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# Proceedings of the 2nd International Conference on Automotive, Manufacturing, and Mechanical Engineering (IC-AMME 2021)

## Enhancing Sustainability and Value-Added Creation in Smart Industries

**Surabaya, Indonesia** • 2 October 2021

**Editors** • Didik Wahjudi, Hariyo P.S. Pratomo, Oegik Soegihardjo, Teng Sutrisno, Siana Halim, I Nyoman Sutapa, and Iwan Halim Sahputra

RESEARCH ARTICLE | JANUARY 18 2024

# Preface: Proceedings of the 2nd International Conference on Automotive, Manufacturing, and Mechanical Engineering (IC-AMME 2021)



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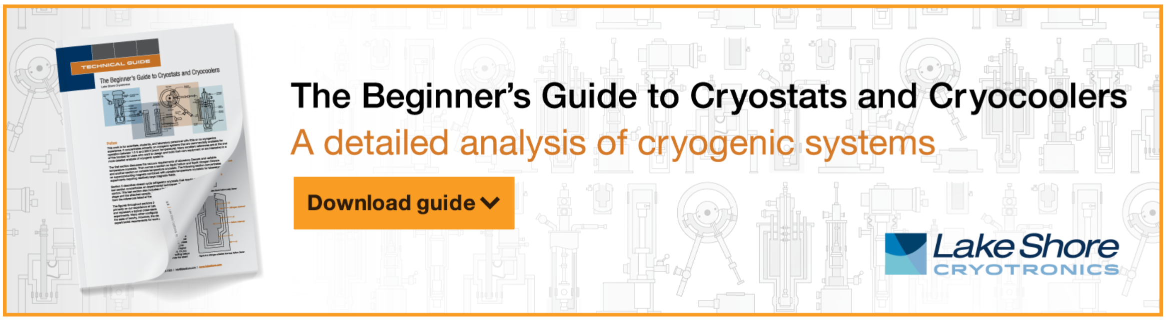

# Preface: Proceedings of the 2$^{nd}$ International Conference on Automotive, Manufacturing, and Mechanical Engineering (IC-AMME 2021)

"Enhancing Sustainability and Value-Added Creation in Smart Industries"

Thank God for holding this 2$^{nd}$ International Conference on Automotive, Manufacturing, and Mechanical Engineering (IC-AMME). This conference was held virtually on the 2$^{nd}$ of October 2021.

This year's conference theme is "Enhancing Sustainability and Value-Added Creation in Smart Industries". In addition, this conference aims to facilitate interaction and collaboration between local and overseas researchers. The committee receives around 70 submissions and accepts 59 full papers from Brazil, France, Japan, Malaysia, Nigeria, Norway, Portugal, Taiwan, Thailand, the USA, and Indonesia. 55 papers in this proceeding are classified into four sections, i.e., Sustainable Issues in Product Development, Sustainable Issues in Energy Management, Sustainability Issues in Manufacturing, and Sustainability Issues in Supply Chain.

On this occasion, I want to thank our keynote speakers, Prof. Takashi Suzuki, Ph.D. from Sophia University, and Prof. Benny Tjahjono, Ph.D. from Coventry University. Many thanks to all reviewers that have done a great job reviewing all the submissions. Special thanks to our partners: the Indonesian Supply Chain and Logistics Institute (ISLI), Sophia University, Lusofóna University, and UCSI University for supporting this conference. I want to appreciate the hard work and dedication of all committee members.

Finally, I would like to thank AIP Conference Proceedings for their support in publishing this proceeding.

Assoc. Prof. Dr. Didik Wahjudi
Conference Chair



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# Evaluation of Covid-19 vaccine effectiveness in handling the Covid-19 pandemic in the city of Surabaya with a dynamic system simulation approach using vensim PLE

Aldo Setyawan Jaya; Siana Halim; Bernardo Nugroho Yahya



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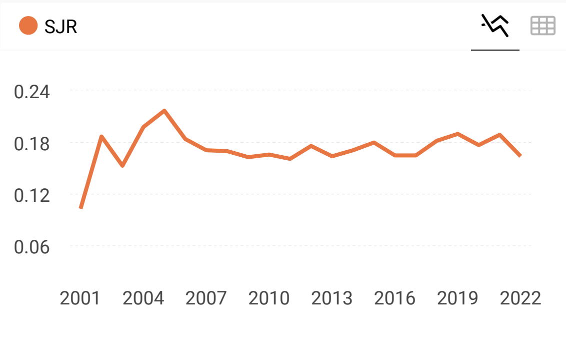


