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Simulation Study of the Spread of Covid 19

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Abstract: The coronavirus disease (COVID-19) pandemic has negatively affected the lives of billions of people around the world. During this time, the method of forecasting modeling by simulation has become an important tool used to predict the course of the epidemic and take measures. In this study, the simulation method was used in the Comsol program. The simulation study conducted 8 different scenario analyses based on data in China. Primarily from the moment the outbreak began, the impact of the first time the measures were taken on the pandemic process was examined. Taking measures as soon as possible appeared to reduce the pandemic process. Simulation analysis of the effect of population numbers on the pandemic later found that control was easy in smaller groups and that the pandemic process could be terminated in 180 days in a 100000 populated location. In addition to different scenario analyses, the impact of parameters (transmission rate, taking measures and population number) that act on the pandemic process was examined with the Taguchi analysis. The transfer rate was found to be the most effective (35%) parameter in the outbreak process. According to the results of the analysis, the transmission rate of the optimum conditions is 0.2, the taking measures are taken is 10th day and population number is 100000. In this optimal condition, the pandemic process was terminated in 90 days. According to the simulation results, measures should be taken as soon as possible, dividing the population into small groups. Furthermore, the simulation result for model validation was compared to actual data, showing that the results varied closely together.

Keywords: Pandemic, SEIR model, COVID 19, forecasting model

Koronavirüsün Yayılmasının Simülasyon Çalışması

Öz: Koronavirüs hastalığı (COVID-19) pandemisi, dünya çapında milyarlarca insanın hayatını olumsuz etkiledi. Bu süre zarfında simülasyon yoluyla tahmini modelleme yöntemi, salgının seyrini tahmin etmek ve önlem almak için kullanılan önemli bir araç haline geldi. Bu çalışmada Comsol programında simülasyon yöntemi kullanılmıştır. Yapılan simülasyon çalışmasında Çin'deki verilere göre 8 farklı senaryo analizleri yapılmıştır. Öncelikle salgının başladığı andan itibaren tedbirlerin ilk alınma süresinin pandemi sürecine olan etkisi incelenmiştir. En kısa sürede önlemlerin alınmasının pandemi sürecini azalttığı görülmüştür. Daha sonra nüfus sayılarının pandemi üzerindeki etkisinin simülasyon analizinde ise daha küçük gruplarda kontrolün kolay olduğu ve pandemi sürecinin 100000 nüfuslu bir yerde 180 günde sonlandırılabileceği görülmüştür. Ayrıca farklı senaryo analizlerine ek olarak pandemi sürecine etki eden parametrelerin (aktarım hızı, popülasyon sayısı ve önlemlerin alındığı sürenin) etkisi Taguchi analizi ile incelenmiştir. Aktarım hızının salgın sürecinde en etkili (%35) parametre olduğu görülmüştür. Analiz sonuçlarına göre optimum koşulların aktarım hızı 0.2, önlemlerin alınma süresi 10. gün ve nüfus sayısı 100000 olarak elde edilmiştir. Bu optimum koşulda ise 90 günde pandemi sürecinin sonlandığı görülmüştür. Yapılan simülasyon sonucuna göre salgında nüfusu küçük gruplara bölerek en kısa sürede önlemlerin alınması gerekmektedir. Ayrıca model doğrulaması için yapılan simülasyon sonucunun gerçek veriler ile karşılaştırılarak sonuçların birbirine yakın olarak değiştiği görülmüştür.

Anahtar Kelimeler: Pandemi, SEIR modeli,COVID 19,forecasting model

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1. Introduction

Now the pandemic that came into our lives under the name Covid 19 is likely to shape our lives for some time to come. But the sooner we can adapt to this situation, the sooner we can become profitable and achieve a healthy social structure. Of course, adapting to it will be made possible by stepping outside our old habits and creating a new social order. Perhaps in the near future, this will become normal and normal. It will become imperative for the person, community, and world health for everyone to keep up with this situation. The most effective tool in preventing this outbreak is increasing social distance (quarantine enforcement) and keeping the environments and people found clean.

