



SYSTEM DYNAMICS OF PEAK PROJECTION COVID-19 IN INDONESIA

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ABSTRACT

Since the emergence of Corona Virus 2019, COVID-19, which was first discovered in December 2019 in Wuhan City, Hubei Province, China, it has been determined as a pandemic by the World Health Organization because this plague that has spread out in a short period of time throughout the world is infectious. In Indonesia itself, this has started from March 2, 2020 and within a month there has been a significant number of cases, in which the number of confirmed cases of COVID-19 was 8,882 people. There were 743 people who died, or the death rate was 8.34%, which is spread 34 provinces or there is 100% of provinces which have confirmed COVID-19 cases. The purpose of this study was to analyze the peak projection COVID-19 in Indonesia. The system dynamics projection is strengthened by the choice of scenarios to see the projection, so that it is possible to know the possibility of COVID-19 cases in Business As Usual, Moderate, Optimistic and even uncontrolled conditions. In Business As Usual condition, it is estimated that the number of cases with a maximum point of around 15,000 cases and the cases will reach the peak on day 80th to 110th, and then the case will start to slowdown. In the uncontrolled condition, it is estimated that the number of cases with a maximum point of around 27,000-30,000, which reaches its peak on day 100-120. In extreme condition, this means that there is a new constant in other provinces for explosion cases. It is estimated that cases will increase to 50,000, which reaches its peak on day 170-180. It will be higher if the same pattern (Extreme Uncontrolled) occurs in other Provinces as at the Java Islands. This is because new constants are increasing in other regions. Application of moderate conditions with precautionary calls, implementation of health protocols including healthy living movement, social distancing, disinfectant spraying, adequacy of medical devices and health facilities, implementation of Stay At Home or Work From Home can delay the maximum number of cases around 9.000 and its peak is on the day 90th, after that the cases will decline slowly.

KEYWORDS

COVID-19, System Dynamics, Systems Thinking, Simulation, Modelling

Introduction

Since the emergence of Corona Virus 2019, COVID-19, which was first discovered in December 2019 in Wuhan City, Hubei Province, China, it has been determined as a pandemic by the World Health Organization because this plague that has spread out in a short period of time throughout the world is infectious. Moreover, this has a continuous infection line and causes a lot of victims. In this case this had been 4 months until the end of April 26th, 2020, and there have been as many as 2,774,135 people who have been declared exposed to this virus with and 190.871 people who were claimed dead. According to WHO 2020, this virus has spread to 202 countries [1]. In Indonesia itself, this has started from March 2, 2020 and within a month there has been a significant number of cases, in which the number of confirmed cases of COVID-19 was 8,882 people. There were 743 people who died, or the death rate was 8.34%, which is spread 34 provinces or there is 100% of provinces which have confirmed COVID-19 cases, and this can still continue to increase due to the growing trend of cases. The highest number of COVID-19 cases is in DKI Jakarta, that is, 42.76% of all confirmed cases in Indonesia, followed by West Java Province by 10.27%, East Java Province by 8.84% and Central Java

Province by 7.31%. Of the four provinces, there has been 69.18% of cases confirmed as the main core area for the cases [2].

In projecting the COVID-19 case in Indonesia, it is very specific and unique because Indonesia is an archipelagic country, so we cannot just project by comparing based on the population in Indonesia. It is necessary to perform an opportunity occurrence based on the number of residents with a constant case of events in each province or island that is different, so the contact opportunities that will occur can be found out. On the other hand, this can illustrate the vulnerability of the region based on the number of cases and consideration of regional economic mobility. To anticipate the increasing number of cases, a strategy is needed to inhibit the rate of growth and spread. Looking at the projected conditions in the future is very important, so we can anticipate with a variety of policy scenario choices. The system dynamics approach is very optimal to see the conditions that will come from the simulation results as well as the scenarios that can be chosen. The ease of seeing the interrelation of variables is reflected from the causality that is formed and the behavior that will occur with the implementation of the scenario. This study aims to see the behavior of the maximum number of cases in Indonesia and the selection of policy scenarios to slow down and resolve COVID-19 cases in Indonesia. The purpose of this study was to analyze the peak projection COVID-19 in Indonesia.