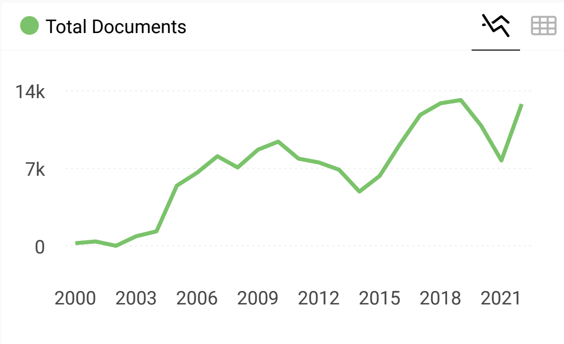


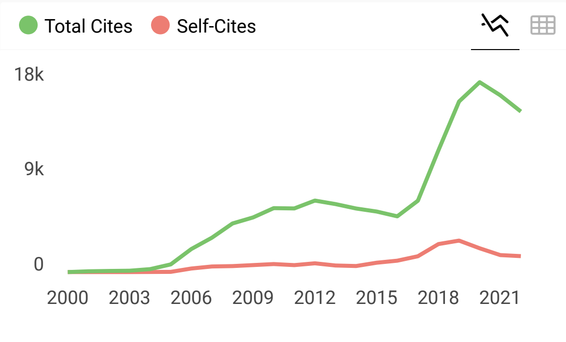


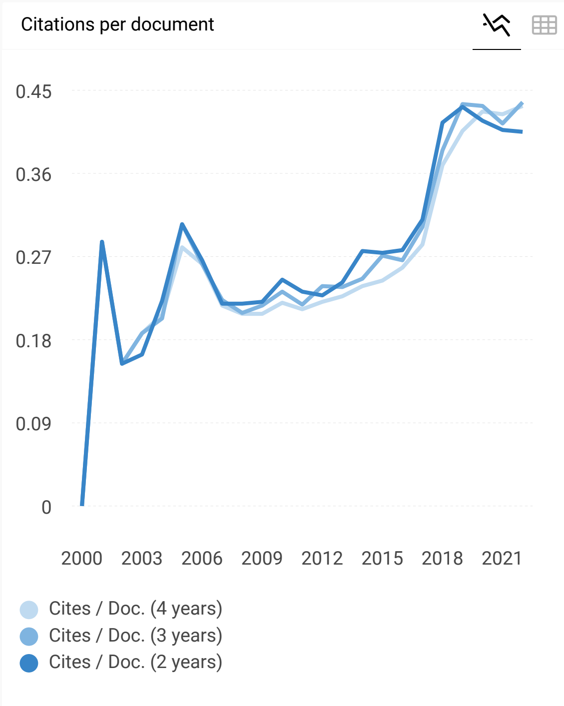


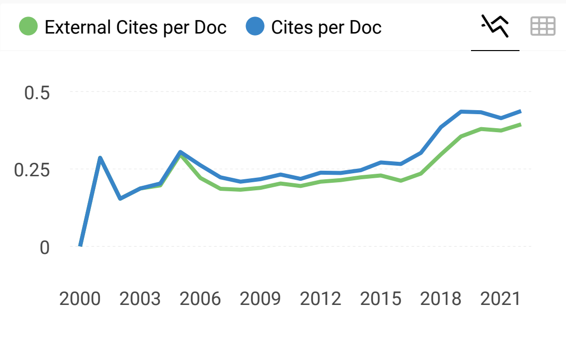


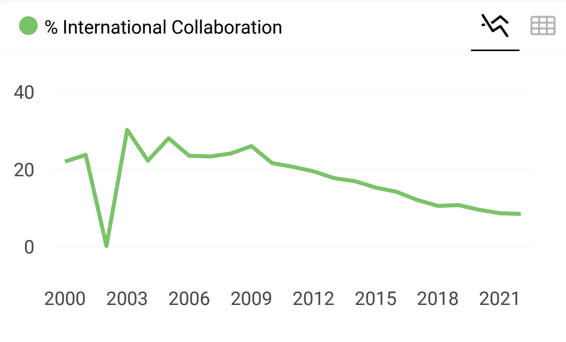


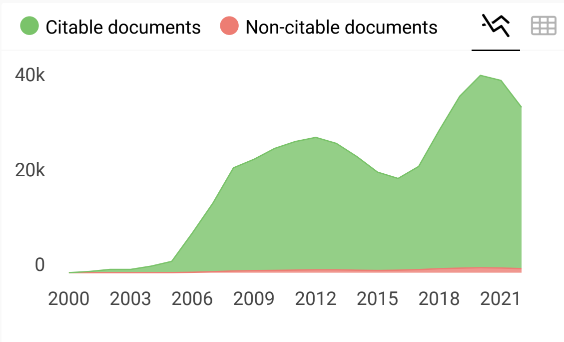


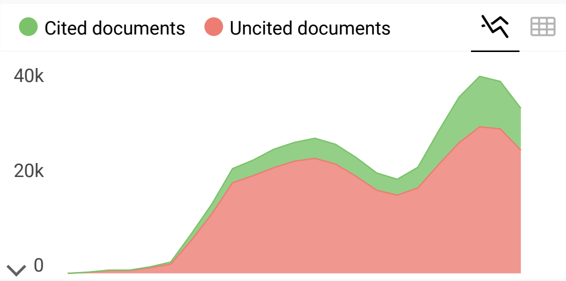



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# Evaluation of Covid-19 Vaccine Effectiveness in Handling the Covid-19 Pandemic in the City of Surabaya with A Dynamic System Simulation Approach Using Vensim PLE

