successful. The modeling of 300 people in an area of 1690.5 m^2 is comparable to a size of a village. So, this simulation successfully simulates the situation like how the people of an area follow the existing health protocols and vice versa. If the community obeys the protocol and the authorities are consistent and precise, an epidemic can be handled quickly and effectively. We also know from the simulation results that if a community does not implement any preventive measures. The first peak or first wave occurs from the 40th-50th day, followed by the second wave, in which the peak occurs from the 65th-75th day. In the first peak, the current total infected people reached 96 people and 52 people on the second peak. This high infection rate resulted in 284 people being infected, or 94.6% of the total population. Meanwhile, if the community implements preventive measures and complies with the existing protocol. (a) The peak only occurred once, namely on the 13th day with 28 people infected. This rate continued to decline due to preventive measures that were implemented from day 14, such as the mask policy and social distancing. 145 people practice social distancing, and everyone wears a mask with a percentage mask lowering 50% chances of getting infected. Quarantine measures help by reducing further infections by separating infected people from others. This is in line with several other articles that review the effect of preventive or treatment measures on their impact on the infection rate of diseases, such as [51] regarding lockdown, [52] regarding social distancing, and [43] regarding the effectiveness of masks.

4. CONCLUSION

From the results of these two tests, it can be seen that there are significant differences between those who use preventive measures and those who do not. Compared with no epidemic prevention measures occurred for 106 days with a total of 284 people infected, 11 of them died and left 16 people who were not infected at all. When preventive measures were implemented, the epidemic lasted for 33 days, with 31 people infected and all of them recovering, 13 of them were quarantined, leaving 269 people uninfected, 145 of whom were practicing social distancing. The lockdown action did not occur as was done on the 40th day nor with the vaccination action which was implemented on the 85th day. The simulation also succeeded in simulating epidemic events clearly in visual animations of every aspect of epidemic events. Like the flow of a person from being susceptible to being infected then recovering or dying. Another process that was successfully simulated was the five preventive measures (mask policy, social distancing, quarantine, vaccination, and lockdown) on how prevention was performed and the resulting impact. These results make it difficult to say which action is more effective because each policy has parameters and accompanying factors. Coupled with the existing simulation bias it is problematic to determine which action is more effective. However, our SIRD epidemic simulation modeling with precautions compiled in Python worked successfully. Every algorithm and function applied for each aspect worked successfully in the testing process. Second, those preventive measures are effective in reducing the infection rate. How effective this action is depending on each action factor, starting from the day it is taken, and how often it is implemented. Third, how much effect this action has on reducing the infection rate depends on the value of each of the accompanying parameters. The thing that needs to be remembered and can be developed further from this simulation program is regarding the problem limits so that the epidemic simulation bias can be reduced. Simulations can be improved by adding more simulation aspects such as factors and functions that completely and accurately represent the epidemic.

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BIOGRAPHIES OF AUTHORS

Mustofa Abi Hamid (Member, IEEE) has been the secretary of Department of Electrical Engineering Vocational Education, Universitas Sultan Ageng Tirtayasa (Untirta), Indonesia, since 2021. He is currently an Assistant Professor with Untirta. He is also an Assistant Professor with the Department of Electrical Engineering Vocational Education, Faculty of Teacher Training and Education, Untirta. He has published more than 40 research articles, with more than 620 citations received in the Google Scholar and Scopus H-index 2. His research interests include in the areas of electrical engineering, electronics, technical and vocational education, curriculum design, learning strategies, learning media, ICT for learning. He has written several papers in the areas of technical and vocational education and training (TVET), learning strategies, learning media, technology enhanced learning, engineering education, curriculum development, education for sustainability development, professional learning. He is on the Editor-in-Chief of the journal VOLT: Jurnal Ilmiah Pendidikan Teknik Elektro and reviewer more than international journal. He can be contacted at email: abi.mustofa@untirta.ac.id.

Dimas Aditama completed his undergraduate studies from Sultan Ageng Tirtayasa University, Electrical Engineering Vocational Education Study Program in 2021. During undergraduate lectures, he is active in participating in competitions, seminars and workshops. He can be contacted at email: 2283170001@untirta.ac.id.

Endi Permata is doctoral student in Faculty of Engineering, Universitas Sriwijaya, Palembang, Indonesia. He received master degree in multimedia intelligent network from Institut Teknologi Sepuluh Nopember (ITS) Surabaya and his bachelor degree in electrical engineering from Universitas Sultan Ageng Tirtayasa. He was a researcher and lecturer with the Department of Electrical Engineering of Universitas Sultan Ageng Tirtayasa 2005 to 2013. In 2014 he joined the Department of Electrical Engineering Education in Faculty of Education and Teacher Training of Universitas Sultan Ageng Tirtayasa, Serang, Indonesia where he currently teaches microprocessor and microcontroller, digital electronics, information technology, power system protection, transformator, electrical machine, control system, computer network. He has written several papers in the areas of image processing, artificial intelligence, artificial neural network and computer architecture. He can be contacted at email: endipermata@untirta.ac.id.

Nur Kholifah is a lecturer at the Department of Clothing and Food Engineering Education, Yogyakarta State University, Yogyakarta, Indonesia. Research interest in the field of empowering vocational communities, learning methods, vocational teachers, and gamification. She can be contacted at email: nur.kholifah@uny.ac.id.

Muhammad Nurtanto is an assistant professor in Department of Mechanical Engineering Education, Universitas Sultan Ageng Tirtayasa, Banten, Indonesia. Research interests in the fields of professional learning, Teacher Emotion, Teacher Identity Philosophy of education, STEM education, gamification, and teacher quality in vocational education. He can be contacted at email: mnurtanto23@untirta.ac.id.

Nuur Wachid Abdul Majid received a B.Ed. in Informatics Engineering of Education and a M.Ed. in Technology and Vocational Education, Universitas Negeri Yogyakarta, Indonesia. Now, he is an Assistant Professor in Program Studi Pendidikan Sistem dan Teknologi Informasi, Universitas Pendidikan Indonesia. His research interest includes Technology and Vocational Education, Instructional Media for Learning, general education, educational psychology, and information system. He can be contacted at email: nuurwachid@upi.edu.