Method

The study has observed the beginning of covid 19 occurrence in Wuhan until now and also the first case that happened in Indonesia. To see the graph of Corona Virus growth behavior, some data obtained from various sources, like WHO (World Health Organization) to see the data in the world and National Disaster Management Agency to see the data in Indonesia are needed. COVID-19 research in Indonesia was developed with a modeling simulation analysis tool with a System Dynamics and with the consideration of ease to visualize the dashboard to the users. While technically, the formulation was developed from various data from Statistical Framework integration with Dynamics Complexity.

The system dynamics projection is strengthened by the choice of scenarios to see the projection, so that it is possible to know the possibility of COVID-19 cases in Business As Usual, Moderate, Optimistic and even uncontrolled conditions if there is an explosion of cases on other islands that will disrupt patterns in Jakarta . With the description of Business As Usual, it can help anticipate all the stakeholders' roles, including the Government, the Community and directly involved institutions that seek to minimize the COVID-19 cases in Indonesia.

The system dynamics models were used to formulate, simulate and validate the sustainable land use for soybean. System dynamics is designed for analysis of complex physical-socio-economic systems [3]. A detailed description of the methodology is presented by Forrester [4]. This methodology has been applied into various fields, including environmental sustainability [5][4], environmental management [6], transport and land use planning [3][7][8], ecological modelling [9].

All system dynamic models are made out of three kinds of variables: stock, rate, and auxiliary, and two kinds of flows, physical/material and information. In system dynamics, simulation is governed entirely by the passage of time and is referred to as "time-step" simulation [3][10]. The purpose of a dynamic system study is to understand how and why the dynamic systems are generated and to search for managerial policies to improve the situation. These policies refer to the long-term, macro-level decision rules used by upper management [3][11].

Result and discussion

Systems Thinking and Formulation

In making a simulation, this can be carried out from the number of cases that exist for some time, but in a system dynamics, this is not only about projecting the existing data. In a system dynamics, it is important to make the relationship first among the variables related to the case and the combination from various projections of the variables forming COVID-19 case.

The development of systems thinking is in casual relationship (causal loop diagram). This is the basis for building the interrelation among variables. There are several specific terms used for people who experience the

symptoms to facilitate the understanding of the COVID-19 case in Indonesia, that is, people under monitoring (PUM) and patient under treatment (PUT). PUM is for those who experience fever ($>38^{\circ}\text{C}$), cough and cold or Acute Respiratory Tract Infection or URI (Upper Respiratory Tract Infection) without Pneumonia and they have a travel history to other countries/ regions in which there is a case of COVID. While PUT is for those who experience fever ($>38^{\circ}\text{C}$), cough and cold or Acute Respiratory Tract Infection or URI (Upper Respiratory Tract Infection), and Pneumonia from mild to severe, and they also have a travel history to countries/ regions in which corona virus occurs and they also have a direct contact with those who are positive.

The first case occurred because there was a carrier and this led to an exposure of people in contact with the carrier. However, because there was an incubation time of 2-14 days, this slowed down to see whether the people were infected or not. If the people were categorized into positive, thus, they would be treated and cared specifically (isolated) so that the virus would not spread out to others. The fast growth of this virus is because there will be some people who are likely positive but they are not categorized into (PUM/PUT), the virus could be transmitted to other people. The speed of transmission depends on the number of contacts, both from people who are likely to be positive directly or indirectly through other infectious media or the region resulting the surge of case in which there are people who are infected or even already positive.

It is necessary to apply the policy model in inhibiting or cutting off the speed of transmission of COVID-19 in various ways. The application to inhibit the rate of development of cases and break the chain of spread is call for alertness, health protocol implementation including Healthy Living Movement, social distancing, disinfectant spraying, adequacy of medical devices and health facilities, Stay At Home or Work Form Home and also the option of limiting the region both regionally partially closed down and lockdown. A description of the relationship and causality of the developed model is shown in Fig 1 and formulation of the model in Table 1.