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**Abstract.** The Covid-19 pandemic, a major global issue, has created a severe health emergency for the past year. In addition, it led to a crisis of governance and policies for handling Covid-19 worldwide, particularly in the city of Surabaya. The Surabaya city government has implemented various policies to handle the Covid-19 pandemic. However, there is no study to evaluate the effectiveness of those policies. This study aims to provide predictions and evaluations regarding the effectiveness of implementing policies for handling the Covid-19 pandemic in the City of Surabaya, especially the Covid-19 vaccination policy. Furthermore, we simulated the effect of those policies on the rate of infected people using the dynamic system model using Vensim PLE. The simulation results show that implementing of the Covid-19 vaccination policy has proven adequate to reduce the total number of infected by 13.25% and reduce the total number of deaths by 35.55%. Moreover, the implementation of vaccination, the enforcement of community activity restrictions (PPKM), convalescent plasma therapy, contact tracing and isolation, and also swab tests have been proven to reduce the rate of increase in Covid-19 cases effectively.

## INTRODUCTION

A new type of coronavirus, SARS-CoV-2, which was first detected in Wuhan, China, in December 2019, caused the Covid-19 outbreak, which spread massively to various countries as a global pandemic, including Indonesia. Since the first case of Covid-19 in Indonesia was discovered on March 2, 2020, Covid-19 has continued to spread throughout Indonesia. Based on data released by WHO, as of October 4, 2021, there were 234,809,103 confirmed cases of Covid-19, including 4,800,375 deaths worldwide, and 6,188,903,420 doses of vaccine have been administered worldwide [1]. Then, based on data released by the Indonesian government, as of October 5, 2021, there were 4,221,610 confirmed cases of Covid-19, including 142,338 deaths in Indonesia, and there were 148,596,138 doses of vaccine that had been administered in Indonesia [2].

East Java Province is in fourth place as the most significant contributor to Covid-19 cases in Indonesia, with 395,891 cases, as of October 4, 2021. In more detail, the City of Surabaya became the highest contributor to Covid-19 cases in East Java, with 66,597 cases, as of October 5, 2021 [3]. The city of Surabaya, with the second largest population in Indonesia, has a high level of population mobility. Therefore, it is essential to determine policies controlling population mobility to reduce the risk of Covid-19 transmission. Various policies for handling Covid-19 that the Surabaya City government has implemented during 2020 are social distancing, application of health protocols, Large-Scale Social Restrictions (PSBB), contact tracing and isolation, convalescent plasma therapy, also mass rapid and swab tests.

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In January 2021, the Indonesian government, including the Surabaya City government, began implementing the policy of Enforcement of Community Activity Restrictions (PPKM). Conceptually, the PPKM strategy is a middle ground between social distancing (PSBB) and total lockdown. For example, if a total lockdown is a closure of an entire city or country, and PSBB is a large-scale social restriction at the provincial level or all cities on the Java Island as a whole, PPKM is a restriction on community activities in a smaller area or social unit scale, which is at the city and district levels [4]. Moreover, in January 2021, the Indonesian government, including the Surabaya City government, began implementing the Covid-19 vaccination policy.

Many researchers have studied public policy to handle the spread of the covid-19, e.g. Goldsztein *et al.* [5] modeled the public policy and economic dynamics of the Covid-19 spread mathematically. Jamieson and Cytrnbaum [6] studied the effectiveness of targeted quarantine for minimizing the impact of Covid-19. Margaretha and Ayuningtyas [7] gave some analysis implementation of Covid-19 prevention policy for disability in Jakarta. This study aims to provide evaluations based on simulation results regarding the effectiveness of implementing policies for handling the Covid-19 pandemic, especially Covid-19 vaccination as a policy strategy implemented by the Surabaya City government in dealing with Covid-19. The spread of Covid-19 in the city of Surabaya models will be carried out using a dynamic system simulation approach based on Fiddaman [8] model and developed further by Hadiwibowo *et al.* [9]. The proposed model attempts to evaluate the policy's effectiveness for handling the Covid-19 pandemic, e.g., vaccination and PPKM in Surabaya.

