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Conference Paper · June 2021

DOI: 10.1063/5.0109176

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Solution of SEIRD Mathematical Model for the COVID-19 Transmission Using Microsoft Excel

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Abstract. Mathematical modeling in the epidemiology study can be applied to describe the current transmission of viruses, one of which is compartments. However, this simulation model is rigorous to understand, especially in interpreting the parameter values in influencing the solution. Therefore, it is necessary to present a coherent mathematical model solution. This study aims to determine the SEIRD model solution in the COVID-19 transmission using Microsoft Excel with three conditions (normal, new normal, and lockdown) to facilitate the interpretation of data. The SEIRD model used in this study considers natural population growth, namely natural births and deaths. Three stages to evaluate the model solution in this study are constructing a mathematical model, deciding the parameter intervals, and creating an applet in Microsoft Excel. The system of differential equations is converted into a system of difference equations to obtain numerical model solutions. The results showed that the differences in the infection rates for old normal, new normal, and lockdown conditions were 24%, 4%, and 3%, respectively.

INTRODUCTION

The COVID-19 pandemic has spread in 216 countries around the world. Until now, the COVID-19 pandemic is still spreading, which is marked by more and more people who are infected. Various parties have taken several steps to anticipate the COVID-19 transmission, including the health policy implementation also predictions made by academics and epidemiologists. It is necessary to predict the COVID-19 transmission so that interested parties can take appropriate action to control this pandemic [1, 2].

Mathematical modeling can be used in the field of epidemiology to describe the COVID-19 transmission. The compartment model is one of the mathematical models that can be applied. Compartment models have been used to model the COVID-19 transmission in China [3], Italy [4], and India [5]. The compartment model divides the population into compartments with specific characteristics. The compartments commonly used in modeling the spread of disease are Susceptible-Infectious-Recovered (SIR) [6]. Exposed [3, 4] and Quarantine [5] are two more compartments that can be introduced based on the disease's characteristics. These characteristics of the COVID-19 virus require time for incubation before it can infect other individuals. Therefore, a compartment is needed to see how the dynamics of the population are at this stage. Furthermore, because the COVID-19 virus is still relatively new, a separate compartment is required to study the dynamics of individual deaths caused by this virus. Finally, the demographic conditions of an area also need to be considered to distinguish the disease death rate from the natural death rate. As a result, we require a mathematical model that can account for the dynamics of each compartment while simultaneously taking into account the demographic characteristics of a given area. As a result, we require a mathematical model that can account for the dynamics of each compartment while simultaneously taking into account the demographic characteristics of a given area.

3rd International Conference on Biospheric Harmony Advanced Research (ICOBAR) 2021
AIP Conf. Proc. 2594, 090006-1–090006-6; https://doi.org/10.1063/5.0109176
Published by AIP Publishing. 978-0-7354-4420-1/$30.00

In real-time, a function represents each compartment. A system of differential equations reveals in this compartment model. Solving the model is obtained by solving systems of differential equations analytically or numerically. The solution to this model will provide an overview of the transmission and prediction of COVID-19 in this population.

The compartment model simulation results are not always easy to understand, especially in interpreting the parameter values in influencing the solution. We have used mathematical modeling in many studies such as agroindustry [7, 8], environment [9–16], healthcare [17,18], and electricity [19, 20]. Therefore, it is necessary to present a less complicated approach to the mathematical model solution. In addition, the public also needs to know the meaning of the influence of parameters on the COVID-19 transmission. As a result, this article will go into how to use Microsoft Excel to determine the numerical solution of the COVID-19 distribution compartment model. When selecting Microsoft Excel, we took into consideration the features that are well-known to the general public.

RESEARCH METHODOLOGY

The SEIRD model is a compartment model that divides the population into five subpopulations, namely *Susceptible (S), Exposed (E), Infectious (I), Recovered (R)*, and *Death (D).* The population is dynamic, which is influenced by the rate of natural births and deaths. Natural birth rate (α), the mortality rate (μ), transmission rate (β), virus incubation rate (σ), recovery rate (γ), and death rate induced by COVID-19 are model parameters (d). The following is a flow chart of the SEIRD model.