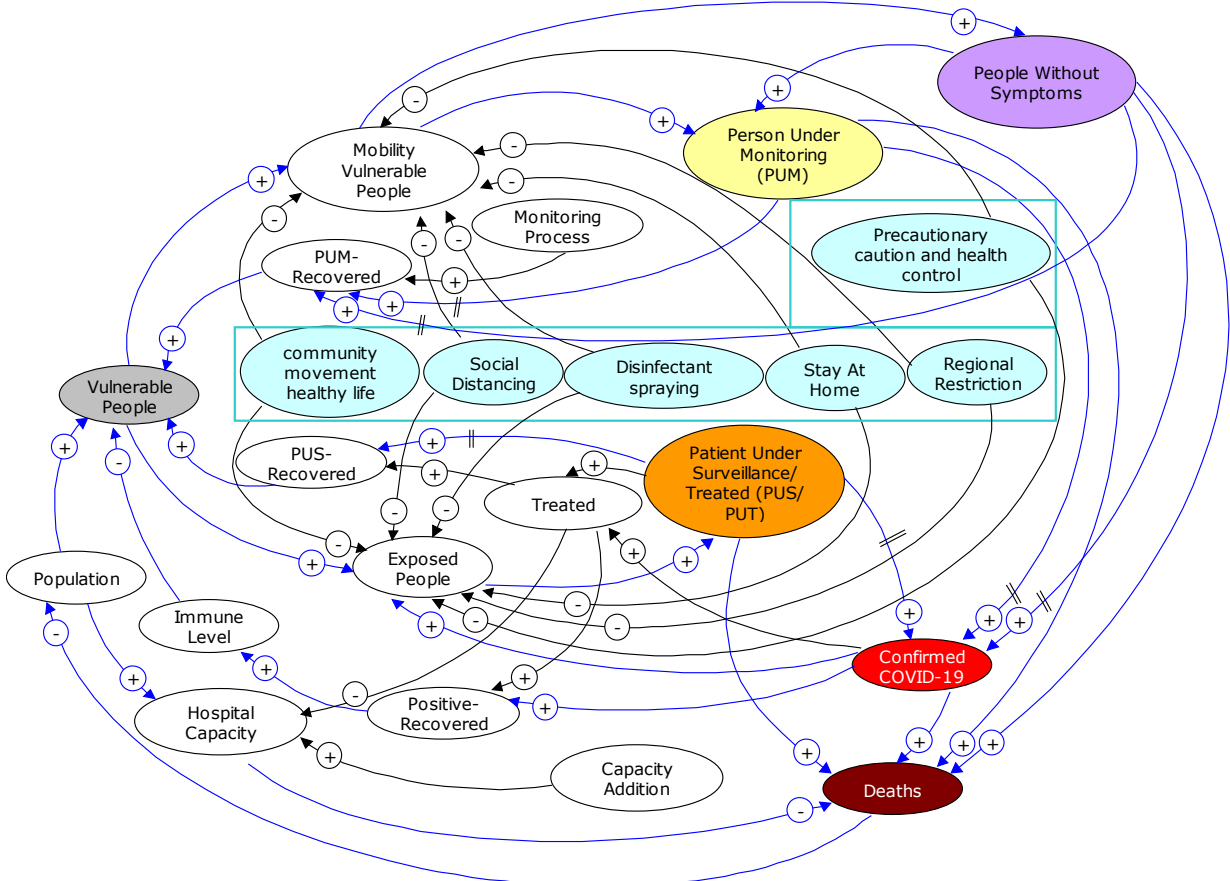


Fig 1. Causal Loop Diagram Model COVID-19 in Indonesia

Regional Vulnerability

Before conducting the simulation, it was crucial to conduct a regional vulnerability analysis because it could cause differences in the number of vulnerability people in each region. This regional vulnerability was seen from the large number of cases in each region and the opportunity for individual contact with residents of the region. On the other hand, interaction among regions could also be a factor in calculating the level of vulnerability, in which high mobilization among regions would lead to higher contact possibilities. Therefore, this would lead to a greater vulnerability of the region. The area vulnerability calculation was based on the number of cases in each region and the average likelihood of a contact during a 2-14 day incubation period, in which the average contact is 10-15 people per day. The illustration of the regional vulnerability level is shown in Fig 2.