In the meantime, treatment and provision of a preventive vaccine are also necessary. Simulation of the spread of this condition is important to combat the process, as well as the fact that the isolation and treatment of these persons and persons in contact with them is important as the epidemic begins. Outbreaks have occurred in different years around the world. Between August and November 2014, Ebola virus disease increased in various parts of Sierra Leone. Case numbers have exceeded the capacity of treatment centers. During December, additional beds were introduced, and many illnesses decreased. Camacho et al. [1] studies have investigated whether mattress capacity is sufficient in the future. They used a mathematical model to estimate how the outbreak changed between 10 August 2014 and 18 January 2015. They compared mattress requirements at the end of March 2015 with the capacity expected in the future. As a result, they found that the outbreak may have peaked in Sierra Leone and that the available bed capacity was sufficient to keep the outbreak under control in most areas. Dash et al. [2] they used support vector regression (SVR) and a deep neural network method to develop predictive models in their studies. SVR is reached on the basis of an educational model, using a function to predict mapping from an input field to actual numbers. In their study, they used SVR and LSTM (The long short-term memory networks) techniques to simulate the behavior of the pandemic. The simulation results suggest that LSTM yields more realistic results in the India scenario. With publicly available data provided by the health authority in the Mohammad et al. [3] they identified a sustainable COVID-19 epidemic prognostic method in Bangladesh using a deep learning model. Throughout the research, they estimated the number of deaths and people recovering, up to 30 days when the actual daily estimate was confirmed. Also, random forest (RF) regression of long short-term memory (LSTM), both machine learning (ML), and support vector regression (SVR) Rahimi et al. [4] In their study, they examined and analyzed the prediction models of COVID-19. They presented their work in two parts. In the first section, they list sciometric analyzes for bibliometric analyzes performed on COVID-19 data from the Scopus and Web of Science databases. In the second part of their study, they discussed the classification of machine learning prediction models, evaluation of criteria and comparison of solution approaches. Shinde et al. [5] classified prediction models as mathematical models and machine learning techniques, using WHO and social media communication as datasets. They also examined important parameters such as death toll, metrological parameters, quarantine duration, medical resources and mobility. Naude [6] has conducted a review of the contribution of artificial intelligence (AI) to COVID-19. It was identified some of the areas where AI has contributed to COVID-19 as early warnings and alerts, monitoring and forecasting, data dashboards, diagnosis, treatments, and social control. Some scientists argue that predicting and modeling the spread of the disease is a complex network mechanism [7]. Many studies show that the SIS, SIR and SEIR models can well reflect the dynamics of different epidemics. In some studies, these models have been used to model COVID-19 [8,9,10].

In the study, the simulation model analysis of the SEIR model was carried out with 8 different scenarios. The effect of population number and measures taken has been studied. Therefore, this article stands out in this aspect from other studies conducted in the literature. The most important contribution of the simulation results has been to determine that taking early precautions and dividing the process into small populations will be the healthiest solution and method of struggle. In this way, the capacity of the health system will be kept under control. Another contribution of this study is that how long the pandemic can be completed has been responded to by different scenarios. With this method, the pandemic process in places with different populations (city, country) will be predicted in advance. Therefore, the pandemic, which will last for many years, will be able to be controlled and completely over in a short time. In addition, the percentage effect of transmission rate, population number and measures taken on the pandemic was investigated with Taguchi analysis. Here it was seen that the duration of taking measures in small groups is the most important parameter.