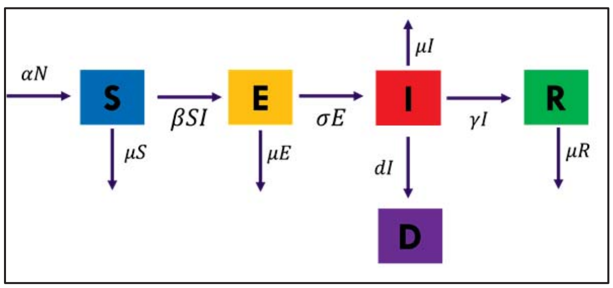

FIGURE 1. Flowchart of SEIRD model

Based on Figure 1 above, a system of differential equations has obtained as follows.

$$\begin{cases} \frac{dS}{dt} = \alpha N - \beta SI - \mu S \\ \frac{dE}{dt} = \beta SI - \sigma E - \mu E \\ \frac{dI}{dt} = \sigma E - \gamma I - dI - \mu I \\ \frac{dR}{dt} = \gamma I - \mu R \\ \frac{dD}{dt} = dI \end{cases} \tag{1}$$

Under $S(0) \geq 0, E(0) \geq 0, I(0) \geq 0, R(0) \geq 0$ and $D(0) \geq 0$. System of differential equations can be solved numerically by first converting the equations system above into a system of altering equations [21]. Furthermore, for the parameters in the model, intervals will be calculated. The parameter values in the model use data sourced from [6, 22–24]. The crude birth rate (CBR) and crude mortality (CDR) in Indonesia during 2018-2020 were $8 \leq CBR \leq 20$ and $6 \leq CDR \leq 8$ [5]. The intervals for the cure rate and mortality rate parameters, namely $0.03 \leq \gamma \leq 0.66$ and $0.03 \leq \gamma \leq 0.66$, are obtained in Berger and Oliger's study [23]. The basic reproduction number ($\Re_0$) and mass contact incidence (a) [24] are used in this article to establish the virus's degree of transmission. The following are the equations used to determine the β parameter.

$$\beta(N) = aN^{-0.95} \tag{2}$$

And,

$$\Re_0 = \frac{N_0\beta(N_0)}{\gamma+d} \tag{3}$$

In Brauer et al. [23], the interval $\Re_0$ is $1.4 \le \Re_0 \le 6.49$. The mass action incidence interval, $0.0443 \le a \le 3.1012$, is calculated using equations (3) and (4). In the study of Zoupeng Xiao et al. [25] obtained the value of the virus incubation rate is $7 \le \sigma \le 14$. The numerical solution of the model calculated using Microsoft Excel. Each parameter in the model is created in the Scroll Bar, is available on the Developer menu. This Scroll Bar application makes the simulation more interactive. Furthermore, iteration is carried out based on the differential equation system above with time units in weeks. The SEIRD model's solution graph is displayed using the Chart function.

RESULT AND DISCUSSION

The system of differential equations for the above system of differential equations is as follows.

$$\begin{cases} \Delta S = (\alpha N - \beta SI - \mu S)\Delta t \\ \Delta E = (\beta SI - \sigma E - \mu E)\Delta t \\ \Delta I = (\sigma E - \gamma I - dI - \mu I)\Delta t \\ \Delta R = (\gamma I - \mu R)\Delta t \\ \Delta D = dI\Delta t \end{cases} \tag{4}$$

Each parameter is given a value during the iteration process. Each parameter's values are listed in Table 1.

TABLE 1. Value of parameter of the model

Parameter	Value	Reference
α	3.7×10^{-4}	CBR Indonesia
μ	1.39×10^{-4}	CDR Indonesia
a	1.13	Assume
d	0.45	Assume
γ	0.28	Assume
σ	10.016	Assume

Transmission rate (β), virus incubation rate (σ), recovery rate (γ), and death rate induced by COVID-19 are model parameters (d) obtained from analysis of daily COVID-19 case data in Indonesia from March to August 2021 published by KawalCOVID-19 [26]. Figure 2 depicts the outcomes of the iteration using Microsoft Excel. The graph in Figure 3 depicts the SEIRD model's solution. The graphs below are made by drawing each point with the coordinates (t, N), (t, S), (t, E), (t, I), (t, R), and (t, D). According to the graph of the SEIRD model solution above, the pandemic peaked at week 8 with a total infected population of 2362 people (23%) and 585 (5%) deaths until 52 weeks. During the 52 weeks, the populaces also experienced growth due to the birth rate and crude mortality rate. As a result, as of the end of week 52, there were 9539 individuals in the population.