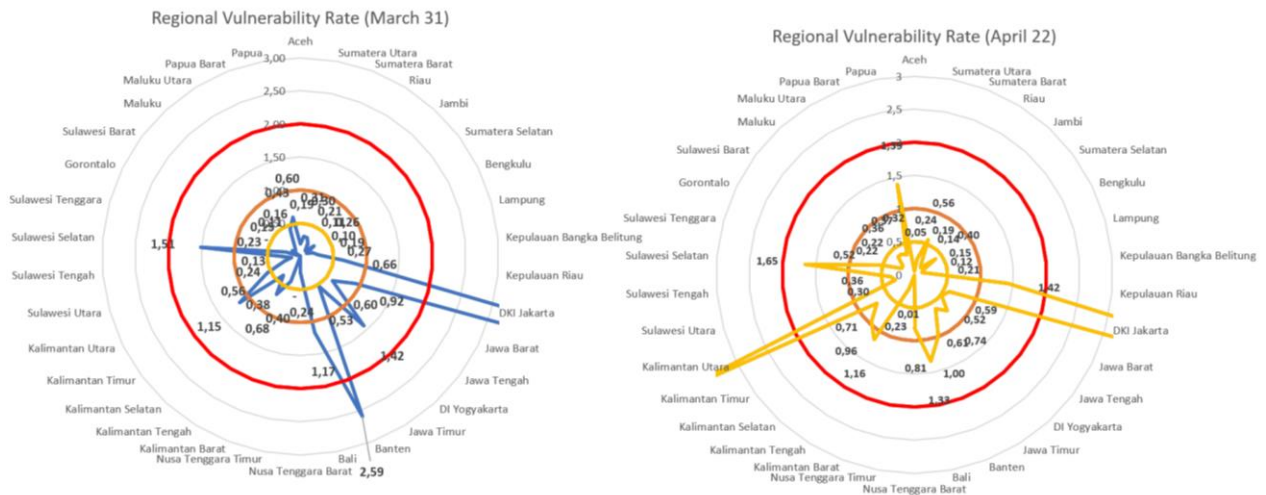


Fig 2. Level of regional vulnerability based on cases to population and economic mobility

Based on the picture of the vulnerability level, especially the case of the total population, it can be seen that the region that has the highest level of vulnerability is the Province of DKI Jakarta with a weight value of 12.12 of the average case and the Province of North Borneo with a value of 4.03. While the next level of vulnerability is the South Sulawesi region (1.65), Riau Islands (1.42), Papua (1.39), Bali (1.33), Central Borneo (1.16) and Banten (1), while other provinces are still in the small category.

Modeling Simulation

After obtaining the possibility of contact from each region with different constant, it could be found out that the possibility of Indonesian categorized into vulnerability was 10,500,000 to 11,000,000 people. Data simulation was carried out to see how long, how many possible cases will occur, and the estimation of when this case will reach a peak. The result of simulation was seen from the number of positive COVID-19 cases. The estimation of those who died was determined from the percentage of research cases and the level of people who were vulnerable. The number of patient needed to be treated both from the positive and from the PUT.

The policy scenario was carried out in a number of conditions including moderate, optimistic and uncontrolled. This system dynamics can provide an overview to stakeholders who want to see the results of their simulations because simulation scenarios can be carried out in accordance with the hope or ability that can be performed in an effort to minimize COVID-19 cases in Indonesia. To facilitate the formulation of policy alternatives, scenarios were formulated in the model. The scenarios were compiled according to type and level of intervention to the existing policy [12]. For the scenario condition, it is presented in table 2. From some of these conditions, it can be chosen the possibility of policy that can be undergone especially the possibility of cases in Business As Usual, while the optimization of policy scenarios is done under moderate and optimistic conditions and in uncontrolled condition, a very significant surge can be clearly seen. For Business As Usual condition, it is shown in Fig 3.

Based on the simulation results there are 2 conditions (fig 3.1), in which the first condition is if it has not been anticipated in advance or an appeal to the community for vigilance when starting the first case drawn on the red line appears. Whereas the second condition on the blue line, this shows that there has been an alert call during the first case, but what needs to be considered is 2-14 days before the first case. In fact the person has made contacts with several other people. In the second graph there is still an increase, this is possible if it does not make progressive treatment and the limited number of health facilities and medical personnel. Whereas in Fig 3.4, it can be seen the number of patients who are positive or PUT needed to be treated in hospitals. Consequently, there will be a surge in the number of patients feared for lack of bed health facilities and equipment for handling COVID-19 cases.