# METHODS

## Data Collection and Processing

The data used in this study consist of Surabaya City population growth rate [10], time-series statistical data on the spread of Covid-19 in the city of Surabaya (including the number of confirmed cases), the number of people undergoing treatment, and the number of people who have recovered and died) [11], number of people who have been vaccinated [12] dan swab tested [11], hospital and public health facilities capacity [13], number of convalescent plasma donors [14], number of social assistance for medical aids, and policy effectiveness level (social distancing [15], health protocols, PPKM [16], contact tracing & isolation [17]).

The effectiveness of health protocols consists of the effectiveness of using masks [18], hand sanitizers and antiseptic soaps [19], and using a thermometer gun to check body temperature [20]. The data were collected from March 1, 2020, to July 31, 2021. In comparison, the model validation process uses March 1, 2020, to September 30, 2021. The dataset does not consider the economic, educational, and other aspects of people's lives and the dynamic of people's behavior toward the Covid-19.

## Conceptual Model Design

The conceptual model of the spread of Covid-19 in the City of Surabaya was created by modifying and developing Tom Fiddaman's Covid-19 pandemic dynamic system model [8], which had been developed further by Hadiwibowo *et al.* [9]. The Hadiwibowo et al. model considered the PSBB, contact tracing, isolation, convalescent plasma therapy, and mass rapid and swab tests policies in Surabaya. The proposed model extends Hadiwibowo's model by considering PPKM and vaccination policies in Surabaya.

The model's modification and development were carried out by designing a causal loop diagram (CLD) and stock and flow diagram (SFD). CLD is used to describe a complex problem and understand the behavior of a system in describing actual situations and help develop strategies to deal with feedback from the system by describing the relationships between variables in the system. SFD is used as a development and a more detailed description of CLD, which pays attention to the effect of time on the relationship between variables. The system dynamics modeling details are available at [21,22].

## Model Verification and Validation

The verifications were done by checking the model's parameters, checking the logical flow, tracing the results, and testing the sensitivity against peculiar inputs. To validate the model, we compare the output of the simulations, e.g., the number of people undergoing treatment, to the recorded data and then compute the mean comparison and the percentage error variance. The mean comparison is given as follows:

$$E_1 = \frac{|\bar{S}-\bar{A}|}{\bar{A}} \tag{1}$$

where, $\bar{S}$ is the average value of the simulation outputs, $\bar{A}$ is the average value of the actual data. While the percentage error variance is given as follows:

$$E_2 = \frac{|S_S-S_a|}{S_a} \tag{2}$$

where, $S_s$ and $S_a$ are the standard deviation of the simulation outputs, and the actual data, respectively. In this study, both $E_1$ and $E_2$ are less than 30%. This standard is following [9]. We also compute the mean absolute deviation (MAD) between the simulation output and the actual data, and the MAD is less than 1000. Since all measurements are considering reasonable, then we conclude that the model is validated.

## RESULTS AND DISCUSSIONS

### Dynamic System Model Design of the Covid-19 Pandemic

The SEIR (Susceptible, Exposed, Infected, Removed) model is implemented to describe the Covid-19 pandemic model [23, 24]. Susceptible is a variable that describes the population of people in a country who are still healthy but have the probability of being exposed to or infected with Covid-19. The exposed variable indicates the population infected with Covid-19 but does not yet have symptoms of the disease. In this case, the person looks healthy but a few days later shows symptoms of being infected. Infected is a variable that describes a population that has been confirmed positive for Covid-19. Finally, removed is a variable that describes the model's output, which is divided into two, namely Recovered and Death. The Recovered variable describes the population who have recovered from Covid-19. At the same time, the Deaths variable describes a population that has died [9]. The relationship between these variables in the dynamic system model of the Covid-19 pandemic can be seen in Fig. 1.