2.Material and Method

2.1.Mathematical Model for Coronavirus

The SEIR model is a method used for the mechanism of human-to-human transmission, first published in the 1920s [11]. It divides the population's number of individuals in each category into four different divisions during an outbreak:

S = suspect (suspected)
E = exposed (exposed)
I = infected (infectious)
R = healed and immune (recovered and immune)

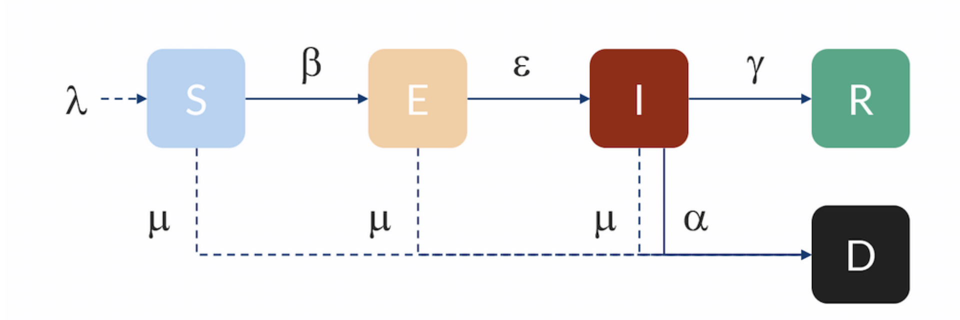


Figure 1. SEIR Model

Sectional model: Individuals pass from S to E at a rate of β, from E to I at a rate of ε, and from I to R at a rate of γ. Individuals can also pass from I to D with the α ratio. Individuals in R are assumed to be immune here and do not revert to S for the duration of the model. The entry of newborns is represented by λ, and the natural death rate is represented by μ.

The unit of the variables S, E, I and R is the number of individuals. For an individual in the suspected compartment to be exposed, they must have had some form of contact with an infected person. The exposure rate is as follows:

$$\mathrm{r}_{nE} = \frac{\beta}{N} SI \tag{1}$$

where β is the transfer rate (1/day). The average number of individuals infected by a contagious individual is R_0, the average number of days a person is contagious (before being isolated or self-isolating) expressed in nids. β transfer rate is given in equation 2.

$$\beta = \frac{R_0}{n_{id}} \tag{2}$$

R_0 is called the re-spread number (dimensionless) and defines the spread of the disease before that person recovers whenever an infected person has contact with a suspect person (when there is no immunity in the population). Any mitigation or containment strategy will aim to reduce the number of spreads, either by reducing the transmission rate β or the time before infectious individuals are isolated.

For shorter (non-seasonal) epidemic simulations, we can assume a stable population with natural deaths and births in balance. Subsequently, the number of suspected individuals decreases with the increase of newly exposed cases, where N denotes the size of the population:

$$\frac{dS}{dt} = -\frac{\beta}{N}SI \tag{3}$$

Accordingly, the term on the right in equation 3 is the source term in the exposure equations, E. However, this equation also has a negative term for those exposed who leave compartment E and become contagious.

$$\frac{dE}{dt} = \frac{\beta}{N}SI - \varepsilon E \tag{4}$$

Here, ε denotes the rate of progression to infection after a single exposure, per unit per day (1/day). The rate is inversely proportional to the length of the incubation period. The number of infected, I, increases with εE per day, but decreases with the rate at which individuals are isolated, recovered, or died. The rate coefficient γ indicates the rate at which people are isolated or recovered. This rate is inversely proportional to the number of days they were infected:

$$\gamma = \frac{1}{n_{id}} \tag{5}$$

There is also a term for the rate at which the infected die from disease αI, and the equation for the infected variable I can be written like this:

$$\frac{dI}{dt} = \varepsilon \mathrm{E} - \gamma \mathrm{I} - \alpha \mathrm{I} \tag{6}$$

The equation for the variable R, which represents individuals who are no longer suspicious, is as follows;

$$\frac{dR}{dt} = \gamma \mathrm{I} \tag{7}$$

The equation for the death toll, D, is as follows:

$$\frac{dD}{dt} = \alpha \mathrm{I} \tag{8}$$

2.2. Introduction to Taguchi Method

Traditional experimental studies call for high-cost process and implementation time. For desirable quality parameters to be tested, it takes a considerable amount of time to apply and investigate factors. At the same time, there are a number of challenges, such as repeatable experiments and validation studies. The Taguchi method is used as an alternative method for systematic analysis and accurate solution of these experimental studies. It offers product development and high-quality design with a small number of experiments. This method is used to assess the optimal conditions of the parameters acting on experimental study data.