Table 2. Scenario Conditions in System Dynamics Simulation

No	Condition	Decription
1	Business As Usual	•Conditions where there is still a deficiency of medical needs for health control, but the healthy life and social distance increases
2	Business As Usual (Deficiency of medical needs)	•Conditions where there is still a deficiency of medical needs for health control, but the healthy life and social distance increases but slowly
3	Uncontrolled and Extreme	•Precautionary Caution is not optimal implemented •Stay at home is not running optimally, because of the activities still carried out •There were highgrowth case on other islands following the core cases islands (DKI, West Java and Banten) •In Extreme new constants in other islands/Provinces fast increase
4	Maximum	•Conditions where there is still a deficiency of medical needs for health control •The healthy life and social distance increases but slowly •Precautionary Caution is not optimal implemented
5	Moderate	•All scenario variables are moderate, and stay at home runs at 60%
6	Optimistic	•All scenario variables are moderate, and stay at home runs at 60%, after day 50 the regionally partially closed down

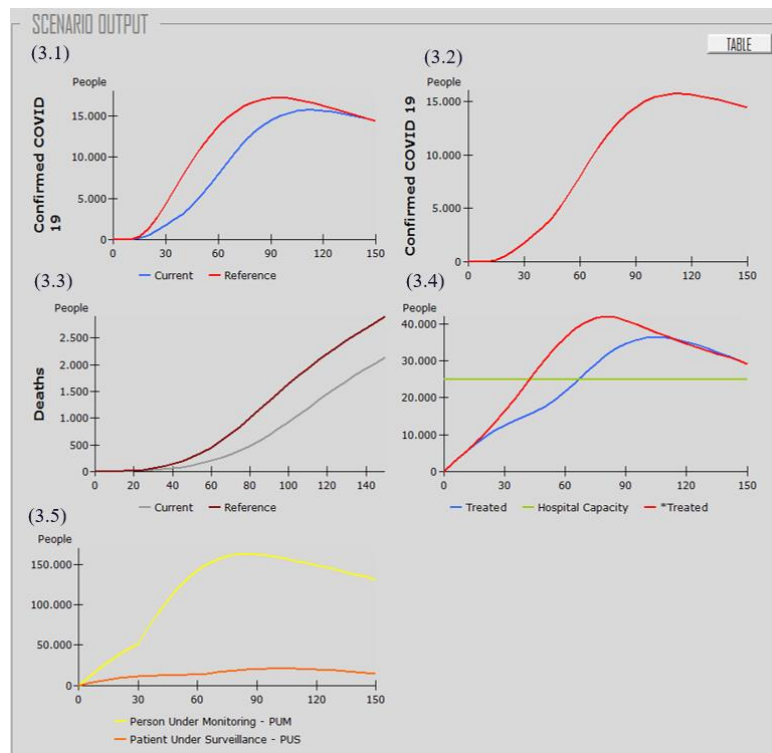


Fig 3. Simulation Results of Business As Usual Conditions before Optimizing the Policy Scenarios.

The peak estimation of COVID-19 in Indonesia is the 80th to 110th day with a high enough number of cases reaching around 15,000 at the optimum point, and the decrease of case number is subsequently quite slow. This shows that there has been a slight slowdown in the decrease of the maximum possible number of cases, but it can at least reduce the number of people dying. While the mortality rate is around 8-9% for now, so it is around 1,200-1,400 people, with a note that this is due to the limitations of health facilities and medical equipment for handling cases. It is not impossible that this will be even higher if other regions outside of Java perform the same pattern as in Jakarta or Java. In addition to handling in Jakarta and nearby areas, anticipation in other provinces is important in order to inhibit the same pattern of spread rate.

Policy Scenario

Minimization of COVID-19 in Indonesia needs to apply a number of policy so that it will run effectively and efficiently. Some scenarios of policy and the stimulation of model drive variables or programs that are applied with the, uncontrolled condition, moderate condition and they are applied progressively (optimistic).