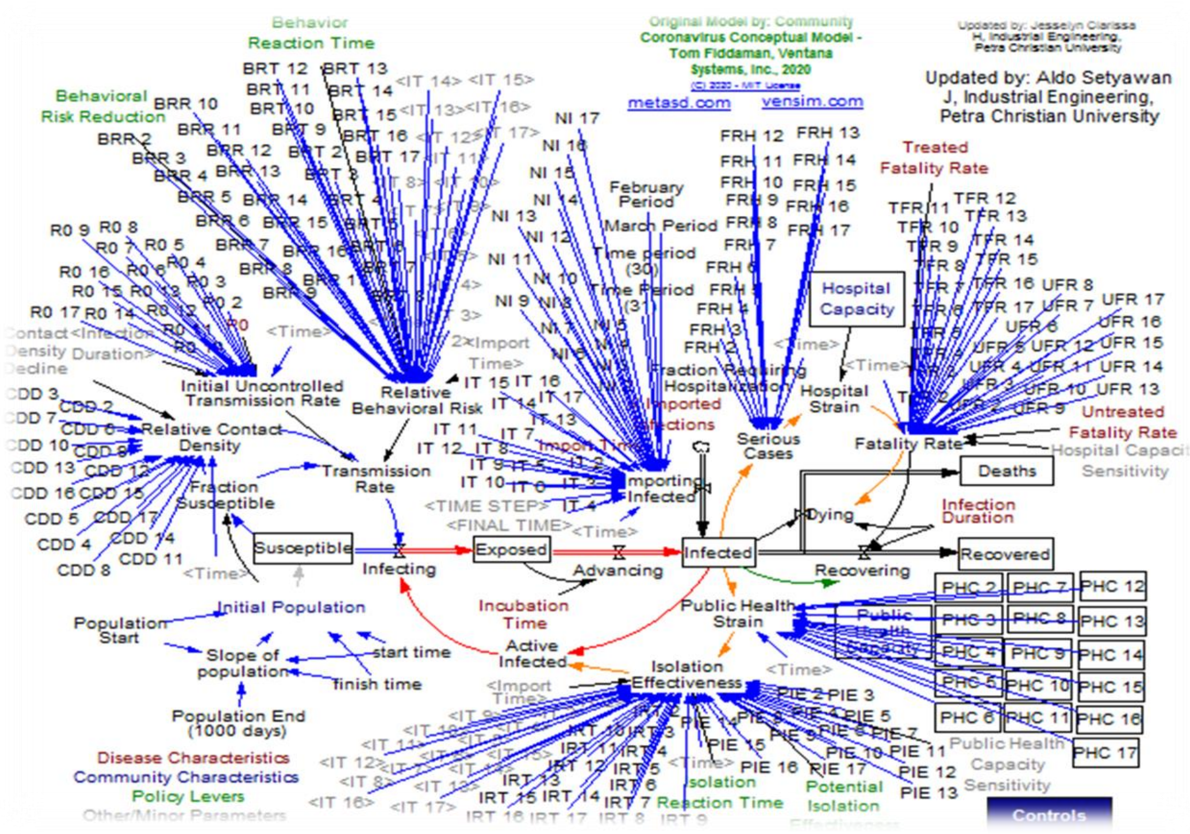



**FIGURE 1.** Dynamic system model of the Covid-19 pandemic

The dynamic system model of the Covid-19 pandemic (see Fig. 1) is composed of three big loops that are interconnected in describing the relationship between variables. The first loop is related to infection and is known as a reinforcing loop, increasing the number of people infected with Covid-19. The second loop is related to the susceptible variable and is called a balancing loop, which is influenced by government policies to inhibit the Covid-19 infection rate. Finally, the third loop is related to the removed variable and is also known as a balancing loop, which can reduce the number of people infected with Covid-19 from time to time due to recovery or death. The recovered people are assumed to have good immunity to Covid-19 so that this loop can inhibit the Covid-19 infection rate.

Several variables are used as parameters to design a dynamic system model of the spread of Covid-19 in the city of Surabaya, namely: (1) Initial population: number of populations in the model. (2) Contact density decline (CDD): contact reduction when the infection has penetrated the less connected parts of the social network. (3) Infection duration: covid-19 infection duration. (4) R0: the rate of Covid-19 transmission that occurs in an area. (5) Behavioral risk reduction (BRR): risk reduction of Covid-19 transmission due to the local government's implementation of policies or interventions. (6) Behavior reaction time (BRT): the time from the first Covid-19 infection appears until a policy is implemented each month. (7) Import time (IT): the time when the first Covid-19 infection entered or occurred in each month. (8) Number imported infections (NI): the number of confirmed positive cases of Covid-19 that first entered and polluted an area. (9) Time step: unit of time steps used in the model for the simulation process. (10) Incubation time: the incubation time of the Covid-19 virus in the human body. (11) Fraction requiring hospitalization (FRH): the ratio of people who are confirmed positive for Covid-19 and need hospital services to the total number of people who have been swab tested. (12) Hospital capacity: the capacity of the Covid-19 referral hospital in the city of Surabaya. (13) Treated fatality rate (TFR): the death rate of infected people who get good health services. (14) Untreated fatality rate (UFR): the death rate of infected people who did not get good health services. (15) Hospital capacity sensitivity: the sensitivity level of a hospital to handle the existing capacity. (16) Public health capacity (PHC): capacity of public health facilities for infected people in Surabaya. (17) Public health capacity sensitivity: the sensitivity level of public health facilities for infected people. (18) Potential isolation effectiveness (PIE): the effectiveness of isolation and monitoring of infected people. (19) Isolation reaction time (IRT): the time from the first Covid-19 infection appearing until the isolation policy is implemented each month.

All variables in this study are modified and developed according to the current actual conditions of the spread of Covid-19 in Surabaya. The parameters for each variable are estimated based on the March 2020 to July 2021 dataset. For example, the R0 1 was estimated from the confirmed Covid-19 transmission rate in March 2020. The R0 2 parameter was estimated using April 2020 dataset, and so on. Moreover, the parameter BRR 11 represents the reduction in the risk of Covid-19 transmission due to government policies implemented in January 2021, while the BRR 12 represents February 2021 government policies implementation. Finally, the estimated parameters were inputted to the Vensim model to be ready for a simulation.



