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Modeling Social, Health, and Vaccines Intervention in Time of COVID-19 Pandemic Impacted in Jakarta - Indonesia

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Abstract

Since the first outbreak of SARS-CoV-2 worldwide, research on modeling and simulation has grown, particularly to estimate the peak and end time of the pandemic which has been exceeded in some cases. This study aims to model the current virus spread with discrete event simulation, using the case of Jakarta. About 2 million of Jakarta's susceptible population was used for the the model's input which ran for a year. The data was obtained from past records and were divided into three main timelines (i.e. initial stage, large scale restriction and new normal) in order to validate the model with real cases step by step. Scenario analysis was then performed by evaluating five possible interventions such as: existing scenarios, social and health intervention, mass vaccination and hybrid intervention. The results show that the model represents real cases with a variation of less than 5% during the timeline. Furthermore, scenario analysis showed that mass vaccination, hybrid and social intervention provide the least positive cases in the system. This study recommends that hybrid intervention should be used while the vaccine is being mass produced, and the implementation of social intervention should be highlighted.

INTRODUCTION

The government around the world has deployed various countermeasures in response to global spread of COVID-19. Modelling has been used to help the decision makers in order to understand the pattern and characteristics of pandemics, including to predict how various intervention may have impact on the outcome (Currie et al., 2020). Miller et al (2008) has implemented the Discrete Event Simulation (DES) to model and analyze the pandemic influenza in San Antonio, Texas, by accommodating public health measure and hospital capacity. Their study developed models for simulating contact and diseases transmission process and for diagnosis and treatment process (Miller, Randolph and Patterson, 2008).

There are some efforts to model the pandemics in Indonesia (Yulida and Karim, 2020), which mainly aims to predict the time (peak or end) and number of cases (infected, dead and recovered

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peoples). Ariawan et al. provided comprehensive framework for modeling scenario of COVID-19 in the early time of pandemic, which also simulating some scenarios from low, mid and high intervention (Ariawan et al., 2020). Based on early endemic data of COVID-19 in Indonesia and compared with similar trend in South Korea, Nuraini predicted the outbreaks would end in April 2020, with number of infected case over 8000 (Nuraini et al., 2020). Permana & Sahadewo built a national epidemic curve used a non-linear Gaussian Process Regression (GPR) to predict the infected person and conduct simulation to predict that the peak of daily new confirmed cases would be in July 2020 and will cease in July 2021. Based on the analysis, they concluded that Indonesia is still nowhere near to win the battle again the pandemic and wondered whether vaccine will be last resort to solve the situation (Permana & Sahadewo, 2020).

Despite of the existing developed models, there is still an urgency to provide more forecast on the pandemics, which can be used as consideration by the government (Erina, 2020). The peak time of pandemic predicted by previous models has been passed. Therefore, this study will develop a DES based model, particularly to preview the current pattern and possible intervention to countermeasure the outbreaks.

Jakarta was selected as case example in this study due to some strategic reasons. Aside from the first case was identified in here, as Indonesian capital, Jakarta has an integrated health facility supported with data transparency and completeness which can be accessed from its official website (Government of Jakarta Capital Special Region, 2020). Jakarta has also the most density of population and thus, along with its tenacious detection capability, contributed to the highest proportion toward national data statistic of infected people.

This research, therefore, aims to model the current COVID-19 pandemic using Discrete Event Simulation (DES), particularly to understand the impact of various intervention toward the infected cases in Jakarta. The structure of this paper is organized as follows: Firstly, research methodology which depict the model flows was provided, along with relevant parameters taken from various sources. In the next section, the result from modeling were discussed, especially to assess the difference between the simulation and the real case. Finally, the model was expanded further, by defining five scenarios after the existing timelines to evaluate the best possible intervention for practical recommendation.

METHODS

Discrete event simulation (DES) refers to the process in which the behavior of a complex system is codified into sequential order of events. Each event occurs at a particular instant in time and marks a change of state in the system (Kiran, 2019). The application of DES has been used widely in health care sector, along with other modelling such as system dynamic (Brailsford & Hilton, 2001) and agent based simulation (Chumachenko & Chumachenko, 2019).

Discrete event simulation consists of a network of queues and activities, with changes in the system occur at discrete points of time. The individual entity flows in the network and the status (such as healthy, infected, recovered, or dead) may changes depend on the occurred activity. The characteristics of activity determine the process, resources, and durations with some probability distributions.

(1) Data Source

The data inputted for this model is mainly based on the statistic daily data provided by National COVID-19 Taskforce (National COVID-19 Task Force Republic of Indonesia, 2020a) and Government of Jakarta (Government of Jakarta Capital Special Region, 2020), supported with other supporting data from various resources as described later. There are some different numbers found among the resources, and in that case, data from Task Force should be preferred (Ferdiaz, 2020).

(2) Process Description

The simplified model can be illustrated in the Figure 1. The model is started with two inputs: healthy person and infected person, in which each of them has distinct process and color. Healthy person and infected person can meet and interact in certain process, and both of them may have similar flow. The output of process is disposal of both healthy and infected person, in the form of leaving the city, death, recovered or remain healthy.

