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CAUCHY – Jurnal Matematika Murni dan Aplikasi Volume ##(##) (####), Pages 1-9 p-ISSN: 2086-0382; e-ISSN: 2477-3344 Submitted: Reviewed: Accepted: Resmawan1, Lailany Yahya2 1,2 Department of Mathematics, Universitas Negeri Gorontalo Jl. Prof. Dr. Ing. BJ. Habibie, Tilongkabila, Bone Bolango, Gorontalo, Indonesia Email: resmawan@ung.ac.id, lailany.math@gmail.com ABSTRACT The study was aimed to introduce a new model construction regarding the transmission of Coronavirus Disease (henceforth, COVID-19) in human population.

The mathematical model was constructed by taking into consideration several epidemiology parameters that are closely identical with the real condition. The study further conducted an analysis on the model by identifying the endemicity parameters of COVID-19, i.e., the presence of disease-free equilibrium (DFE) point and basic reproduction number.

The next step was to carry out sensitivity analysis to revealed that the parameters ???? , ?? , , and ?? in sequence showed the most dominant sensitivity index towards the basic reproduction number. Moreover, the results indicated positive index in parameters ?? and ?? ???? that represented transmission chances during contact as well as contact rate between vulnerable individuals and exposed individual. This suggests that an increase in the previous parameter value could potentially enlarge the endemicity of COVID-19.

On the other hand, parameters ?? and , representing movement rate of exposed individuals to the quarantine class and proportion of quarantined exposed individuals, showed negative index. The numbers indicate that an increase in the parameter value could decrease the -19 should focus on restriction of interaction between individuals and optimization of quarantine.

Keywords: Sensitivity Analysis; Mathematical Model; Coronavirus Disease; COVID-19; Basic Reproduction Number INTRODUCTION Coronavirus Disease (henceforth, COVID-19) has shocked many thanks to its very rapid spread. Firstly identified to occur in Wuhan city of China, the disease has shortly became one of the main talking points as it reached the whole world and took thousands of death toll in a very short period.

The disease somewhat instigates all parties to conduct active measures in finding options to the best treatments and anticipatory means to prevent damage on a much wider scale. In mathematical perspective, the concern is closely related to implementation of mathematical model to identify potential solutions. Mathematical modelling is one of the key tools in epidemic preparation, including the COVID-19 pandemic.

The system allows one to comprehend and identify the correlation between COVID-19 spread and several epidemiology parameters, conduct preparatory Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 2 measures for future planning, and implement best practices of pandemic treatment. Previous studies, albeit little in number, has begun to address this problem and design mathematical model for COVID-19 transmission [1][2][3][4].

The model involved accurate and effective public health interventions. On top of that, a study compared between the outbreaks of current COVID-19 and previous MERS disease that spread in Middle Eastern countries and Korea [5]. Other studies designed mathematical model that predict COVID-19 cases in different countries [6][7].

Several models proposed in previous studies has discussed that the virus started from an unknown source and eventually began to spread to human population. The virus source, further referred to as reservoir variable, is suspected to be the place of first infection-to-human case. The present study introduces a different approach on mathematical modelling to the virus transmission by also involving the epidemiology parameters; a variable that is not discussed in previous studies.

Previous models have assumed that the virus transmission only occurs in interactions between individuals that have contracted the virus; differing from that, this article takes into consideration transmission cases caused by vulnerable individuals and exposed individuals. It views the importance of involving such parameters, considering the number of infections that occurred in the interaction between exposed individuals yet to be detected as infected.

Moreover, the model lays its emphasis on the pattern of transmission between human after the virus has became epidemic or pandemic, therefore, disregarding the reservoir variable. The model thus overlooks the process of first human infection and focuses on how the virus has spread within human-to-human interactions. In addition to that, the model employs new parameter representing death cases of COVID-19, pertaining to the fact that the virus has taken numbers of death toll.

The model also takes into account cases of quarantined individuals that were identified to be exposed to the virus. The following section elaborates construction of mathematical model in this study. Further, the article presents the research results in the form of model analysis. Within this section, the study focuses on the construction of basic reproduction number and sensitivity analysis to identify which parameter is the most sensitive to the change in basic reproduction number value. Finally, the last section proposes several conclusions to the research findings and discussion.