## Model Verification

All relationships between variables, mathematical models, and estimated parameters used in the simulation model are relevant and logically make sense. Additionally, the simulation program is correct; no error warnings appear in Vensim after the model is simulated. Finally, the perturbation to the input parameters by changing those parameters with extreme values shows logical and relevant outputs to the simulation model. Therefore, the model's logical structure is verified. In addition, the proposed model is further validated to check the representation with the situation in Surabaya.

## Model Validation

In the simulation model validation process, a comparison is performed between the actual data and the simulation results for the infected, recovered, and deaths variables. Figure 2 and Figure 3 exhibit a comparison of the infected, recovered, and death data set to the simulation ones. The simulations can capture the actual condition of the infected and the death evidence. However, this result is slightly different from the recovered one. The simulation performance and the summary statistics are presented in Table 1.

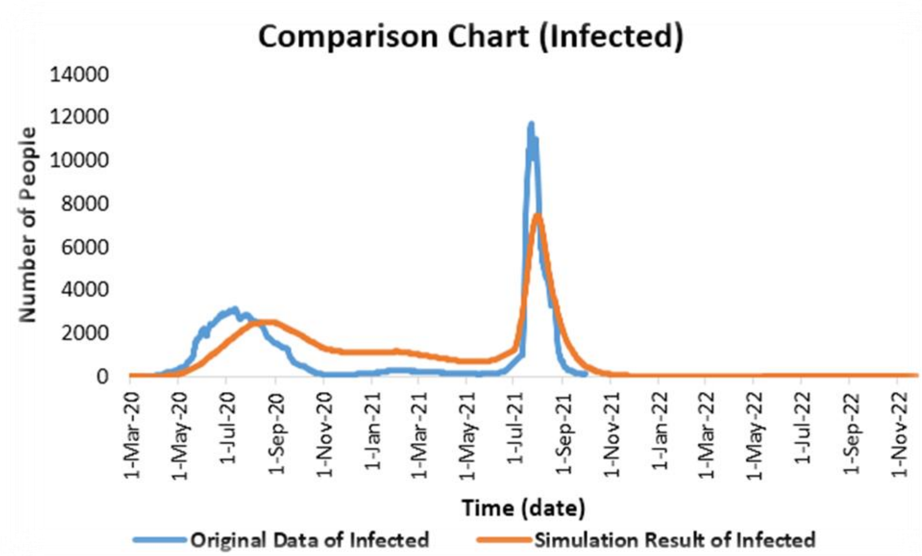
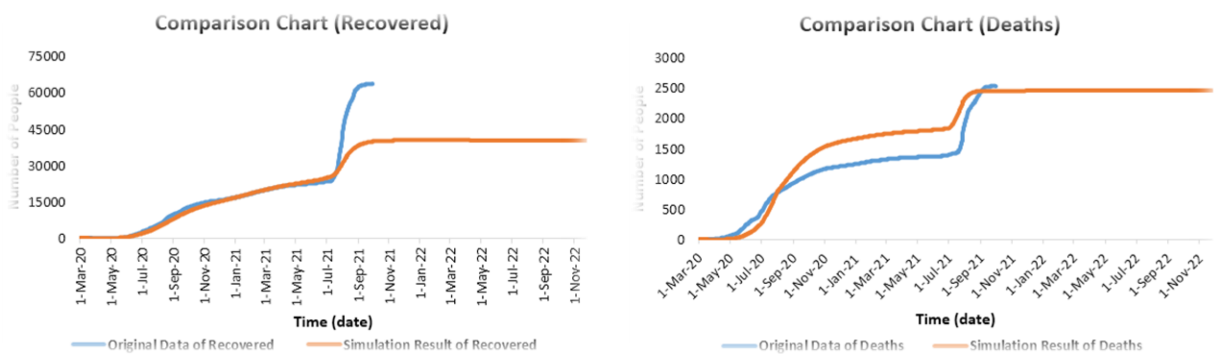



**FIGURE 2.** Comparison chart between original data and simulation result of infected.




(a) (b)

**FIGURE 3.** (a) Comparison chart between original data and simulation result of recovered, (b) comparison chart of deaths.