(3) Running Time

This model was running with the starting date is 14 February 2020, i.e., the starting of the first case has a contact and got infected in Indonesia. It did not start from the first case identified by laboratory in Indonesia (1 March 2020) as the earlier start time in particular aimed to understand the possibility of undetected case, due to unrecognized syndrome in the early stage. The modelled process can be run with discrete event simulation software, such as Arena. The model will be simulated gradually according to the time period fragmentation until new normal period, followed by intervention scenario for remaining months until a year.

(4) Epidemic Model

Epidemic modelling can be used to study the mechanisms of a diseases spread, to project the future course of an outbreak and to evaluate the im-

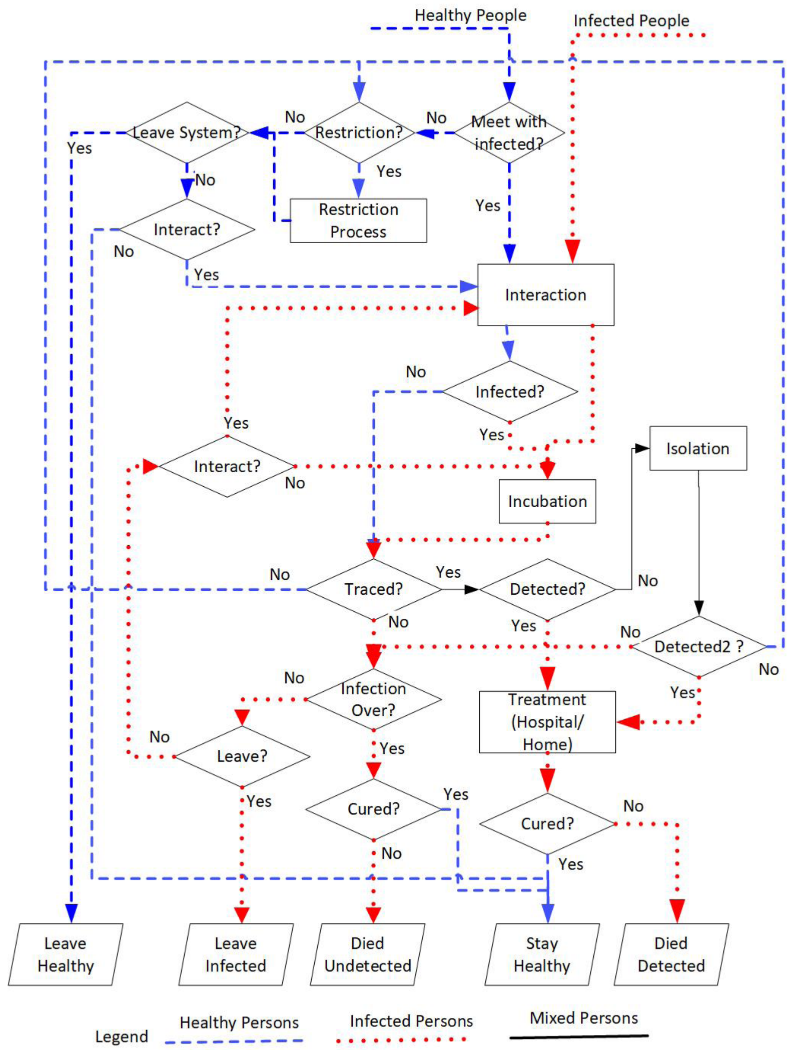

Figure 1 Simplified Flow Chart for Modelling COVID-19

pact of various interventions. It has long history, which can be traced back from John Graunt's book to quantity the cause of death in 1662 followed mathematical model developed by Dainel Bernoulli in 1760 to show the effectiveness of inoculation against smallpox (Hethcote, 2000). In 1889 P.D. Enko's work on discrete model has fitted several measles epidemics in Russia (Dietz, 1988). Epidemic model widely used typically based on S-I-R (Susceptible – Infectious – Recovery) compartment model originated from Kermack–McKendrick in 1927. This model is developed by assuming that each member of a population is either susceptible, infectious (infected with the disease) or recovered from the disease with life-long immunity (van den Driessche, 2017).

(5) Reproduction Number

There are generally two types of indicators used in order to measure the transmission potential of a disease, namely basic and effective reproduction number. Basic reproduction (*Ro*) number illustrate the expected number in average of secondary cases generated by one case in a population where all individuals are susceptible, while effective reproduction number (*Rt*) is the number of cases generated in the current state of a population, both susceptible and non-susceptible (Rothman et al., 2008).

The basic reproductive number is affected by several factors, such as the rate of contacts in the population, the probability of infection being transmitted during contact and the duration of infectiousness (Barratt et al., 2018). *Ro* represent a number without dimension, which consist of some elements as follows (Jones, 2020):

$$Ro = \left(\frac{infection}{contact}\right) \cdot \left(\frac{contact}{time}\right) \cdot \left(\frac{time}{infection}\right)$$

Thus, the formula can be specifically written as follow:

$$Ro = \tau \cdot \bar{c} \cdot d \quad \text{......} \qquad \text{(Eq. 1)}$$

where

τ : the transmissibility (i.e., probability of

Table 1. Timeline Fragmentation for Modelling the Pandemic

No.	Timeline	Period	Duration (days)	Characteristics
1	Initial Stages (Pre-Restriction)	14 February 2020 - 9 April 2020	56 days	The government intensify the warning about Covid-19, despite of the citizen seems still doing the business normally. Low detection ability due to limited resources Start Working from Home (WFH), with some exception for strategic sectors
2	Large Scale Restriction	10 April 2020 - 4 June 2020	56 days	The government imported new medical devices and protective equipment, thus, increase the testing capability. The government announce the implementation of large-scale restriction (PSBB)
3	New Normal	5 June 2020 - 13 September 2020	101 days	The government gradually lift the restriction and started PSBB transition. Citizen started to work from office with limited number allowed (i.e., 20-50% employee)

infection given contact between a susceptible and infected individual),
c : the average rate of contact between suscep tible and infected individuals,
d : the duration of infectiousness.

