Numerical Estimation of the Final Size of the Spread of COVID-19 in West Java Province, Indonesia

Subiyanto, Yuyun Hidayat, Eddy Afrianto, and Sudradjat Supian

***Abstract*—The purpose of this paper is to predict the final size of the COVID-19 in West Java Province, Indonesia. This paper describes the mathematical modeling and dynamics of a COVID-19 by using the SIR epidemic model. To predict the final size of the positive cases of COVID-19 that occur, the minimum function of the final number of susceptible and recovered is performed. The numerical simulation was performed with data after West Java Government implemented Large-Scale Social Restrictions. Based on the numerical results is founded the final size of the COVID-19 in West Java Province is 22743 people. This number might have been greater if the Government did not carry out Large-Scale Social Restrictions.**

***Index Terms*—Minimum function, Large-Scale Social Restrictions, recovered, susceptible, SIR epidemic model**

I. Introduction

THE COVID-19 disease pandemic that first appeared at the end of 2019 has now spread throughout the world and affects all aspects of human life. Coronaviruses are a large family of viruses that cause illnesses ranging from mild to severe symptoms. There are at least two types of coronavirus that are known to cause illnesses that can cause severe symptoms such as Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS) [1], [2]. Coronavirus Disease 2019 (COVID-19) is a new type of disease that has never been previously identified in humans. The virus that causes COVID-19 is called Sars-CoV-2. Coronaviruses are zoonotic (transmitted between animals and humans) [3], [4]. Research states that SARS is transmitted from civet cats to humans and MERS from camels to humans. Meanwhile, the animal that is the source of transmission of COVID-19 is still unknown [5], [6].

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Subiyanto, Ph.D. is the Assistant Professor of Department of Marine Science, Faculty of Fishery and Marine Science, Universitas Padjadjaran. (Corresponding author to provide e-mail: subiyanto@unpad.ac.id).

Yuyun Hidayat, Ph.D. is the Associate Professor of Department of Statistic, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. (e-mail: yuyun.hidayat@unpad.ac.id).

Dr. Eddy Afrianto is the Associate Professor of Department of Fishery, Faculty of Fishery and Marine Science, Universitas Padjadjaran. (e-mail: eddy.afrianto@unpad.ac.id).

Prof. Dr. Sudradjat Supian is the Professor of Department of Mathematic, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. (e-mail: sudradjatt@unpad.ac.id).

On December 31, 2019, the WHO China Country Office reported a case of pneumonia of unknown etiology in Wuhan City, Hubei Province, China [7], [8]. On January 7, 2020, China identified pneumonia of unknown etiology as a new type of COVID-19 [1], [2], [9]. In Indonesia, this case began to develop at the beginning of March 2020 and until now there is still an increase in new infections. The number of positive cases of COVID-19 in Indonesia continues to increase until July 2020. Especially in the province of West Java, positive cases of COVID-19 reached 6584 people with 210 deaths [10]. The trend of the number of positive cases of COVID-19 in West Java Province is presented in Fig.1.

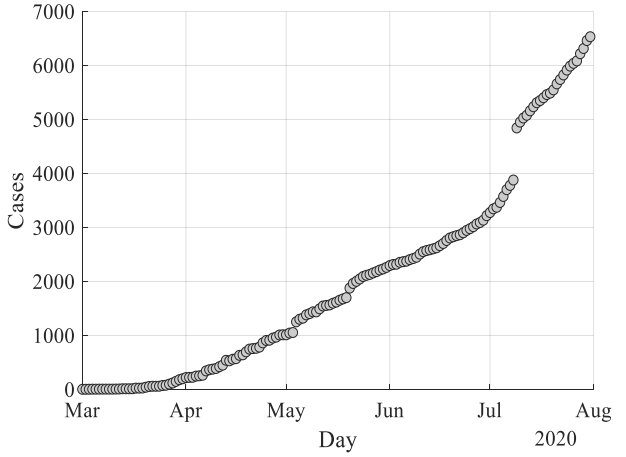

Fig. 1. the number of positive cases for COVID-19 in West Java Province on March 2020 until July 2020.

The source of the data in Fig. 1 is obtained from the official website of the West Java Province [10].