**TABLE 1.** Validation of simulation model

| Variable | Mean Comparison | | | Percentage Error Variance | | | MAD |
|---|---|---|---|---|---|---|---|
| | Original Data | Simulation Result | E1 | Original Data | Simulation Result | E2 | |
| Infected | 1126.37 | 1458.21 | 29.46% | 1624.08 | 1252.46 | 22.88% | 886.37 |
| Recovered | 17888.74 | 15293.94 | 14.51% | 17022.11 | 11822.32 | 30.00% | 2939.88 |
| Deaths | 1095.00 | 1322.57 | 20.78% | 666.00 | 806.69 | 21.13% | 277.96 |

The E1 and E2 of the simulation are less than 30%, and we conclude that these errors are reasonable. The MAD of Infected and Deaths are less than 1000. However, for the Recovered, it is greater than 1000. There is a jump for this prediction around the 1st of July 2021. The model has a drawback while it predicts the recovery rate flat after the 1st of July 2021.

## RESULTS AND DISCUSSION

The dynamic system model of the Covid-19 pandemic in Surabaya was simulated for 1000 days starting in March 2020. Based on the simulations carried out on the dynamic system model of the Covid-19 pandemic in Surabaya, the simulation results are obtained. Figure 4 exhibits the simulation outputs of the study.

Figure 4 shows the graph of changes in the values of the susceptible, infected, recovered, and deaths variables over time due to the model simulation. Based on the infected variable graph, it can be analyzed that the infected value first appears on the 18th day, which then continues to increase over time. Thus, in its development, there was a dynamic pattern of ups and downs in the number of infected until it reached the highest number on the 518th day, namely on July 31, 2021, with 7,455 people infected with Covid-19, which shows the peak point of the Covid-19 pandemic. Then the curve of infected continues to decrease until it reaches a value of 0 on the 700th day, that is on January 29, 2022, which shows the end of the Covid-19 pandemic. From these results, it can be analyzed that the total period of infection that occurred in the City of Surabaya was 682 days, with a total number of infected people reaching 42,874 people.

The simulation predicts that the Covid-19 inclines on the 700th day. It also shows that among 42,874 infected people, 40,414 people had recovered, and 2,460 died because of Covid-19. In addition, the susceptible graph predicts there will be 3,130,240 residents of the city of Surabaya who are in the susceptible category. These persons are still healthy or not infected by the Covid-19.

Furthermore, the infected graph shows that there is a surge point. It reached the peak point of the pandemic, and then drastically the trend is downward in a short time. This phenomenon is happened due to the modification and adjustment of parameter values in several variables in the model based on the implementation of several government policies that are being intensively carried out in July 2021. The policies implemented are Covid-19 vaccination, Enforcement of Community Activity Restrictions (PPKM), convalescent plasma therapy, contact tracing, isolation, and swab tests.

The implementation of vaccination policy affects the R0, FRH, TFR, UFR, and PIE parameter values. According to the Ministry of Health in Jakarta in the January-June 2021 study, the Covid-19 vaccination policy can reduce the risk of Covid-19 infection by 84%. In addition, it reduces the risk of treatment due to Covid-19 by 64% on average. It also reduces the risk of death due to Covid-19 by 87% on average [25].

The implementation of a convalescent plasma therapy policy affects the parameter values of the R0 and TFR variables. Calculation of the convalescent plasma therapy effectiveness was carried out using data on the number of convalescent plasma donors conducted in the city of Surabaya [14]. The convalescent plasma therapy effectiveness was obtained from the average increase in the number of recovered people to the confirmed cases each month. The convalescent plasma therapy effectiveness level is 90.82%. The implementation of the swab test policy affects the parameter value of the R0 variable. The effectiveness of the swab test is obtained from the multiplication of the number of people who were swab tested and confirmed positive with the parameter value R0 then divided by the total population of the city of Surabaya. The effectiveness level of the swab tests policy is 5.5%.

The implementation of PPKM policy affects the parameter value of the R0 variable. Amir [16] stated that the effectiveness of the implementation of PPKM in Jakarta is 65.92%. The implementation of contact tracing and isolation policy affects the parameter value of the R0 variable. Kucharski [17] stated that the spread of Covid-19 could be controlled up to 90% only if 80% of the contacts were successfully traced and then isolated.

Four scenarios are simulated in this study to evaluate the effectiveness level of the policies implemented in reducing the number of infections and deaths. In the first scenario, both the Covid-19 vaccine and PPKM policy are not implemented. In the second scenario, the Covid-19 vaccine policy is implemented, but PPKM is not implemented. In the third scenario, the Covid-19 vaccine policy is not implemented, but PPKM is implemented. In the fourth scenario, both the Covid-19 vaccine and PPKM policy are implemented.

Table 2 shows that the Covid-19 vaccination policy has proven effective in reducing the total number of infected by 13.25%, reduce the total number of deaths by 35.55%, and reduce the infection duration by 2.13%. PPKM policy has proven effective in reducing the total number of infected by 15.47%, reducing the total number of deaths by 17.51%, and reducing the infection duration by 2.13%. Both Covid-19 vaccination and PPKM policy implemented effectively reduced total infected by 19.97% and reduced the total deaths by 37.93%. Therefore, it can be summarized that the Covid-19 vaccine is more effective in reducing the total number of deaths, while PPKM is more effective in reducing the total number of infected.