This study tried to capture these factors into process and indicator, i.e., probability of infectious per contact, frequency of interaction (number of contacts per time) and duration of infectiousness (time per infectious).

(6) Time Period Fragmentation

Since first case on 2 March 2020, the graph of infected person has varied fluctuate with increasing trend. During this time, Indonesia, particularly Jakarta, has also experienced various event and intervention, which play role to the moving indicator of the graph.

Time fragmentation was used to provide better understanding toward events occurred, such as implementation of policy or action. Accordingly, this study used time fragmentation based on government of Jakarta (The Government of Jakarta, 2020) can be described in Table 1.

RESULTS AND DISCUSSION

(1) Parameters of the Model

a. Healthy Person

Initially, it is predicted that the number of susceptible person in Indonesia is around 700,000 persons (Nugraheni & Kuwado, 2020), or about 0.27 % proportion of 260 million national population. According to government statistics, Jakarta has population around 10.5 million in 2019 (Badan Pusat Statistik Provinsi Jakarta, 2020). Assuming same ratio of capital's population toward national's, this susceptible number is equal to around 28,000 persons in Jakarta.

This ratio, however, is relatively small compared other studies. A model of UK population predicted that at least 20% population in UK might be susceptible to the COVID-19 (Hilton, 2020). Further, it was estimated that around 22% global population has increased risk of severe COVID-19 if infected, while 4% else will be at high risk (Clark et al., 2020).

Among the susceptible person, patient with comorbidity such as diabetic mellitus and cardiovascular may be more vulnerable to infection (CDC, 2020c). The comorbidity factor also includes hypertension, chronic respiratory disease, cancer and chronic renal failure (Bulut & Kato, 2020). According to public health office of Jakarta, the prevalence of diabetic in Jakarta was estimated 3.4% population or about 260.000 people in 2018 (Manurung & Hantoro, 2020). Assumed the population in 2020 is 10.5 million, the number may reach 357.000 people. The number of chronic renal failure was estimated around 399.000 (3.8%), mostly due to hypertension or diabetic (Hamonangan, 2019). Considering this number, which has surpassed the initial prediction, the susceptible ratio from UK's study will be preferred as input for this model.

Not all of the susceptible persons will enter the modelled system and get exposed at the same time, as the virus need time to spread. Therefore, in this study, the susceptible number were daily allocated to enter system during an estimated duration of pandemic. Assuming around 2.1 million of the susceptible persons in Jakarta (20% population) will face pandemic for whole a year, it is estimated that each person will enter the system in the interval 15 seconds. After entering, the person will remain within system until they are disposed due to leaving system, remain healthy, recovered or death (either detected or undetected by statistics data).

b. Imported COVID-19

Imported virus came from either foreigners or Indonesian people who returned from overseas, including migrant workers, students, visitors, etc. Imported case in Jakarta was mostly dominated by Indonesian migrant worker returned from overseas, which reached about 539 cases (about 8.74 % of total cumulative positive cases) until 27 May 2020 (CNN Indonesia, 2020).

The first imported case identified in Indonesia was on 1 March 2020 and reported officially one day after in statistical record. This case involves 2 Indonesian people who got contact with foreigner in a multinational dance party held in Jakarta at 14 February 2020 (Ihsanudin & Erdianto, 2020). However, the symptom was initially assumed as influence before they heard news that the foreigner was declared as infected with corona, thus, they further went to further diagnostics and identified as infected as well. The regional government of Jakarta has also anticipated this pandemic earlier as they have conducted detection test toward suspected person in the end of February 2020 (Government of Jakarta Capital Special Region, 2020). Meanwhile, Marc Lipsitch from Harvard University on February 2020 predicted that Indonesia may have around 5 cases at the time, considering link and interaction between Indonesia and China through air transportation(Cahya, 2020).

c. Interaction Frequency

Identifying the interaction patterns, such as quantity and duration are important to understand the disease spread. The rate at which infectious individuals spread the disease depends on the number of adequate contacts (the contacts that will result in infection) between infected and susceptible (Del Valle et al., 2007). A study on population in Portland found that the number of interactions might varies depend on ages, which range from 8 – 23 contacts per day (Del Valle et al., 2007), with average around 18. Based on the probability of interaction frequency for each age in this study, multiplied by the demography population of Jakarta for each age, the result assumed to follow a Weibull distribution with mean = 18.75, shape parameter $\alpha = 6.13$ and scale parameter $\beta = 20.18$ (95% CI). This result then multiplied by a stay-at-home ratio, which represent the effectiveness of restriction policy to be implemented. For instance, if normally a people interact with 10 persons, with the stay-at-home ratio 20% means that he or she only interact with 8 persons (2 remaining peoples are stay at home and do not interact).

d. Incubation

It may take several days after the exposure for symptom to appear and have better chance to be accurately detected. In certain cases, there is a possibility that infected person is not showing symptoms, but they still can transmit the virus. Test should not be performed too early to avoid false negative result (Fornel, 2020). Antibody tests can be performed but the infected person does not begin producing antibodies immediately (Harvard Medical School, 2020), while PCR test results have more effective diagnosis after a week of infection (CDC, 2020b).