Recently, the Taguchi method has stood out as a powerful method supported by research and development studies to obtain fast and low-cost products in industrial applications. Analyses use the orthogonal array and ANOVA method. ANOVA helps to examine the impact of factors on characteristics. The advantage of the Taguchi method over traditional statistical methods defines experimental conditions with the least diversity in optimal conditions [12]. The results of the experiment obtained in the Taguchi method are analyzed by translating to signal-to-noise (S/N) ratio. Experimental design can be done using multiple levels and factors. The value that yields the largest S/N ratio as a result interpretation refers to the good experiment result. In the ranking of the factors, the best performing factor is said to have the highest S/N ratio. It can also be learned in variance analysis with Taguchi analysis what factor has an impact on the process. The optimal working conditions of this process can be determined [13].

Taguchi creates orthogonal arrays so that numerous experiments to be performed can be tested in small numbers. Orthogonal sequences 2, 3, 2 and 3 can be gradually determined. Its general representation is referred to as L_a (b^c). Here L is the orthogonal index, a total number of experiments, the level number of b factors, and the number of c factors. L4, L8, L12, and L 32 are used for 2 levels, and for L9, L18, and L27 3 levels. The total degree of freedom of the factor group helps us decide which level to select the orthogonal array from. The total degree of freedom of all factors and interactions is equal to the degree of freedom of the factor group. When 1 is added to the total degree of freedom, the correct array is selected if the number of experiments is equal. It would be more appropriate to select a top series if it is not equal. The results of the experiments of the designed system are converted to S/N (signal/noise) ratio in the Taguchi method and expressed decibel.

2.2.1. Taguchi Analysis Equations

Equality (9), (10) and (11) are used for maximum, minimum and nominal performance values [14].

$$\mathrm{S/N}_{max} = -10log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{{y_i}^2}\right) \tag{9}$$

$$\mathrm{S/N}_{min} = -10log\left(\frac{1}{n}\sum_{i=1}^{n}{y_i}^2\right) \tag{10}$$

$$\mathrm{S/N}_{nom} = 10log\left(\frac{\bar{y}^2}{s^2}\right) \tag{11}$$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \qquad s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2 \tag{12}$$

Where n is the number of tests in a trial, y_i is the i of the observed experimental data for the performance characteristics. is the mean of the $\bar{y}$ observation values and the variance of the s^2 observation values. The experimentally obtained data can also be estimated as a result of the analysis made by the Taguchi method.

$$\mathrm{S/N}' = \mathrm{S/N}_{avg} + \textstyle\sum_{i=0}^{p}\left(\mathrm{S/N}_i - \mathrm{S/N}_{avg}\right) \tag{13}$$

Here; $\mathrm{S/N}'$ is the estimated S/N ratio, $\mathrm{S/N}_{avg}$ is the mean of all S/N ratios, p is the number of factors, $\mathrm{S/N}_i$ is the optimal S/N ratio of each factor.

By using the calculated estimated S/N' ratio in equation (14), the estimated measurement result value for the optimum combination of simulations is obtained. Then, by comparing this value with the test result, it can be investigated whether the Taguchi analysis and the test results are compatible.

$$Estimated\ measurement\ result = 10^{-\frac{S/N'}{20}} \tag{14}$$

3. Results and Discussion

A sample with mathematical expressions in this model can be explained as follows for a better understanding of the subject;

- The country's population is 1 million people,
- R = 2.25: This ratio represents the spread of disease in every contact with a suspicious person when there is no immunity in society.
- Average number of days a person is infectious (before being isolated or self-isolated): 5 days
- Total number of individuals infected: 10
- 1 million-10: suspected persons (number of people with potential for contracting the disease

In the first case, Höhle ran a simulation in which the outbreak was allowed to proceed without restrictions on social distances in the population. In a second case, Höhle assumes that authorities with 1 million people have taken action to reduce the number of sprawls by not allowing, for example, the gathering of larger groups of people (sporting events, concerts, cinema, theatre, school, etc.). The first step, after 28 days of outbreak, is to reduce the basic number of spreads by introducing restrictions on social interaction. This reduction is sustained for five weeks when measures are relaxed, after which the propagation factor (reproduction factor) is allowed to rise again to 1.8. Fig. 2 shows two states: Case 1 no quarantine, Case 2 quarantine.