The SEIRD model solution presentment using Microsoft Excel simplifies for the general public to understand pandemic behavior. Also, the scroll bar feature allows users to increase or decrease the parameter values depending on their preferences. After changing the parameter values, the user will immediately read the solution graph from the model. That feature will give users an overview of the effect of parameter values on the COVID-19 transmission. In addition, the existence of interventions carried out by the government through the application of health protocols can also influence the solution of the model. The health protocol implementation through 3M activities (wearing masks, washing hands, and maintaining a distance) will reduce the risk of COVID-19 infection. In addition, lockdown areas for the strict regulation of COVID-19 transmission are present in several countries. The SEIRD model will apply any of these interventions. The application of the health protocol to the population is called the new normal condition.

Iteration Table of SEIRD Model

t	N	ΔN	$\beta(N)$	S	ΔS	E	ΔE	I	ΔI	R	ΔR	D	ΔD
0	10008	0.29216	0.00018	10000	-0.93199	3	-2.95098	5	3.71312	0	0.462	0	0.0315
0.14	10008.3	0.26878	0.00018	9999.07	-1.86428	0.04902	2.11938	8.71312	-0.79141	0.462	0.80508	0.0315	0.05489
0.28	10008.6	0.27377	0.00018	9997.2	-1.66506	2.16841	-1.05171	7.92171	2.2586	1.26708	0.73194	0.08639	0.04991
0.42	10008.8	0.25955	0.00018	9995.54	-2.2316	1.1167	0.98965	10.1803	0.56088	1.99903	0.94062	0.1363	0.06414
0.56	10009.1	0.25602	0.00018	9993.31	-2.37168	2.10635	-0.25797	10.7412	1.89324	2.93965	0.99243	0.20044	0.06767
0.7	10009.4	0.24411	0.00018	9990.94	-2.84593	1.84838	0.57808	12.6344	1.34461	3.93208	1.16735	0.2681	0.0796
0.84	10009.6	0.23564	0.00018	9988.09	-3.18214	2.42646	0.10374	13.979	2.02248	5.09942	1.29156	0.3477	0.08807
0.98	10009.8	0.22291	0.00018	9984.91	-3.68798	2.5302	0.46418	16.0015	1.96829	6.39099	1.47842	0.43577	0.10081
1.12	10010.1	0.21052	0.00018	9981.22	-4.17967	2.99439	0.30504	17.9698	2.42488	7.8694	1.66026	0.53658	0.11321
1.26	10010.3	0.19525	0.00018	9977.04	-4.7851	3.29943	0.48282	20.3947	2.61324	9.52966	1.88428	0.64979	0.12849
1.4	10010.5	0.17879	0.00018	9972.25	-5.43682	3.78225	0.4576	23.0079	3.0323	11.4139	2.12571	0.77828	0.14495
1.54	10010.6	0.15969	0.00018	9966.82	-6.19235	4.23986	0.57156	26.0402	3.37462	13.5397	2.40585	0.92323	0.16405
1.68	10010.8	0.13844	0.00018	9960.63	-7.03208	4.81142	0.60995	29.4148	3.84295	15.9455	2.71762	1.08728	0.18531
1.82	10010.9	0.11423	0.00018	9953.59	-7.9871	5.42137	0.7098	33.2578	4.31887	18.6631	3.07266	1.27259	0.20952
1.96	10011	0.08702	0.00018	9945.61	-9.05869	6.13117	0.78623	37.5767	4.88782	21.7358	3.47166	1.48212	0.23673
2.1	10011.1	0.05623	0.00018	9936.55	-10.2694	6.9174	0.89458	42.4645	5.50778	25.2074	3.92323	1.71885	0.26753
2.24	10011.2	0.02154	0.00018	9926.28	-11.6309	7.81198	1.00186	47.9723	6.21848	29.1307	4.43207	1.98638	0.30223
2.38	10011.2	-0.01764	0.00018	9914.65	-13.1646	8.81385	1.13099	54.1907	7.00945	33.5627	5.00657	2.2886	0.3414
2.52	10011.2	-0.0618	0.00018	9901.48	-14.8891	9.94484	1.26978	61.2002	7.9034	38.5693	5.65415	2.63	0.38556
2.66	10011.1	-0.11159	0.00018	9886.59	-16.828	11.2146	1.42835	69.1036	8.90372	44.2235	6.38431	3.01556	0.43535
2.8	10011	-0.16769	0.00018	9869.77	-19.0051	12.643	1.60292	78.0073	10.0276	50.6078	7.20689	3.45092	0.49145
2.94	10010.9	-0.23087	0.00018	9850.76	-21.4482	14.2459	1.79858	88.0349	11.2854	57.8147	8.1333	3.94236	0.55462
3.08	10010.6	-0.30197	0.00018	9829.31	-24.1862	16.0445	2.01494	99.3203	12.6934	65.948	9.17592	4.49698	0.62572
3.22	10010.3	-0.38195	0.00018	9805.13	-27.2514	18.0594	2.25511	112.014	14.2657	75.1239	10.3486	5.1227	0.70569
3.36	10009.9	-0.47184	0.00018	9777.87	-30.6779	20.3145	2.51996	126.279	16.0196	85.4725	11.6666	5.82839	0.79556
3.5	10009.5	-0.57278	0.00018	9747.2	-34.5027	22.8345	2.81165	142.299	17.9717	97.139	13.1465	6.62395	0.89648
3.64	10008.9	-0.68602	0.00018	9712.69	-38.7644	25.6461	3.13131	160.271	20.1402	110.286	14.8069	7.52043	1.00971