The incubation for symptom to show up (or and consequently followed by testing) ranges from 2-14 days, with 6 days on average (World Health Organization, 2020a)(Chung, 2020). A study on Wuhan, published in March 2020, estimated the incubation period using Weibull distribution, with mean is 8.62 days and median is 8.13 days (Qin et al., 2020). This estimation was based on 1211 cases and will be referred in this model. Later study on 268 confirmed cases in India (published in June 2020) showed that incubation period was best approached by normal distribution with mean 6.93 (SD=±5.87, 95% CI: 6.11-7.75) followed by Weibull distribution with mean 8.17 (Patriakar et al., 2020). Prior the symptom to appear, due to not realizing for being infected or having contact with infected person, the infected persons is assumed to have normal daily interaction with other persons. Even the secondary case requires some times to get informed that he or she got exposed with infected person.

e. Probability for being Infected

There is a number of studies on how much probability of a person being infected during interaction. Researchers based in China and the United States used data on 350 COVID-19 patients and nearly 2,000 of their close contacts to estimate the virus's "secondary attack rate" — i.e., the probability that an infected person transmits the disease to someone else. According to their findings, the average patient had just a 2.4 percent chance of infecting someone they did not live with, that figure jumped to 17.1 percent — around one in six — among cohabitants (Global Health Security Team, 2020). A report of WHO-China Joint Mission on COVID-19 also identified that between 1% to 5 % contacts were positively laboratory confirmed cases, through meticulous tracing efforts (World Health Organization, 2020b). This study estimated 6.47% probability of being infected at the early stages, which then adjusted accordingly with the implemented policy to fit the real cases. Using Equation 1, assuming the duration of infectiousness is 6 days, this number equals to *Ro* around 6.99, a bit higher than a study in March 2020 which showed *Ro* 6.8 (Damarjati, 2020). In reality, the probability of susceptible person being infected is not same during interaction process, due to heterogenous of population including age, gender, different factor of comorbidities etc. (Falasca et al., 2020). It may also be affected by some countermeasures such as physical distancing, wearing mask, good sanitation practice, etc. (Shereen et al., 2020).

f. Stay at Home Ratio

A restriction policy may impact the number of people involved in interaction process. One of indicators for its effectiveness is how much people remain stay at home during the policy, as measured by COVID-19 community mobility index provided by Google (COVID-19 Community Mobility, 2020; Castillo et al., 2020; Setyawan & Lestari, 2020) and compared with Cuebiq Mobility Insight (UNICEF, 2020). This index shows the percentage of mobility changes of people in various places compared to baseline (prior to pandemic). According to the index, the percentage of Indonesian people stay at residential area are changes before, during restriction and new normal, i.e., 31.5%, 42.9% and 33.5%. The highest changes occurred on 10 April 2020 when the policy implemented in the first day, as it led to about 54% people stay at home.

g. Leaving System

The number of people leaving Jakarta in this model was approached by number of vehicles as recorded in the interconnecting highway. Jakarta has also railroad station and harbor, which is shared not only by Jakarta's citizen but also communities from neighboring cities (Jabodetabek: Jakarta, Bogor, Depok, Tangerang, Bekasi). By implementing social distancing, the seat capacity is also reduced maximum 70% of capacity (family members may sit in close seat). Considering this limitation, along with facility sharing with users from neighboring cities, it is estimated that the number of citizens in Jakarta leaving via rail and sea are less than 0.1% of population in average per day. The railroad and ship company in some cases did not operate the vehicles, such as during large scale restriction policy. Therefore, railroad and sea transport will be not modelled at present and will be leave for future study.

Under normal circumstance (prior to pandemic), the number of vehicles leaving Jakarta as detected through interconnecting highway is 963,065 (Andri *et al.*, 2020) or around 2.59 million peoples (24.6% population). Despite of earlier phase of first case announced in March 2020 the number slightly decreased less than 5% of 24.6% population (Dewi, 2020), thus, the proportion is around 23%. The number of vehicles leaving Jakarta during restriction policy in daily average reach 705 thousand or around 1.7 million peoples (Antonius, 2020). This equals to 16 % of 10,5 million population of Jakarta (Badan Pusat Statistik Provinsi Jakarta, 2020). After restriction (new normal phase), the number of vehicle leaving Jakarta reach normal rate, (Triatmojo & Simanjuntak, 2020) which is estimated around 24 % of population in this study.

The entering person to Jakarta can be classified as healthy and infected person. Infected person will be modelled as imported case in the system input, while healthy person will not be modelled due to some reasons. First, as incoming people from outside of Jakarta were assumed healthy, they will not infect local citizen. In the early phase of pandemic, the source for infection is located in Jakarta during a dance party, thus, entering people from outside of Jakarta are still healthy and will not bring any harm. During the pandemic, a restriction policy makes people from outside of Jakarta need to be screened. Only healthy people allowed to pass while infected person will be quarantined or rejected. Secondly, the healthy incoming person may get infected by local citizen, but they assumed only temporarily visit Jakarta and interact with limited people. Due to health insurance policy, even if they get infected and show some symptoms –unless it is emergency-, they should go to the doctor near to their living residence (outside of Jakarta), thus, their infected status will be recorded in their respective region's statistics and not in the Jakarta.

h. Detection

Detection in this study refer to the capability for tracing and detecting virus, which was estimated by the average number of testing performed by the local government of Jakarta (Government of Jakarta Capital Special Region, 2020).