Researchers in Indonesia have developed several models and predictions of COVID 19 cases, but the results are not completely accurate. This is due to different patterns in each region so that to accommodate these differences, simulations, and predictions are needed at the national level. In this paper, a mathematical model will be introduced to predict the final size of positive cases of COVID-19 in the West Java province. The prediction is done based on the SIR epidemic model whose parameters are estimated based on the data [11].

II. Mathematical Model of SIR Epidemic

The SIR model is an epidemic model that is carried out by grouping the population into three compartments, namely the number of susceptible individuals, the number of infectious individuals, and the number of removed (and

immune) or deceased individuals [12]. The model variables and parameters for the prediction of the final size of positive cases of COVID-19 in the West Java province is given by;

Variable	Description
S	The number of susceptible persons at time *t*. When an individual who is vulnerable and infectious becomes ' infectious contact' the person who is susceptible contracts the disease and changes to the infectious compartment.
I	The number of infected persons at time *t*. Some people are contaminated and able to infect susceptible people.
R	The number of recovered persons at time *t*. These are people who were infected and either healed from the disease and entered the compartment removed, or died. The number of deaths is believed to be insignificant compared with the total population. This compartment can also be deemed "safe" or "recovered."
N	The number of the sum of these three compartments $(S+I+R)$ at time *t*.

Parameter	Description
α	The contact rate. This is parameter states the level of infection, namely the number of interactions between a susceptible individual and an infected individual that causes an individual to become infected.
β	The parameters that state the cure rate of an infected patient with $\frac{1}{\beta}$ is the average infectious period

This research uses a deterministic endemic model [13], [14]. The dynamics of an epidemic are often much faster than the dynamics of birth and death, therefore, birth and death are often omitted in simple compartmental models [15], [16]. The SIR system without so-called vital dynamics (birth and death, sometimes called demography) can be expressed by the following set of ordinary differential equations:

$$\frac{dS}{dt} = -\frac{\alpha}{N} SI \tag{1}$$

$$\frac{dI}{dt} = \frac{\alpha}{N} SI - \beta I \tag{2}$$

$$\frac{dR}{dt} = \beta I \tag{3}$$

The SIR mathematical modeling on the spread of COVID-19 is a theoretical study. The system equation above is solved by using Runge-Kutta 45 Method [17]. Numerical simulation of model uses data on the number of positive cases of COVID-19 in West Java Province. This simulation is used to predict the final size of positive cases of COVID-19 in the West Java province.

III. Results and Discussion

To predict the final size of positive cases of COVID-19, it defines the initial condition from a set of ordinary differential equations in equation 1 to equation 3.

Let set the initial condition as follows:

$$S(0) = S_0$$

$$I(0) = I_0$$

$$R(0) = R_0$$

Then, dividing the first differential equation (1) by the third differential equation (3), separating the variables and integrating as follows:

$$\frac{\frac{dS}{dt} = -\frac{\alpha}{N} SI}{\frac{dR}{dt} = \beta I} \tag{4}$$

Rearrange the equation 4, then it is obtained:

$$\frac{dS}{dR} = -\frac{\alpha}{N\beta} S \tag{5}$$

Integrate the equation 5 with interval $R_0 < R < R_t$ and $S_0 < R < S_t$, then it is obtained as follows:

$$\int_{S_0}^{S_t} \frac{1}{S} dS = -\frac{\alpha}{N\beta} \int_{R_0}^{R_t} dR$$

$$\ln|S|\Big]_{S_0}^{S_t} = -\frac{\alpha}{N\beta}(R)\Big]_{R_0}^{R_t}$$

$$\ln\left|\frac{S_t}{S_0}\right| = -\frac{\alpha}{N\beta}(R_t - R_0)$$

$$\exp\left(\ln\left|\frac{S_t}{S_0}\right|\right) = \exp\left(-\frac{\alpha}{N\beta}(R_t - R_0)\right)$$

$$S_t = S_0 \exp\left(-\frac{\alpha}{N\beta}(R_t - R_0)\right) \tag{6}$$

In the limit $t \to \infty$ the number of susceptible people left S_∞ is;

$$S_\infty = S_0 \exp\left(-\frac{\alpha}{N\beta}(R_\infty - R_0)\right) \tag{7}$$

where, R_∞ is the final number of recovered people. The final number of infected people is zero, so that:

$$N = S_\infty + R_\infty \tag{8}$$

Substitute equation (7) to equation (8), it is obtained as follows:

$$N = R_\infty + S_0 \exp\left(-\frac{\alpha}{N\beta}(R_\infty - R_0)\right) \tag{9}$$