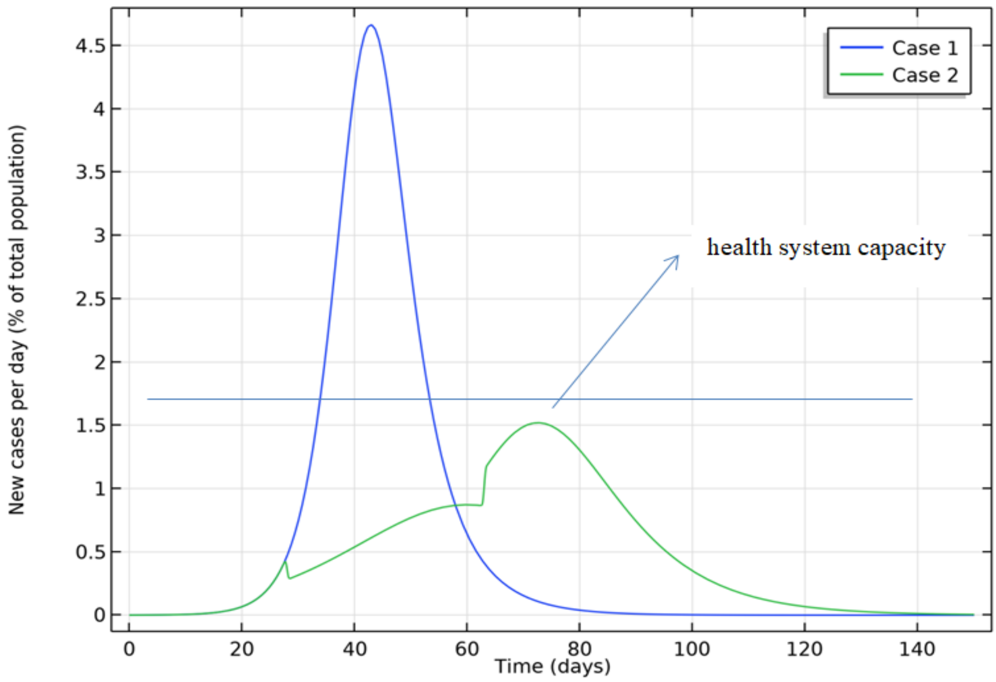


Figure 2. Result graph

The equation for the death toll, D, is as follows: Individuals meet an infected person and become infected. In the model, this would correspond to a very large value of ε (the rate of spread of infection when exposed in one day). The input data and the result graph of Michael Höhle [15], who solved mathematical equations, are given in Fig. 2.

The precautions taken 28 days later, as shown in Fig. 2, resulted in a sudden reduction in the curve and then a slight increase. But when measures are not taken, it appears that the number reaches the top spot and then decreases. What is really important here is that the curve is flattened as soon as possible, so that the health system is kept at capacity. It will take some time to flatten the curve. As important as it is to prepare hospitals during this time, there will also be a reduction in the total number of people infected during the outbreak.

The results of the number of people suspected, infected and recovered for both conditions were also shown in Fig. 3. "Fig. 3" also shows the number of suspects in the letter S for both conditions, the number of patients infected I and the number of people who have recovered or become immune R.

The part of the population infected with epidemia is 85% in the condition 1, while the condition is only 68% in 2. Therefore, the measures taken not only temporarily reduce the burden on the health system, but also reduce the total number of patients over the entire outbreak.