FIGURE 2. Iteration using Microsoft Excel

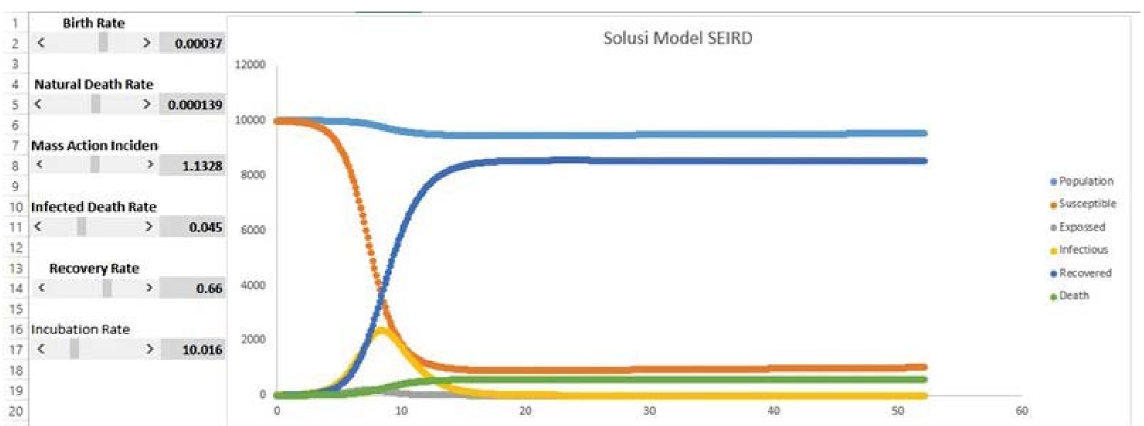

FIGURE 3. Solution of SEIRD model

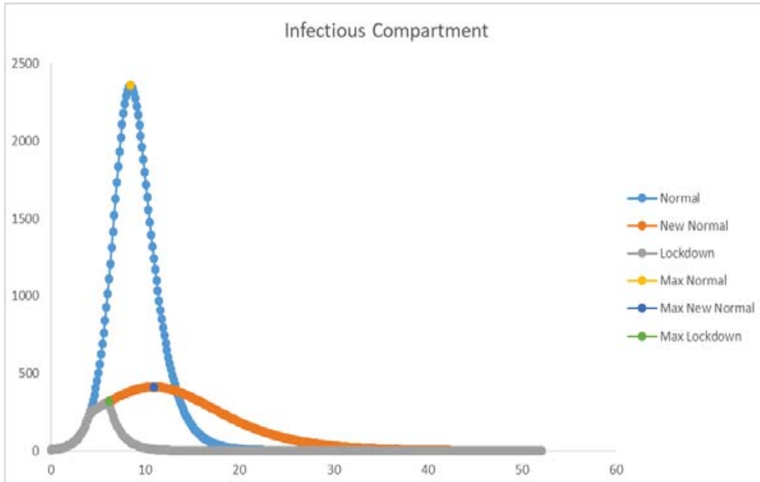

FIGURE 4. Comparison of Normal, New Normal, and Lockdown Conditions for Infectious Compartment.

New normal assuming a reduction in virus transmission rates of up to 50% with apply this condition. Meanwhile, the COVID-19 infection rate can decrease to 0% by executing lockdown conditions. All of these interventions are assumed to begin at week 4. Based on the graph in Figure 4, the comparison of the peak of the COVID-19 pandemic for three conditions, namely week 8 for old normal conditions, week 10 for new normal conditions, and week 6 for lockdown conditions. Furthermore, the infection rates for these outbreaks were 24%, 4%, and 3%, respectively.

CONCLUSION

The SEIRD model solution is determined numerically using a system of difference equations. The simulation results show that individual and government interventions have a positive impact in preventing the transmission of COVID-19. New Normal and Lockdown strategies can reduce infected individuals by 20% for 52 weeks. The iteration has been performed with Microsoft Excel assistance by users (the general public). The features in Microsoft Excel can be applied to understand the graphic interpretations of the COVID-19 transmission in Indonesia. The discrete method in solving the system of differential equations is a limitation in this study. The future research requires to compare the margin of the solution produced with the system's analytical solution in this study.