With the selection of variables, the policy simulation scenarios can be performed on the simulation requirements according to its implementation capability, but from this initial case of study up to the 30th day with business as usual conditions and some moderate improvements have been made. The Indonesian government has implemented many public recommendations to contain COVID-19 transmission. The participations from the community are a vital role to overcome this pandemic condition. Many countries have shown the obedience of the community to the government's decision has influenced the growing cases and death cases. The community should implement the social distancing and self-isolation protocol since there are also some asymptomatic COVID-19 patients who are called as carriers. The personal hygiene behavior, including hand-wash, should be implemented regularly, as soon as we have touched anything. We realize that there are many obstacles for this implementation in Indonesia due to the economic and religious reasons [13]. Policies that have been implemented in stages such as health protocols, the Healthy Living Community Movement, and the provision of work at home with a value of 60%. They started with patients triage, education for patient and family through handouts and web-site, and strengthening the policy of "stay at home". A phone triage line, providing personal protective equipment (PPE), and also test to symptomatic medical staff, were provided [14]. Stay at home is still quite difficult to carry out maximally. This can be seen that there are still many business owners and small-medium sized business owners who mobilize highly in order to fulfill their daily need.

Whereas the optimistic conditions were carried out as business as usual conditions until the 30th day, it was then only implemented on day 40th to be a progressive (optimistic) unless the spraying is performed in the condition of moderate because this is quite difficult to carry out to the whole areas. Stay at home can be really applied up to 90%. This cannot be performed completely 100% because some people still need to do their activities. In this condition, the most important thing is the adequacy of facilities and medical devices. In some regencies/ cities, the red category needs to be limited in its region (regionally partially closed down). For the simulation projection result, this is presented in Fig 4.

In extreme condition, this means that there is a new constant in other provinces for explosion cases. It is estimated that cases will increase to 50,000, which reaches its peak on day 170-180. It will be higher if the same pattern (Extreme Uncontrolled) occurs in other Provinces as at the Java Islands. This happens when there is an increase in contact in other islands/provinces, a decrease in social distancing, and government's appeal. In this uncontrolled condition, this means that there is a similar pattern of explosion of cases, such as in the island of DKI Jakarta, West Java and Banten. It is estimated that cases will increase to 27,000-30,000, which reaches its peak on day 100-120. This happens when there is an increase in contact, a decrease in social distancing, and government's appeal. Limited the number of referral hospitals adequately and equip such hospitals for treatment properly. This includes to properly set up treatment facilities (e.g. respirators, isolation chambers), diagnostics facilities (e.g. PCR machines, diagnostics kits), medicine and pharmaceuticals, management, medical doctors, specialists, nurses, health volunteers, and safety and protection equipment for frontline practitioners (e.g. safety goggles, protection masks, hazardous materials suits) [15] and new constants are increasing in other regions.