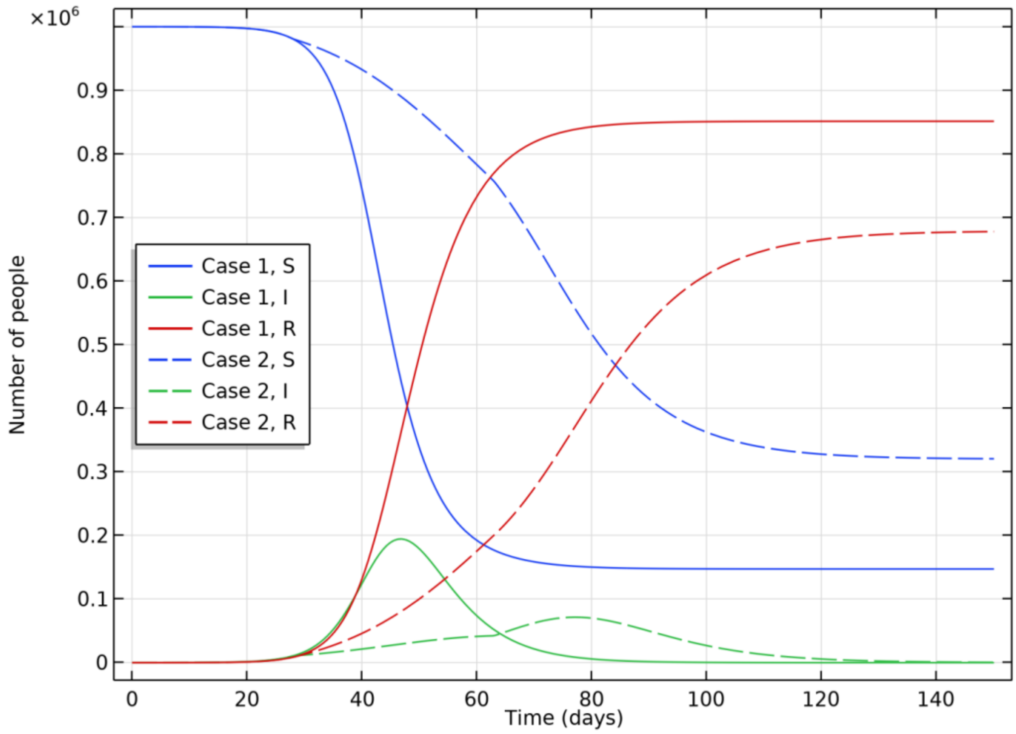


Figure 3. Number of people suspected, ınfected and recovering for both conditions

Restrictions on social distance and social interaction result in less infected and fewer deaths, making the community more susceptible to the next outbreak, so we need to keep the measure unavailable.

The aim of epidemic model-based approaches to flattening the curve can be said not only to reduce the number of spreads but also to keep the course of the outbreak under control.

It's worth noting that mathematical models are merely tools for getting ideas. What is important here is that measures are taken to flatten the curve by reducing infectious contacts and monitoring the contact network (filiation).

3.1. Validation Study

A parameter estimate has been obtained using available data for Hubei, where the outbreak began. It is known that the number of infected individuals is not reliable data because most individuals have not been tested or diagnosed with COVID-19, with the number of deaths taken as the most reliable data [16].

The mortality rate was 0.66% and the virus was assumed to be contagious before an average of 3 days of isolation. It also applied the start date, rate of spread and average duration of the outbreak to data reported in Hubei, taking into account the time from the onset of symptoms to an average of 18 days of death [16].

On January 22, 2020, authorities announced a reduction. At the end of that month, measurements showed a marked decline in the number of spreads [17]. After the effect of this reduction began on 23 January 2020, the results in February and March were released in Fig. 4.