REFERENCES

1. R E Caraka, Y Lee, R Kurniawan, R Herliansyah, T Toharudin and B Pardamean. Impact of COVID-19 large scale restriction on environment and economy in Indonesia *Glob. J. Environ. Sci. Manag.* **6** (2020) 65–84
2. A Sumaryana, T Toharudin, R E Caraka, R S Pontoh, R C Chen and B Pardamean. Short communication: COVID-19 pandemic and attitude of citizens in Bandung City Indonesia (Case study in Cibiru Subdistrict) *Int. J. Criminol. Sociol.* **9 (**2020)
3. R M McLeod. *The Generalized Riemann Integral (*1980)
4. C Godsil and G F Royle. Algebraic graph theory *Springer* **207, (**2013)
5. A Gara, M A Blumrich, D Chen, G L T Chiu, P Coteus, M E Giampapa, R A Haring, P Heidelberger, D Hoenicke, G V Kopcsay, T A Liebsch, M Ohmacht, B D Steinmacher-Burow, T Takken and Vranas P. Overview of the Blue Gene/L system architecture *IBM J. Res. Dev.* **49, (**2005)
6. F Brauer, C Castillo-Chavez and Z Feng. Correction to: Mathematical models in epidemiology (2019).
7. R E Caraka, B D Supatmanto, M Tahmid, J Soebagyo, M A Mauludin, A Iskandar and B Pardamean. Rainfall forecasting using PSPline and rice production with ocean-atmosphere interaction *IOP Conference Series: Earth and Environmental Science. (*2018)