To find the prediction of the final size of positive cases of COVID-19, it can be solved by minimizing the function in equation (9).

$$\min\left[f(R_\infty)\right] = N - R_\infty - S_0 \exp\left(-\frac{\alpha}{N\beta}(R_\infty - R_0)\right) \tag{10}$$

Numerical results based on the data from the official website of the West Java Province are shown in Table 1. The number of positive cases of COVID-19 in West Java Province was fitted using the model (2) and (3), and the fitting effect was significant as shown in Fig. 2. For the number of positive cases of COVID-19 in West Java Province, the values of a positive case in the simulation are fairly close to the real cases, and the absolute value of the

average relative error is less than 2%. The true number of confirmed COVID-19 positive cases on July 31, 2020 (data from the official website of the West Java Province [10]), is 6532 people, close to its simulation value of 6612 people.

TABLE I
NUMERICAL RESULTS

Day	Prediction Results	West Java Province Data
1-Mar	3	2
2-Mar	12.45788527	2
3-Mar	22.07589622	2
4-Mar	31.85674697	4
5-Mar	41.80319453	4
6-Mar	51.91803755	4
7-Mar	62.20412506	4
8-Mar	72.66435654	5
9-Mar	83.3016819	5
10-Mar	94.1191015	6
11-Mar	105.1196662	6
12-Mar	116.3065293	7
13-Mar	127.6831325	12
14-Mar	139.2526257	12
15-Mar	151.018163	15
16-Mar	162.9829701	15
17-Mar	175.1503439	27
18-Mar	187.5236527	29
19-Mar	200.1063361	37
20-Mar	212.9019048	46
21-Mar	225.9139411	52
22-Mar	239.1460986	55
23-Mar	252.6021019	62
24-Mar	266.2857474	63
25-Mar	280.2009023	67
26-Mar	294.3515055	73
27-Mar	308.741567	101
28-Mar	323.3751683	123
29-Mar	338.2564621	151
30-Mar	353.3896723	177
31-Mar	368.7790944	186
1-Apr	384.429095	212
2-Apr	400.344112	228
3-Apr	416.5286548	230
4-Apr	432.9873039	249
5-Apr	449.7247112	255
6-Apr	466.7456001	266
7-Apr	484.054765	343
8-Apr	501.6570719	364
9-Apr	519.5574578	374
10-Apr	537.7609313	384
11-Apr	556.2725722	418
12-Apr	575.0978604	448
13-Apr	594.242456	547
14-Apr	613.711566	550
15-Apr	633.5105108	579
16-Apr	653.6447297	591
17-Apr	674.1197812	651
18-Apr	694.9413431	660
19-Apr	716.1152124	714
20-Apr	737.6473054	743
21-Apr	759.5436574	752
22-Apr	781.8104229	758
23-Apr	804.4538759	781
24-Apr	827.4804093	855
25-Apr	850.8965353	899
26-Apr	874.7088853	910
27-Apr	898.9242101	949
28-Apr	923.5493793	968
29-Apr	948.5913821	1006
30-Apr	974.0573266	1010
1-May	999.9544404	1010
2-May	1026.29007	1041
3-May	1053.071681	1052
4-May	1080.306859	1248
5-May	1108.003309	1296
6-May	1136.168852	1316
7-May	1164.811433	1377
8-May	1193.939113	1400
9-May	1223.560073	1431
10-May	1253.682614	1431
11-May	1284.315154	1486
12-May	1315.466291	1542
13-May	1347.145646	1550
14-May	1379.362195	1559
15-May	1412.12471	1590
16-May	1445.442164	1615
17-May	1479.323729	1646
18-May	1513.778777	1673
19-May	1548.816876	1694
20-May	1584.447797	1870
21-May	1620.681508	1956
22-May	1657.528178	1996
23-May	1694.998173	2039
24-May	1733.10206	2085
25-May	1771.850605	2107
26-May	1811.254774	2124
27-May	1851.325729	2151
28-May	1892.074835	2176
29-May	1933.513654	2208
30-May	1975.65395	2228
31-May	2018.507681	2258
1-Jun	2062.087011	2295
2-Jun	2106.404297	2313
3-Jun	2151.472099	2343
4-Jun	2197.303176	2351