The input for detection came from infected persons and their relevant partners during interaction. In initial stage, there is a probability 9.6 % in average of tested person to be positively confirmed, according to the data provided by the local government of Jakarta (Government of Jakarta Capital Special Region, 2020). This positive ratio refers to the ratio between number of positively confirmed cased compared to testing number. The positively confirmed person during the restriction policy and new normal in average is 6.49% and 7.08% respectively. In the case of the detection result shows negative result, the person which has contact with the infected people should stay at home and do physical distancing. Within 10 days, they should be tested again according to the Health and Medical Guideline for COVID-19 (National COVID-19 Taskforce Republic of Indonesia, 2020b).

i. Treatment

Around 80% of infected people recover from the disease without needing special treatment, as they have minor illness. However, some of remaining people develop difficulty in breathing and require hospital care (WHO Indonesia, 2020). The number of hospitalized persons in Jakarta may around 29% - 73% (Detikcom, 2020)(Government of Jakarta Capital Special Region, 2020). The duration for staying at hospital is based on the severity of infectiousness and may depend on the comorbidity factors in the patients.

The duration of medical treatment at hospital until the patient are recovered varies between 4 to 53 days within China, and 4 to 21 days outside of China (Rees et al., 2020)with rapidly increasing demand for healthcare in hospitals and intensive care units (ICUs. The average duration can reach 25 days in India (95% C.I. 16 days to 34 days) (Barman et al., 2020). In Indonesia, the length in hospital is around 2 weeks for patient without comorbid and 3 weeks with comorbid (Manafe, 2020). In certain cases, the length may be shorter, i.e. 7-10 days (Government of Riau Province, 2020) or longer until 75 days (Fauziah, 2020). In this model, a triangular distribution with range between 7-28 days in initial stages is used for duration at hospital. After treated in hospital and confirmed negative, patients are required to do further isolation at home.

Treatment at home, particularly for patient with mild symptom, has duration which may similar to those in hospital and can be faster (Gallagher, 2020). A similar range is used in this study for those treated at home. No concerned data found regarding the possibility of re-infection with SARS-CoV-2 after recovery from COVID-19 (CDC, 2020b), therefore after recovered patient (from hospital and home) will stay healthy and leave the system.

j. Recovery Rate

The recovered rate of infected person is relatively lower at early stages and increased significantly during large scale restriction phases and new normal phase, which reached 83.92% and 96.72% respectively (National COVID-19 Task Force Republic of Indonesia, 2020a).

According to precaution issued by Centers for Disease Control and Prevention, U.S. Department of Health & Human Services, no confirmed cases of SARS-CoV-2 reinfection found during 6 months after the emergence of SARS-CoV-2 (CDC, 2020a). Therefore, in this model, all recovered person will be counted in healthy state.

(2) Running the Model

a. Model Validation

The model is run during three timelines, particularly to verify whether the model has represented the current existing system. Some parameters will be measured for each timeline, which were summarized in Table 2. According to the table, it can be seen that the difference between simulation and real cases varies from -4.47% to 1.6%. This indicate that model can be used to represent real cases, with the variation below 5% of the real cases.

b. Estimating Undetected Cases at Initial Stages

In the beginning of April 2020, there is a study that predicted the number of positive cases found in Jakarta is just around 2.3 % of 32,000 the real case (97,7 % undetected), by considering the population density of Jakarta (Ferdiaz, 2020). This undetected rate is higher that an estimation of the beginning in-

Table 2. Comparison between Model and Real Cases for Initial Stages, Large Scale Restriction and New Normal

No.	Parameter	Initial			Large Restriction			New Normal		
		S[a)]	R[b)]	D[c)] (%)	S[a)]	R[b)]	D[c)] (%)	S[a)]	R[b)]	D[c)] (%)
1.	Number of testing	13,053	12,981	0.55	115,796	121,396	-4.61	757,104	759,672	-0.34
2.	Number of confirmed positive	1,141	1,163	-1.89	6,918	7,008	-1.28	54,594	53,733	1.60
3.	Number of cured	65	68	-4.41	2,414	2,475	-2.46	40,767	40,705	0.15
4.	Number of dead detected	171	179	-4.47	463	479	-3.34	1,383	1,371	0.88

[a)]Number from simulation, [b)]Number from Real Case, [c)]Difference between simulation and real case

Table 3. Alternative Scenario

No.	Scenario	Description	Adjusted Parameter
1	Existing Scenario	Based on current parameter (new normal), the simulation run until 365 days	None.
2	Social Intervention	The policy encourages people to work from home and restrict the number of people work at office. This is also supported by people awareness to wear mask and do social distancing.	Stay at Home Ratio increased 50%, Infected Probability reduced 50%, Leaving Ratio reduced 50%.
3	Health Intervention	This scenario assumes that more testing is conducted with higher detected number of infected persons, as well as more effective treatments are performed, resulting higher rate of recovered patients.	Tracing Capability increased 50%, Detection Rate increased 50%, Recovered Ratio reduce death rate by 50%.
4	Mass Vaccination	The vaccinated person is assumed immune to any COVID-19 virus and will not infect others, thus, can interact with other like normal person.	After new normal until the end of simulation run, number of vaccinated persons is assumed 60% effectively (Rantung, 2020).
5	Hybrid Intervention	This scenario is combination of Social and Health intervention, to anticipate the long waiting time for the vaccines.	Stay at Home Ratio increased 50%, Infected Probability reduced 50%, Leaving Ratio reduced 50% Tracing Capability increased 50%, Detection Rate increased 50%, Recovered Ratio reduce death rate by 50%.