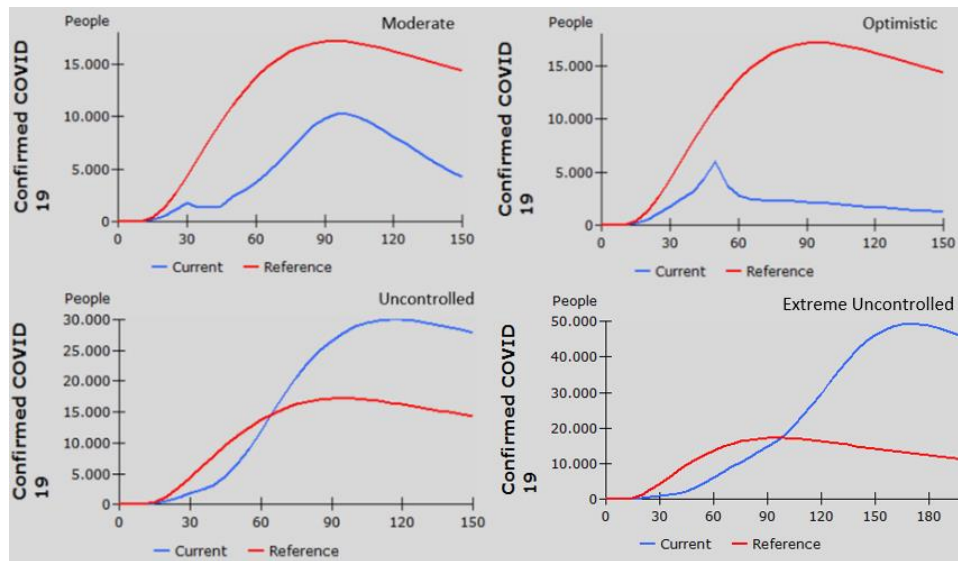


Fig 4. Simulation Projection with Scenario

Moderate Condition, The simulation of scenario in the moderate condition can slow the increase rate of cases to only 9,000-10,000 positive cases of COVID-19 that occur, in which the pattern still remains the same as the present condition. It is crucial to start the restriction outside of the Java Island. However, if the region does not apply the same thing, it is likely to increase the cases. If this can be applied, the cases will slow down on day 90th, and begins to decrease by half. From these results, it seems that there has been a decrease of one third of the maximum cases. This is already quite significant, but there is still a slight increase and the maximum point of day 90th. The decline is slightly slower due to the positive cases, and the existence of PUM and PUT around the community, on the other hand, the activity will have started to run again. The effectiveness and societal impact of quarantine and social distancing will depend on the credibility of public health authorities, political leaders, and institutions. It is important that policy makers maintain the public's trust through use of evidence-based interventions and fully transparent, fact-based communication [16]. For the case of death, it can be minimized because the handling of the hospital capacity is very sufficient, but the slowdown will still occur because there have been a limitation of medical devices for handling COVID-19 since the initial case occurred. social distancing within hospitals is equally vital in reducing nosocomial spread, especially in hospitals where the majority of patients are nursed in multi-bedded cohort rooms, rather than in single-occupancy rooms [17].

Progressive Condition (Optimistic), For the simulations on progressive or optimistic conditions, it is very influential to the suppression and decrease of COVID-19 positive cases sharply. Based on the simulation results in this condition, the 45th-65th day (6,000 Cases) can be reduced by the rate of case estimated at around 3,000-4,000 cases on day 70th and 80th. The number of existing cases have started to decrease greatly, in which the point is slowly declining even though there are still some cases but these cases are absolutely solvable. The application of this is similar. In other word, this is done together to all regions so that this can run effectively. In the red zones, it is very urgent to do regionally partially closed down. Hence, the number of death cases will not exceed 300 people. Based on the number of simulation results and system dynamics scenarios, these can help estimate the condition of COVID-19 in Indonesia, but it is inseparable from the choice of policy scenarios and community participation to jointly break the chain of distribution or minimize the cases that occur. To place each best scenario with some consideration of various aspects is important to resolve COVID-19 in Indonesia, therefore, it is crucial to follow the health protocols and regulations that are applied, and it is better to stay at home as long as the cases are still increasing.

Conclusions

The conclusion of these research results with System Dynamics to handle COVID-19 cases in Indonesia, in which the assumption limitation of the regions outside Java Island do not imitate the pattern of the core areas of Covid-19, or permanent constant application is used compared to the core areas, but on the other sides, the

regions have applied all the same applications applied in the core areas of Covid-19, then the conclusion results are as follows: In Business As Usual condition, it is estimated that the number of cases with a maximum point of around 15,000 cases and the cases will reach the peak on day 80th to 110th, and then the case will start to slowdown.

- In the uncontrolled condition, it is estimated that the number of cases with a maximum point of around 27,000-30,000, which reaches its peak on day 100-120. But in extreme condition this is because new constants are increasing in other regions/Provinces, It is estimated that cases will increase to 50,000, which reaches its peak on day 170-180. It will be higher if the same pattern (Extreme Uncontrolled) occurs in other Provinces as at the Java Islands.
- Application of moderate conditions with precautionary calls, implementation of health protocols including healthy living movement, social distancing, disinfectant spraying, adequacy of medical devices and health facilities, implementation of Stay At Home or Work From Home can delay the maximum number of cases around 9.000 and its peak is on the day 90th, after that the cases will decline slowly.
- In addition to applying moderate condition in optimistic condition, the optimistic condition is increased. Moreover, there is an addition of regional restriction policy that is selected together or regionally partially closed down. It is estimated that the maximum cases are 6,000 cases and the peak cases are on day 45th to 65th, can be reduced by the rate of case estimated at around 3,000-4,000 cases on day 70th and 80th.