8. Jamilatuzzahro, R E Caraka, R Herliansyah, S Asmawati, D M Sari and B Pardamean. Generalized Space Time Autoregressive of Chili Prices *Proceedings of 2018 International Conference on Information Management and Technology, ICIMTech 2018.* (2018)
9. R E Caraka, Y Lee, R C Chen, T Toharudin, P U Gio, R Kurniawan and B Pardamean. Cluster around latent variable for vulnerability towards natural hazards, non-natural hazards, social hazards in West Papua *IEEE Access* **9** 1972–86 (2020)
10. R E Caraka, R C Chen, H Yasin, S Suhartono, Y Lee and B Pardamean. Hybrid vector autoregression feedforward neural network with genetic algorithm model for forecasting space-time pollution data *Indones. J. Sci. Technol.* **6** 243–66 (2018)
11. I N Setiawan, R Kurniawan, B Yuniarto, R E Caraka and B Pardamean. Parameter optimization of support vector regression using Harris Hawks Optimization *Procedia Comput. Sci.* **179** 17–24 **(**2021)
12. R E Caraka, M Tahmid, R M Putra, A Iskandar, M A Mauludin, Hermansah, N E Goldameir, H Rohayani and B Pardamean. Analysis of plant pattern using water balance and cimogram based on oldeman climate type *IOP Conference Series: Earth and Environmental Science (*2018)
13. R E Caraka, M Ulhusna, B D Supatmanto, N E Goldameir, B Hutapea, G Darmawan, D C R Novitasari and B Pardamean. Generalized spatio temporal autoregressive rainfall-enso pattern in East Java Indonesia *2018 Indonesian Association for Pattern Recognition International Conference (INAPR)* pp 75–9 (2018)
14. R E Caraka, R C Chen, T Toharudin, B Pardamean, H Yasin and S H Wu. Prediction of status particulate matter 2.5 using state Markov chain stochastic process and HYBRID VAR-NN-PSO *IEEE Access* **7** 161654–65 (2019)
15. R E Caraka, R C Chen, S A Bakar, M Tahmid, T Toharudin, B Pardamean and S-W Huang. Employing best input SVR robust lost function with nature-inspired metaheuristics in wind speed energy forecasting *IAENG Int. J. Comput. Sci* (2020)
16. R E Caraka, R C Chen, T Toharudin, M Tahmid, B Pardamean and R M Putra. Evaluation performance of SVR genetic algorithm and hybrid PSO in rainfall forecasting *ICIC Express Lett. Part B Appl.* **11** 631–9 (2020)
17. R E Caraka, R C Chen, Y Lee, P U Gio, A Budiarto and B Pardamean. Latent regression and ordination risk of infectious disease and climate *Procedia Comput. Sci.* **179** 25–32 (2021)
18. R E Caraka, N T Nugroho, S K Tai, R C Chen, T Toharudin and B Pardamean. Feature importance of the aortic anatomy on endovascular aneurysm repair (EVAR) using Boruta and Bayesian MCMC *Commun. Math. Biol. Neurosci.* (2020)
19. R E Caraka, S A Bakar, B Pardamean and A Budiarto. Hybrid support vector regression in electric load during national holiday season *2017 International Conference on Innovative and Creative Information Technology (ICITech)* pp 1–6 (2017)
20. R E Caraka, R C Chen, T Toharudin, B Pardamean, S A Bakar and H Yasin. Ramadhan short-term electric load: a hybrid model of Cycle Spinning Wave-Let and Group Method Data Handling (CSW-GMDH) *IAENG Int. J. Comput. Sci.* **46** 670–6 (2019)
21. J A Adjaye, J France and J H M Thornley. Mathematical models in agriculture. *J. Oper. Res. Soc.* **35 (**1984)
22. F E Browder. Nonexpansive nonlinear operators in a Banach space *Proc. Natl. Acad. Sci.* **54 (**1965)
23. M J Berger and J Oliger. Adaptive mesh refinement for hyperbolic partial differential equations *J. Comput. Phys.* **53 (**1984)
24. Y Liu, A A Gayle, A W Smith and J Rocklöv. The reproductive number of COVID-19 is higher compared to SARS coronavirus *J. Travel Med.* **27 (**2020)
25. Z Xiao, X Xie, W Guo, Z Luo, J Liao, F Wen, Q Zhou, L Han and T Zheng. Examining the incubation period distributions of COVID-19 on Chinese patients with different travel histories *J. Infect. Dev. Ctries.* **14**
26. Kawal informasi seputar COVID-19 secara tepat dan akurat provided by KawalCOVID-19. 2020. Available from: Kawalcovid19.Id (2020)