*) Notes: According to Rantung (2020), 66% of population is estimated willing to get vaccinated. Assuming 90% will develop immunity, this number equal to around 60% of population effectively vaccinated.

fection rate at Wuhan, which predicted that up to 87% was unascertained (Hao et al., 2020). Another study using Autoregressive Integrated Moving Averages Model (ARIMA) predicted that undetected cases in Jakarta varies between 6-12 % (Fadly & Sari, 2020). Based on this simulation, the number of undetected positive cases was predicted 3,960 persons (77.63% of total cases) or around 3.47 times of detected cases. According a study in Europe, the ratio of undetected cases in some countries such as Italy, Germany, Spain, UK, Greece and Austria was estimated varies from 1.2 to 1.4 times of detected cases (Böhning et al., 2020).

c. Impact of Restriction Policy

Different simulation was conducted to identify the impact if no restriction policy is implemented after initial stage. A parameter related to restriction policy, i.e., stay at home ratio, was adjusted with values were returned same to initial stages. Within same period of running, the result displayed that the number of infected persons can reach 14.310 with 812 die. In actual case, when PSBB was applied, the number became 51.62% lower for infected person and 42.98% lower for dead person. This may be interpreted that the policy is effective to halve the pandemic growth.

(3) Foreseeing the Next: Defining Five Scenarios

Current practice has been already performed by combining social and health intervention. However, at existing progression rate, there is a warning from Indonesian Medical Association regarding possibility of overcapacity with the increasing testing number toward population (Hauzah & Saubani, 2020). Jakarta prepared 172 hospitals and 1200 beds for treating the infected patients, and the number of personal protective equipment also doubled after the pandemic (Junita, 2020). In certain hospitals, the queuing has reached 70 persons and sometimes they could not receive further incoming registrant (Wahyudi, 2020). Therefore, alternative scenario will be evaluated if some of parameters are adjusted and boosted, as defined in the Table 3.

(4) Analysis of Intervention Scenario

The results for five possible scenarios are il-

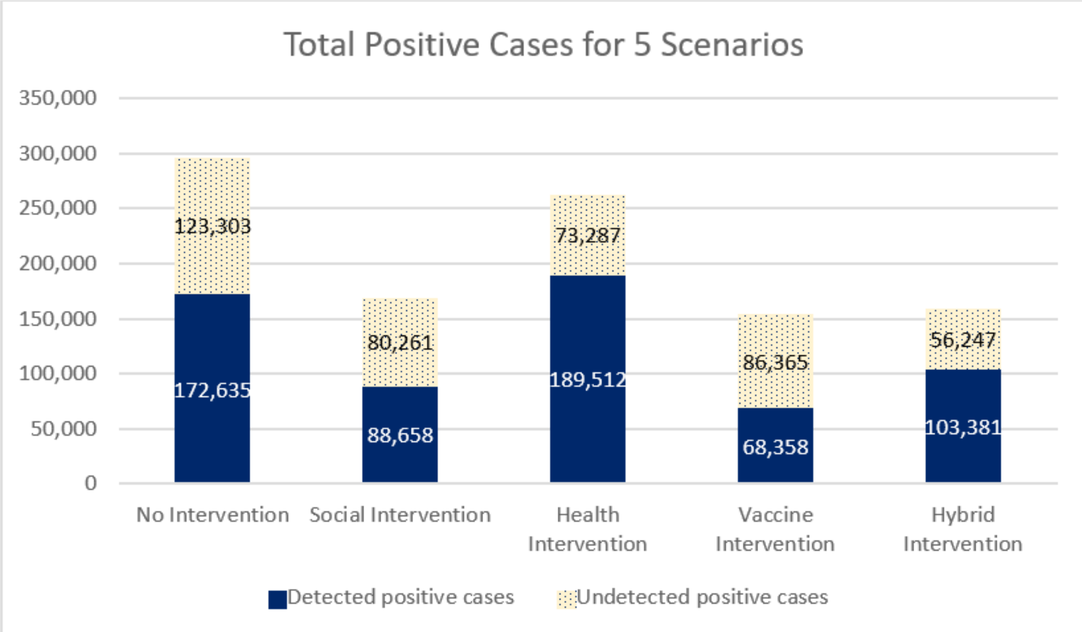

Figure 2. Total Positive Cases (either detected or undetected) for 5 Scenarios

lustrated in Figure 2. Based on this figure, if no special intervention is introduced after new normal, it is estimated the number of positive cases in Jakarta during a year is almost 300,000. Among possible scenario, mass vaccination overall has best performance, as it has the least number of positive cases in the system, both detected and undetected (Singh & Upshur, 2020). However, in case of the vaccines have not commercially produced, hybrid intervention may provide good approach to inhibit the positive cases, as it has nearly comparable positive cases to vaccines. Social boost intervention may also provide good approach and can be used in case lack of resource for performing health intervention concurrently.