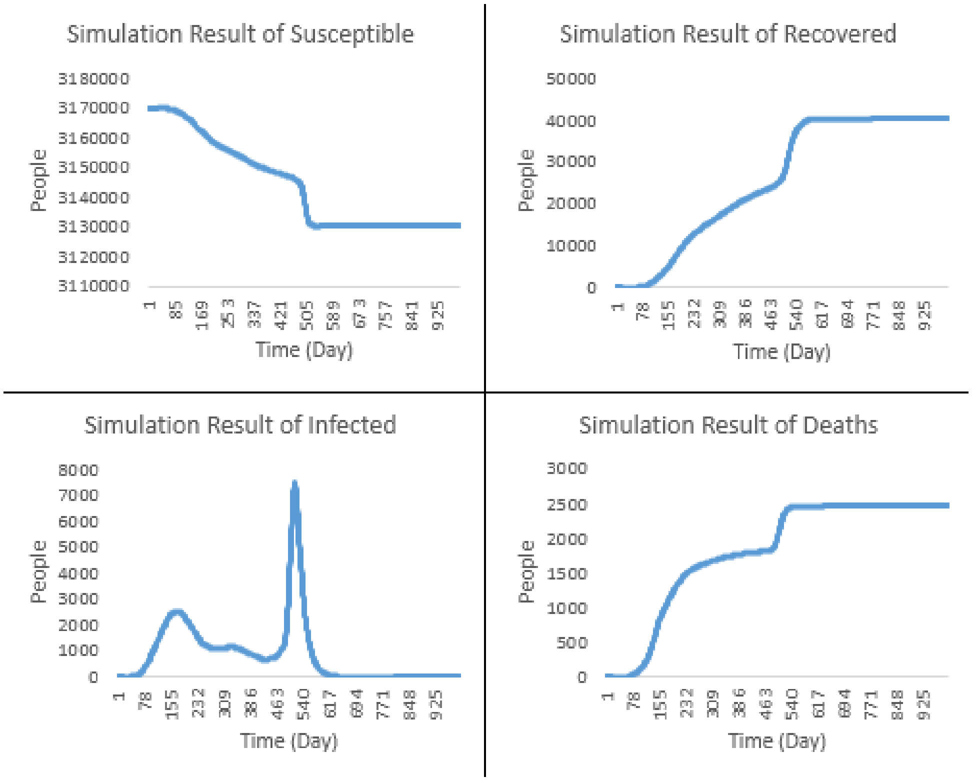



**FIGURE 4.** Graph of model simulation results for 4 main variables.

**TABLE 2.** Simulation results

| Policies | Effectiveness Level | | |
|---|---|---|---|
| | **Reduce Total Infected** | **Reduce Total Deaths** | **Reduce Infection Duration** |
| Covid-19 Vaccine | 13.25% | 35.55% | 2.13% |
| PPKM | 15.47% | 17.51% | 2.13% |
| Covid-19 Vaccine & PPKM | 19.97% | 37.93% | 3.13% |

## CONCLUSION

The Covid-19 pandemic has caused a crisis of governance and policies for handling Covid-19 in Surabaya. The Surabaya City government has implemented various policies during 2020. In January 2021, the Surabaya City government began implementing the Covid-19 vaccination and PPKM. This study aims to provide predictions and evaluations regarding the effectiveness of implementing policies for handling the Covid-19 pandemic in Surabaya, especially the Covid-19 vaccination. The Covid-19 pandemic in Surabaya was modeled using a dynamic system modeling and simulation to analyze the policies' effect on the number of Covid-19 cases.

The simulation of the dynamic system model of the Covid-19 pandemic in Surabaya found that the peak of the Covid-19 pandemic occurred on July 31, 2021, with 7,455 people infected with Covid-19. Then, the Covid-19 pandemic is predicted to last for 682 days until it ends on January 29, 2022, with a total number of infected people reaching 42,874 people, of which 40,414 have recovered 2,460 people have died. However, this prediction will be valid only if under the condition that all policies implemented in the simulation model in this study continue to be implemented by the Surabaya City government in the future continuously.

This study concludes that the implementation of the Covid-19 vaccination policy has proven effective in reducing the total number of infected by 13.25% and the total number of deaths by 35.55%. Moreover, the implementation of PPKM, convalescent plasma therapy, contact tracing and isolation, and swab tests have been proven to effectively reduce the rate of increase in Covid-19 cases in Surabaya. After all, the dynamic system model of the Covid-19 pandemic designed in this study follows the actual conditions that occurred in Surabaya, and the results of the model simulation are valid, only if in the condition that there are no new variants of the Covid-19 virus that enter and pollute the city of Surabaya in the future.

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