METHODS In this model, the total of human population was denoted in and divided into six classes: vulnerable individuals , exposed individuals in incubation period , infected individuals without clinical symptoms , infected individuals with clinical symptoms , quarantined individuals , and individuals that have recovered from COVID-19 ?? (??) . Therefore, the total population was stated in ?? (??) = ?? (??) + ?? (??) + ?? (??) + ?? (??) + ?? (??) + ?? (??) .

Recruitment rate of natural human natality and mortality is given the parameter ? and ?? sequentially. Vulnerable individuals (??) will be infected from enough contact with other vulnerable individuals (??) , infected individuals with clinical symptoms (??) , and infected individuals without clinical symptoms (??) in respective rate of ?? ?? ???? , ???? and , in which is the infection probability during contact between individuals. ???? , ???? , and ???? each states the contact rate between vulnerable individuals (??) and individual groups of ?? , , and .

The parameter and in respective order is the proportion of infected individuals without clinical symptoms and quarantined exposed individuals, while parameter states movement rate of exposed individuals to the quarantined individuals. Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 3 Parameter ?? and ?? each represent transmission rate after incubation period and status change to ?? and ?? class.

Quarantined individuals can be transferred to the class of infected individuals with symptoms at the rate of ?? and proportion of ?? . . Parameter ?? , ?? , ?? each states the recovery rate of infected individuals without symptoms, quarantined individuals, and infected individuals with symptoms to be transferred to recovered individuals class ?? . Further, death rate of COVID-19 in ?? class is represented in ?? .

Schematically, the transmission pattern of COVID-19 is displayed in Figure 1 below. Figure 1. Compartment diagram of COVID-19 transmission Based on the schematic diagram of virus transmission in Figure 6, the article presents model in the form of differential equation system as follows: ???? ???? = ? - ???? (?? ???? ?? + ?? ???? ?? + ?? ???? ??) ?? - ???? (?? ???? ?? + ?? ???? ?? + ?? ???? ??) ?? - (???? + ???? + ?? + ?? - ???? - ????) ?? ???? ???? = ???? ?? - (?? + ??) ?? ???? ???? = ???? ?? - (???? - with early condition: , , , , , Dynamics of population in total is acquired by totaling the five equations in model (1), resulting in: ???? ?? + ?? ???? ?? + ?? ???? ??) ?? ?? ?? (1 - ?? - ??) ?? ?? ???? ?? (1) Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 4 ???? ???? = ? - Positive invariant region that meets the model (1) is given by RESULTS AND DISCUSSION The Disease-free Equilibrium Point and The Basic Reproductive Number The equilibrium point is acquired at, therefore, the system of equation (1) indicates that the DFE point denoted by , i.e., The basic reproductive number denoted by is the expected value of infection rate per time unit.

The infection occurs in a vulnerable population, caused by an infected individual. Based on the equation system (1), the article generates equation that involves the classes of exposed population, infected population without symptom, and infected population with symptom, as follows: ???? (?? ???? ?? + ?? ???? ?? + ?? ???? ??) ?? - (???? + ???? + ?? + ?? - ???? - ????) ?? ???? ???? = ???? ?? - (?? + ??) ?? ???? ???? = ???? ?? - (Further, the basic reproduction number is calculated by referring to the job [8].

From the equation (6), the study generates matrix and , i.e. ???? (?? ???? ?? + ?? ???? ?? + ?? ???? + ???? + ?? + ?? - ???? - ????) ?? (?? + ??) ?? - ???? ?? (?? + ?? + ??) ?? - (1 - ?? - ??) Using the DFE point in equation (5), Jacobian matrix and is generated, i.e.

(4) (5) (2) (3) (6) (8) (7) Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 5 ?? = [?? ?? ???? ?? 0 ?? 0 0 0 ?? ?? ???? ?? 0 ?? 0 0 0 0 0 0 0 ?? ?? ???? ?? 0 ?? 0 0 0] = [?? ?? ???? 0 0 0 ?? ?? ???? 0 0 0 0 0 0 0 ?? ?? ???? 0 0 0] ???? + ???? + ?? + ?? - ???? - ???? - ???? - ???? - (1 - ?? - ??) ?? 0 ?? + ?? 0 0 0 0 The basic reproduction number is acquired from the largest positive eigenvalue of next generation matrix, , i.e.