5-Jun	2243.910485	2363
6-Jun	2291.307183	2373
7-Jun	2339.506626	2401
8-Jun	2388.522369	2421
9-Jun	2438.368167	2454
10-Jun	2489.057973	2505
11-Jun	2540.605941	2551
12-Jun	2593.026979	2569
13-Jun	2646.337179	2584
14-Jun	2700.551137	2601
15-Jun	2755.68365	2620
16-Jun	2811.749849	2659
17-Jun	2868.765198	2703
18-Jun	2926.745493	2756
19-Jun	2985.706865	2805
20-Jun	3045.665778	2823
21-Jun	3106.639027	2843
22-Jun	3168.643741	2864
23-Jun	3231.697383	2898
24-Jun	3295.817749	2939
25-Jun	3361.022967	2975
26-Jun	3427.331497	3012
27-Jun	3494.762136	3059
28-Jun	3563.33401	3089
29-Jun	3633.06658	3137
30-Jun	3703.97964	3222
1-Jul	3776.093317	3278
2-Jul	3849.42807	3344
3-Jul	3924.004692	3373
4-Jul	3999.84431	3466
5-Jul	4076.968382	3572
6-Jul	4155.3987	3698
7-Jul	4235.15739	3780
8-Jul	4316.26691	3879
9-Jul	4398.750051	4844
10-Jul	4482.629936	4952
11-Jul	4567.930025	5025
12-Jul	4654.67412	5075
13-Jul	4742.888592	5159
14-Jul	4832.59914	5233
15-Jul	4923.830166	5308
16-Jul	5016.606628	5347
17-Jul	5110.954039	5399
18-Jul	5206.898471	5459
19-Jul	5304.466552	5486
20-Jul	5403.685467	5596
21-Jul	5504.582955	5707
22-Jul	5607.187316	5762
23-Jul	5711.527404	5822
24-Jul	5817.632631	5913
25-Jul	5925.532963	5986
26-Jul	6035.258928	6037
27-Jul	6146.841605	6088
28-Jul	6260.312633	6216
29-Jul	6375.704206	6312
30-Jul	6493.049078	6459
31-Jul	6612.380555	6530

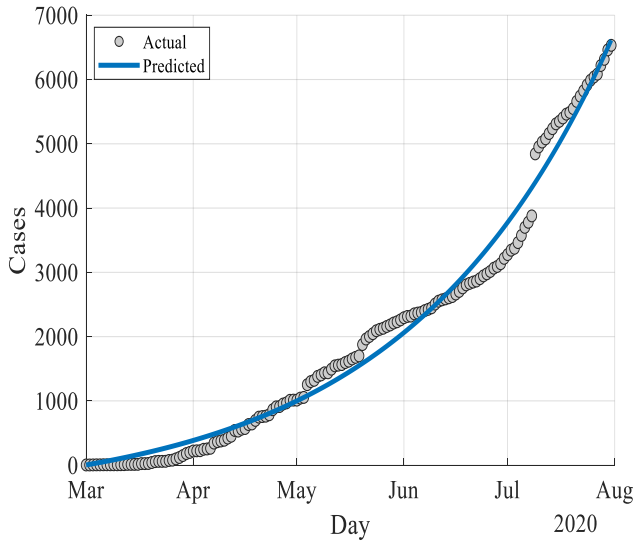

Fig. 2. Actual and predicted number of positive cases for COVID-19 in West Java Province on March 2020 until July 2020.

Fig. 2 shows the results, where the correlation coefficient measures the degree of linear correlation between positive case and *t*. The determination coefficient (R^2) reflects the reliability of the regression function positive case. The values of the determination coefficient both go from 0 to 1.

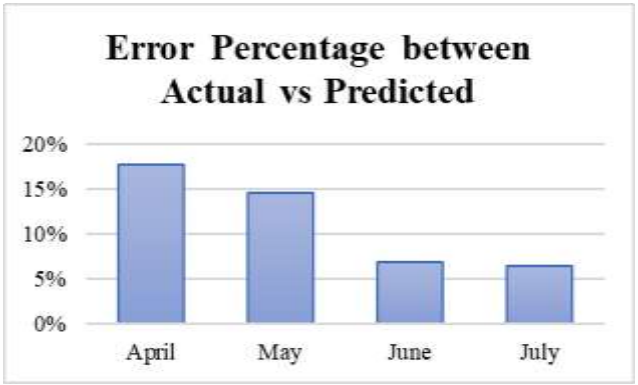

Fig. 3. Error percentage between actual and predicted number of positive cases for COVID-19 in West Java Province each month from April 2020 until July 2020.