References

- [1] World Health Organization (WHO). 2020. Corona Virus Disease (COVID-19) Dashboard Situation [Internet]. [Cited April 26, 2020]. <https://covid19.who.int/>
- [2] BNPB (National Disaster Management Authority). 2020. COVID-19 Situation in Indonesia [Internet]. [Cited April 26, 2020]. <https://bnpb-inacovid19.hub.arcgis.com/app/dashboard-pemantauan-inacovid-19>
- [3] Shen, Q., Q. Chen, B. Tang, S. Yeung, Y. Hu and G. Cheung. 2009. A system dynamics model for the sustainable land use planning and development. *Habitat International*, 33: 15–25.
- [4] Forrester, J. W. 1968. *Principles of system dynamics*. Productivity Press, Cambridge.
- [5] Forrester, J. W. 1961. *Industrial dynamics*. The MIT Press, Cambridge, MA.
- [6] Mashayekhi, A. N. 1990. Rangeland destruction under population growth: the case of Iran. *System Dynamics Review*, 6 (2): 167–193.
- [7] Heimgartner, C. 2001. System dynamic modelling of transport and land use: a first model draft. The first Swiss Transport Research Conference.
- [8] Luo, G., C. Yin, X. Chen, W. Xu and L. Lu. 2010. Combining system dynamic model and CLUE-S model to improve land use scenario analyses at regional scale: A case study of Sangong watershed in Xinjiang, China. *Ecological Complexity*, 7: 198–207.
- [9] Li, F.J., S.C. Dong and F. Li. 2012. A system dynamics model for analyzing the eco-agriculture system with policy recommendations. *Ecological Modelling*, 227: 34al M
- [10] Coyle, R. G. 1996. *System dynamics modelling: A practical approach*. Chapman and Hall, London.
- [11] Saisel, A.K., Y. Barlas and O. Yenigun. 2002. Environmental sustainability in an agricultural development project: a system dynamics approach. *Environmental Management* 64 (3): 247–260.
- [12] Widiatmaka, Ambarwulan W., Firmansyah I., Munibah K., Santoso P.B.K, Sudarsono. 2014. Land Suitability and Dynamic System Modelling To Define Priority Areas Of Soybean Plantation In Paddy Fields In Karawang, West Jawa. *Agrivita* Vol. 36. No. 3 : 235-248.
- [13] Hamid, A.R.A.H. 2020. Social Responsibility of Medical Journal: a Concern for COVID-19 Pancemic. *Medical Journal Of Indonesia*. Vol 29: 1-3.
- [14] Brahma, B. Oncologists and COVID-19 in Indonesia: What can we learn and must do?. *Indonesian Journal of Cancer*, [S.l.], v. 14, n. 1, p. 1-2, mar. 2020. ISSN 2355-6811. Available at: <<https://indonesianjournalofcancer.or.id/e-journal/index.php/ijoc/article/view/728>>. Date accessed: 26 apr. 2020. doi:<http://dx.doi.org/10.33371/ijoc.v14i1.728>.
- [15] Djalante, R., Lassa J, Setiamarga D, Sudjatma A, Indrawan M, Haryanto B, Mahfud C, Sinapoy M.S, Djalante S, Rafliana I, gunawa L A, Surtiarti G.A.K, Warsilah H. 2020. Review and Analysis of Current response to COVID-19 in Indonesia : Periode of January to March 2020. *Progress in Disaster Science* 6 (2020) 100091.
- [16] Lewnard J A, 2020. Scientific and Ethnical Basis for Social Distancing Intervention Against COVID-19. *The Lancet Infectious Disease*. DOI:[https://doi.org/10.1016/S1473-3099\(20\)30190-0](https://doi.org/10.1016/S1473-3099(20)30190-0)
- [17] Wee L.E., Conceicao E.P., Sim X.Y.J., aung M.K., Tan K.Y., Wong H.M., Wijaya L, Tan B.H., Ling M.L., Venkatachalam I. 2020. Minimising Intra-Hospital Transmission of COVID-19: The Role of Social Distancing. *The Journal of Hospital Infection*. DOI: <https://doi.org/10.1016/j.jhin.2020.04.016>