Therefore, it is generated that: ???? (?? + ??) + ?? ?? ???? ???? - ???? ???????? + ?? ?? ???? (?? - ????) (?? + ?? + ??) (?? + ?? - ????) (?? + ?? + ???? - Further, can be stated in the form: with ???? (?? + ??) (?? + ?? + ???? + ???? - ????) ?? 2 = ?? ?? ???? ?????? +

?? ?? ???? (?? - ???? - ????) (?? + ?? - ???? + ???? - ????) Baseline Parameter Values Parameter value implemented in the equation model (1) involves parameter value as a result of fitting process from several valid references based on real cases of COVID-19 that has been reported and published.

The complete parameter values implemented in the present study are displayed in the following Table 1. By referring to the parameter values in Table 1 in equation (10), the study acquires estimation of basic reproduction number of 097 . This indicates that every infected individual is potential to infect minimum of three new individuals.

(9) (10) (11) Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 6 Table 1. Estimation of parameter values in COVID-19 cases Parameter Description Value Source ?? ?? ?? ???? ?? ???? ?? ???? ?? ?? ?? ?? ?? ?? ?? ?? ?? ?? ?? Natural mortality rate Transmission probability during contact Rate of contact between vulnerable individual and exposed individuals Rate of contact between vulnerable individual and infected individuals without clinical symptom Rate of contact between vulnerable individual and infected individuals with clinical symptom Proportion of infected individuals without clinical symptom Proportion of quarantined exposed individuals Movement rate of exposed individuals to quarantined individuals Transmission rate after incubation period and transferred to infected with clinical symptom class Transmission rate after incubation period and transferred to infected without clinical symptom class Movement rate of quarantined individual to infected individuals with clinical symptoms Proportion of quarantined infected individuals with clinical symptoms Recovery rate of infected individuals without clinical symptoms and transferred to R class Recovery rate of quarantined individuals and transferred to R class Recovery rate of infected individuals with clinical symptoms and transferred to R class Mortality rate due to COVID-19 3 . 57 × 10 - 5 0.2 0.09 0.07 0.05 0.12 0.04 0.13266 0.005 0.00048 0.1259 0.05 0.854302 0.11624 0.33029 1 .

78 × 10 - 5 Estimation Estimation Estimation Estimation [4] Estimation Estimation [3] [4] [4] [3] Estimation [4] [2] [2] [3] Sensivity Analysis To determine the most optimum approach in suppressing the number of infected individuals, one needs to identify several factors that contribute to the transmission of the virus and its prevalence. The first case of COVID-19 transmission closely relates to ?? 0 and persons exposed to COVID-19, as of ?? , ?? , ?? , and ?? group.

In this section, the study calculates the sensitivity index of each parameter model that correlates with the basic reproduction numbers, ?? 0 . This index provides information about the importance of each parameter to the model representing the transmission of COVID-19. The index is used to identify the parameter that has the most significant impact on ?? 0 which is later served as the intervention target.

The parameter with a high impact in shows that the parameter has a dominant influence on the endemicity of COVID-19. The parameter of the sensitivity index towards the basic reproduction number is calculated using the approach similar to the one seen in [9]. Based on the explicit form of Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 7 ?? 0 in equation (10), the study derivate the analytic expression for the sensitivity ?? 0 to the parameter ?? that is ?? ?? ?? 0 = ?? ?? 0 Table 2.