Fig. 3 shows the percentage error from the prediction results and actual data every month. The percentage error of the prediction results in April and May reached 18% and 15%, respectively. Meanwhile, the percentage error from the prediction results reached 7% and 6% for June and July, respectively.

TABLE II
NUMERICAL PREDICTION FINAL SIZE

Day	N	S_∞	R_∞	α	β	R_0	R^2
121	38833	35569	3263	1.19	1.14	1.04	0.99
122	41422	38113	3309	1.23	1.18	1.04	0.99
123	44440	41079	3360	1.28	1.23	1.04	0.99
124	48059	44640	3419	1.33	1.28	1.04	0.99
125	51809	48331	3478	1.37	1.33	1.03	0.99
126	56588	53039	3549	1.43	1.39	1.03	0.99
127	62963	59323	3640	1.51	1.46	1.03	0.99
128	71624	67868	3756	1.59	1.55	1.03	0.99
129	82116	78226	3890	1.69	1.65	1.02	0.99
130	95422	91371	4052	1.80	1.76	1.02	0.99
131	153111	148422	4688	2.15	2.11	1.02	0.98
132	273857	267974	5883	2.54	2.52	1.01	0.98
133	590866	582110	8756	2.96	2.94	1.01	0.97
134	2231651	2208907	22743	3.35	3.33	1.01	0.97
135	1.4E+17	1.4E+17	0	3.49	3.47	1.00	0.97
136	5.8E+17	5.8E+17	0	3.41	3.39	1.01	0.97

According to Table 2, the minimum value of the determination coefficient is 0.97. The prediction result of the final size of the positive case of COVID-19 in West Java Province can be shown in Table 1. Because the final number of infected people is zero, so it can be estimated the final size of the positive case of COVID-19 by using R_∞ value.

From the results in Table 2, the final size of the positive case of COVID-19 is 22743 people.

IV. CONCLUSION

From the results of the research conducted, it can be concluded that the final size of a positive case of COVID-19 in West Java Province is predicted to be around 22743 people. It should be noted that the simulation in this article is based on data after West Java implemented Large-Scale Social Restrictions. The government closed public places such as schools, markets, and others. This means that if these public facilities are reopened, the infection rate may increase and result in the final size of Covid-19 being also higher than this result.

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Subiyanto, Ph.D., received his Ph.D. degree from Universiti Malaysia Terengganu. He is currently working as an Assistance Professor in the Department of Marine Science at Universitas Padjadjaran, west Java, Indonesia. He has more than 10 years teaching experience and 10 years of research experience. He has published more than 60 papers in international journals. He became a Member of IAENG in 2019 and He became member of Indonesia Operation Research Association (IORA) in 2016. His research area is mathematical modeling.

Yuyun Hidayat, Ph.D., received his Ph.D. degree from Universiti Malaysia Terengganu. He is currently working as an Associate Professor in the Department of Statistics at Universitas Padjadjaran, west Java, Indonesia. He has more than 34 years teaching experience and 20 years of research experience. He has published more than 50 papers in international journals of repute. His research area is quality control.

Dr. Eddy Afrianto, received his Ph.D degree from Universitas Padjadjaran. He is currently working as an Associate Professor in the Department of Fisheries at Universitas Padjadjaran, west Java, Indonesia. He has more than 34 years teaching experience and 10 years of research experience. He has published more than 20 papers in different national and international journal. He is a life member of Indonesian fishery product processing community (MPHPI). His research area is special fish microbiology.

Prof. Dr. Sudradjat Supian., received his Ph.D. degree from University of Bucharest, Romania. He is currently working as a Professor in the Department of Mathematics at Universitas Padjadjaran, west Java, Indonesia. He has more than 35 years teaching experience and 30 years of research experience. He has published more than 70 papers in international journals of repute. His research area is operation research and optimization.