The highest recorded number of recovered people can be achieved if health intervention is implemented, since this scenario allow larger number of medical resource utilization such as diagnostic kit and hospital capability (Figure 3). However, this intervention is not as good as hybrid intervention in term of mortality number, as the hybrid intervention has not only utilize health resource but also social intervention. Vaccine intervention, on the other hand, do not offer least number of dead person nor highest number of recovered persons. However, this intervention offers promising number of dead and recovered person, which in total is the least amount among other intervention. In this context, achieving least mortality number should be prioritized rather than highest recovering number. High recovering number also reflects that many persons get infected and need treatment, thus, high recovering number is not always good thing. Therefore, hybrid intervention offers promising choice to achieve least number of dead persons.

Number of persons leaving system (Jakarta) can also affect the model. More people leaving Jakarta make less people in the system has chance to get infected, as well as less person need medical treatment. It seems good thing for Jakarta, however, it actually only shifts the burden to another city, particularly if the leaving person is bringing the virus. Social intervention, combined with health intervention, have the best scenario to hamper the virus spread. Strict prohibition to leave Jakarta can push the people to stay at home, as well as push the infected person to have treatment as soon as possible at hospital within city. This, in turn, make the death number can be reduced, as described previously. Vaccine intervention has the highest number of people leaving Jakarta due to this scenario does not restrict people to leave Jakarta. In addition, with vaccine, less infected case found compared to no intervention (Figure 4) as more people are immune, thus, they can leave the city instead of staying in the bed.

After estimating the number of people disposed from the system through dead, recovered and leaving city, the remained number of people within system after a year can be predicted. According to the simulation, vaccine intervention has the least remaining infected person, followed by social intervention and hybrid intervention with the little difference (Figure 5). Hybrid intervention has slightly a greater number of infected persons compared to

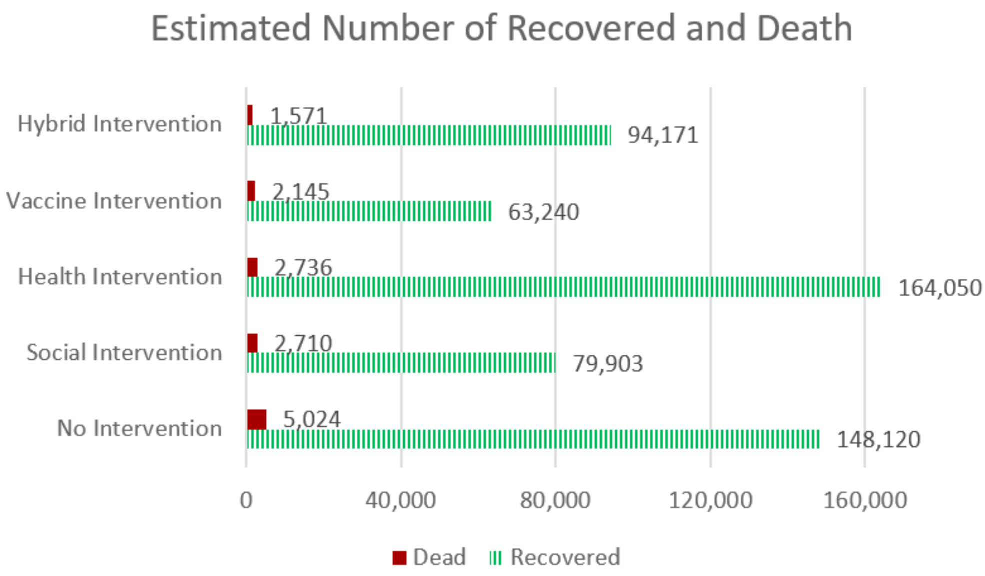

Figure 3. Number of Recovered and Dead Peoples for Five Scenarios

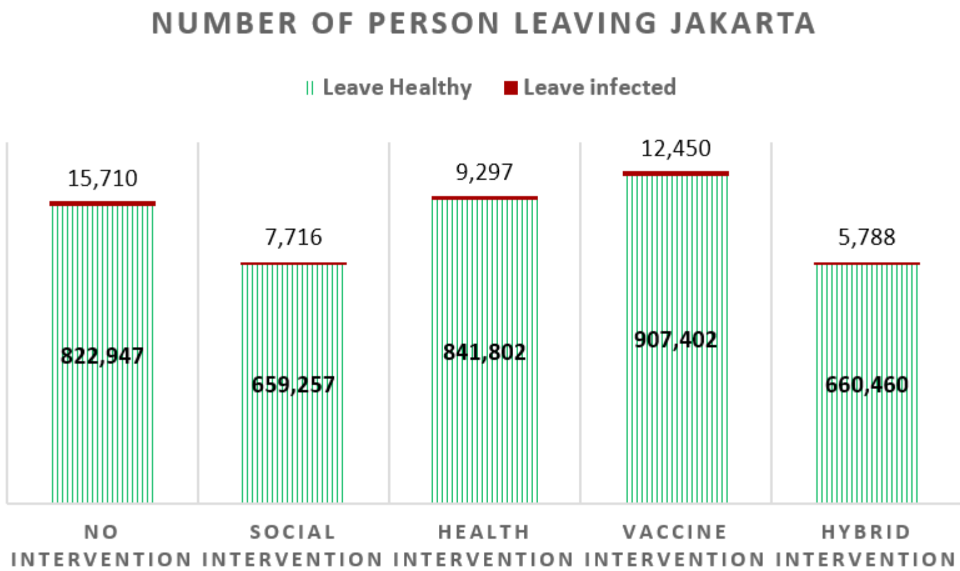

Figure 4. Number of persons leaving Jakarta for 5 Scenarios

social intervention due to its capability to trace more of infected person. Hybrid has also better capability to provide treatment, therefore, make the healthy number remained in the system is higher than social intervention.