Model parameter index that is related to basic reproduction number Parameter Description Sensitivity Index ???? ?? ?? ?? ?? ?? ?? ???? ?? ?? ?? ?? ?? ?? ???? ?? ?? Transmission probability during contact Rate of contact between vulnerable individual and exposed individuals Movement rate of exposed individuals to quarantined individuals Proportion of quarantined exposed individuals Transmission rate after incubation period and transferred to infected with clinical symptom class Transmission rate after incubation period and transferred to infected without clinical symptom class Natural mortality rate Rate of contact between vulnerable individual and infected individuals with clinical symptom Recovery rate of infected individuals with clinical symptoms and transferred to R class Proportion of quarantined infected individuals with clinical symptoms Movement rate of quarantined individual to infected individuals with clinical symptoms Recovery rate of quarantined individuals and transferred to R class Proportion of infected individuals without clinical symptom Rate of contact between vulnerable individual and infected individuals without clinical symptom Recovery rate of infected individuals without clinical symptoms and transferred to R class Mortality rate due to COVID-19 in class of infected individuals without clinical symptoms + 1 . 000 + 0 . 999 - 0 . 911 - 0 . 908 - 0 . 0715 - 0 . 0098 - 0 . 0061 + 0 . 0012 - 0 . 0011 + 0 . 0005 + 0 . 0005 - 0 . 0005 + 0 .

0004 + 0 . 00005 - 0 . 00005 - 6 . 4 × 10 - 8 By referring to the formulation of equation (12) and parameter value in Table 1, it is generated the sensitivity index of each parameter in the basic reproduction number ?? 0 , presented in Table 2.

As an example, the sensitivity index of towards parameter ???? is ???? × ?? ???? ?? 0 = ?? (?? + ?? + ???? - ???? ?? 0 (12) Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 8 = ?? ?? ???? (?? + ?? + ???? - 999 The sensitivity index in Table 2 sequentially shows the parameter with the highest sensitivity to the lowest sensitivity. In general, four parameters are significant to the changes in the basic reproduction number.

Those parameters include the chances of transmission during contact (??), the rate of contact between vulnerable individuals and exposed individuals (?? ????), the movement rate of individuals to the quarantine class (??), and the proportion of quarantined exposed individuals (??). The parameter ?? and ?? ???? has a positive sensitivity index, while the parameter ?? and ?? have a negative sensitivity index.

Parameters with a positive sensitivity index represent the positive significance in the increase of basic reproduction numbers. Thereby, enlarging (or scaling down) the value of pr,while other arametevalue ns same,will ute the increase (or decline) in the basic reproduction numbers. Parameters with a negative sensitivity index represent the negative significance to the increase of basic reproduction numbers.

In other words, enlarging (or scaling down) the value of the parameter, while the other prs' v e remains the same, will contribute to the decline (or increase) in the basic reproduction numbers. The sensitivity index shows that contact with exposed individuals and the chance of transmission during the contact is the most dominant parameters contributing to the COVID-19 transmission.

On the one hand, the proportion of quarantined exposed individuals is the parameter that suppresses the transmission of the disease the most. Since ?? ?? 999 , enlarging (or scaling down) the parameter ???? by 10% will result in a decline of the value ?? 0 by 9.99%. The result that ?? ?? ?? 0 = - 0 . 911 signifies that enlarging (or scaling down) the parameter ?? by 10% will lead to a decline (or increase) in the value of ?? 0 by 9.11%.

Interrupting the rate of transmission with exposed individuals and maximizing quarantine for exposed individuals and suspects are crucial. However, inadequate knowledge and lack of medical kits to detect those who have been contacted with COVID- 19 are now hindering the countermeasures for combating the disease. It can be said that there is no strong evidence to determine those who have been contacted with COVID-19 and those who are not carrying the virus.

Due to the situations, preventive measures, such as social and physical distancing, are still the only option to halt the transmission of COVID-19. CONCLUSIONS The index of the sensitivity parameter shows that the parameter ?? and ???? that represents the chance of transmission during the contact and the rate of contact between the vulnerable individuals and exposed individuals have the most dominant sensitivity to raise the endemicity of COVID- 1 the hand pa d s, represent the movement rate of exposed individuals to the quarantine and the proportion of quarantined exposed individuals, are the ones that can decrease the endemicity of COVID-19 the most.

The effectiveness of the measurement against COVID-19, therefore, can be assured by suppressing the interaction rate between vulnerable individuals and exposed individuals and maximizing treatment in the quarantine for those who are infected with the disease. All these attempts can be optimized by adhering to the health Sensitifity Analysis of Mathematical Model of Coronavirus Disease (COVID-19) Transmission Resmawan 9 protocol, such as by keeping space between oneself and the other, or well-known as social or physical distancing.

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