(5) Implication and Limitation

a. Research Implication to Support Innovation Policy

This model can be used by policy maker to devise one or more strategic plan, such as research and manufacturing of products required for mitigating the pandemic. For instance, it can be used to estimate the demand of medicine, vaccines, and personal protective equipment (PPE). Drug for healing the infected patient can be estimated based on the number of positive cases, while vaccine can be prepared by considering population, particularly prioritization for susceptible person and those in the front of lines such as medical professional, police officer or volunteer who help in socializing and implementing social distancing regulation. Further study can also be developed further by involving these resources into model.

Whatever scenario will be taken, there is unrefusable fact that PPE such as mask, face shield, gloves, apron, gown, and tissue paper plays essential role during the pandemic. Whether the intervention is preventive (i.e., social distancing, vaccination) or curative (treatment for patient recovery), PPE is demanded not only by medical professional but also

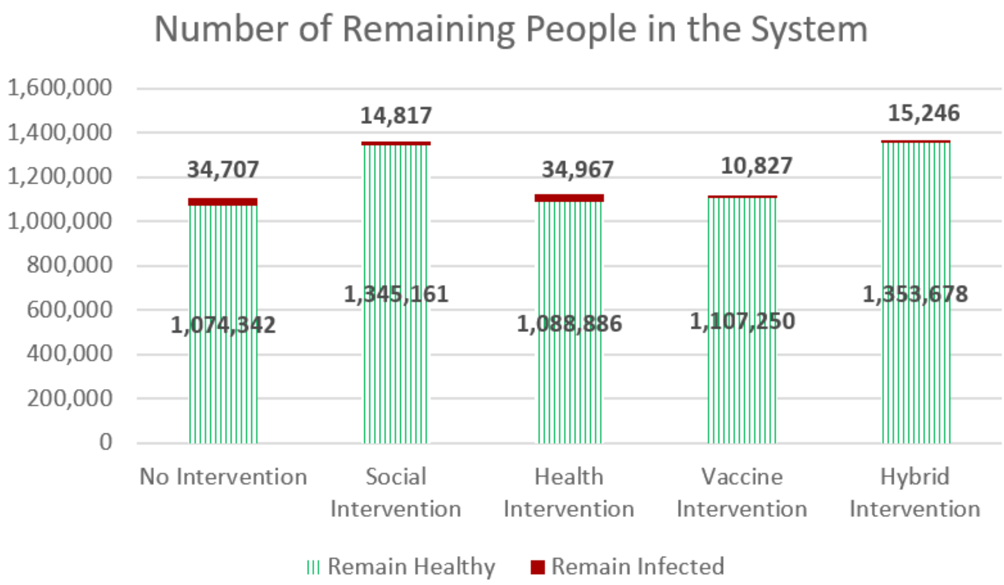

Figure 5. Number of Remaining People in the System

common societies (Lewnard & Lo, 2020). Therefore, the production as well as research on this topic will also have significant contribution, particularly to protect person for getting infected from others. This model can help the relevant stakeholder (government, industry, and community) to predict which PPE is more required in correspond to the implemented intervention. For instance, if health intervention is implemented, research and production of PPE is more required for treatment purpose at hospital, but if vaccine intervention is implemented, PPE should be allocated further for improving the capability to identify undetected cases.

b. Limitation

This study run the model using parameters without considering resource cost and economic impact. Implementing social intervention may require resources such as mobilizing officer to implement the policy, technology development or purchasing such as mobile application to trace people and thermometer gun, providing reserved mask for public use, sanitation, etc., while medical intervention require more testing kit (rapid test, PCR, etc.), developing and purchasing medicine, ventilator, expanding capacity of bed and hospital, etc. Measuring economic impact may require macroscopic understanding, particularly since an intervention may make person loss his job or income, thus, decreasing economic activity in a region. This may also need reprosical and risk analysis, such as to predict whether a city or region need to implement one or more intervention while waiting the possibility of a vaccine to be developed and mass produced.

CONCLUSION

COVID-19 has been spreading diversely across country, thus, research and effort to mitigate the pandemic should be performed relentlessly. Modeling and simulating the spread of pandemic can be implemented to provide support for policy makers, particularly to predict how an intervention may affect the cases. This study utilized discrete event simulation to model the virus spread in Jakarta, in order to estimate the number of cases such as undetected cases, number of infected, cured, and dead. Further simulation on different intervention scenarios illustrated the importance of mass vaccination to hamper the spread. However, while waiting the vaccine production, hybrid effort should be implemented optimally with social intervention as main driver supported by health intervention. Further study can be developed by considering other aspect such as resource cost and economic impact.

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