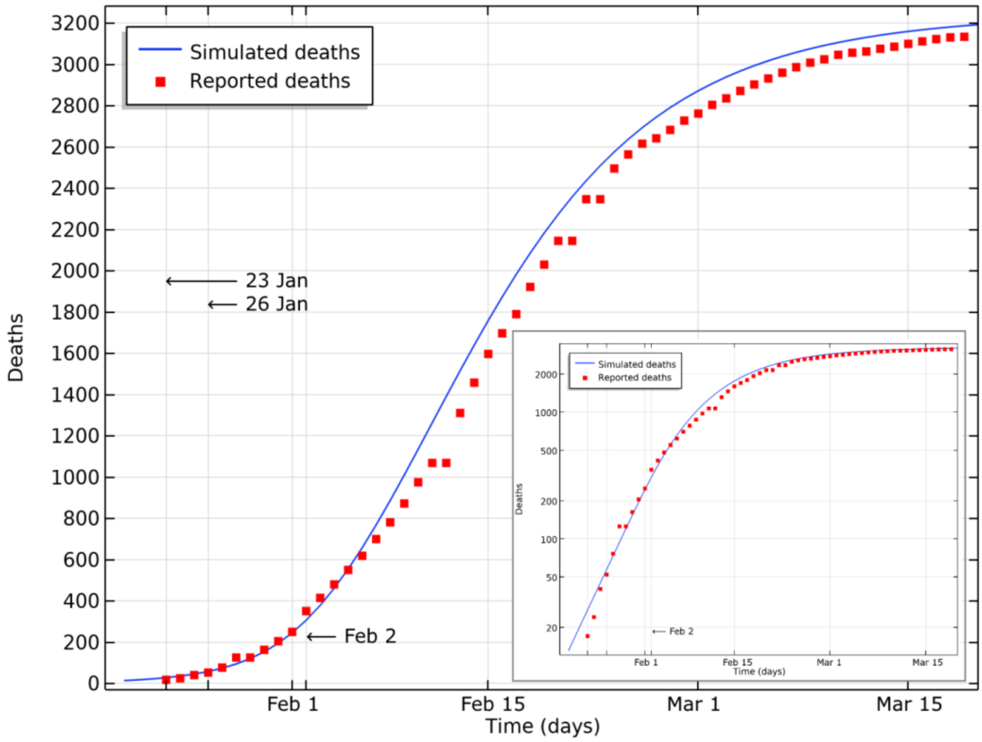


Figure 4. Modeled data for number of deaths compared to data reported in Hubei

The model created appears to align well with the data. The difference in the numbers given in Fig. 4 is explained by the delay in reporting as the number of deaths rises.

In Fig. 4, we can see that the number of deaths is exponential growth, which is about 400 logarithmic linear by February 2, 2020. After February 3, 2020, the death toll decreases. The increase here is no longer exponential. This is due to restrictions on social distance and quarantine processes. The impact of cases of immunocompromised COVID-19, which will also limit the number of spreads, is yet to be seen at this stage.

3.2. Overall Impact of Early Adoption of Measures on Pandemic

A math model of the outbreak was simulated through a country of sixty million people in 4 different scenario analyses. From the moment the outbreak first began, restriction (there is closure to external countries but domestic travel is free) and quarantine measures have been put in place for 5th day, 10th day, 20th day and 30th day. Transmission rate 0.3, reproduction number 3.031, erlang mean rate 3.335 was originally assumed to have coronavirus in 10 person. The simulation period is scheduled for 250 days. The collective results obtained were given in Table 1 and Fig. 5.

Based on the results of the analysis, measures 5th day from the day, 10 th day from the day, 20th day day and 30th day day in order to be taken and applied from the day onwards, 400 days, 500 days, 690 days and 750 days continued, and the pandemic would be terminated. There appears to be a drastic increase in numbers if measures are taken after the 20th day and 30th day The pandemic will end if measures continue uninterrupted for 690 and 750 days, even if measures are taken on the day. In this case, the precautions must be continued for nearly two years without interruption so that the pandemic can end. Therefore, the sooner measures are taken, the shorter the pandemic will be, the lower the number of people who have passed away and are infected.

Table 1. Total results as a result of 250-day simulation by day of precautions

	5th day	**10th day**	**20th day**	**30th day**
Number of pandemic-ending days	400 days	500 days	690 days	750 days
Number of exposed individuals	5	18.33	234.2	1750
Number of infectious individuals	5.4	19.77	252.8	1914
Number of individuals who have recovered and become immune	2753	9496	111600	1187000
Number of deaths individuals	17.76	61.36	720.9	7695

3.3. Study of Determination of Days Numbers Required for Complete End of Pandemic Process

The analysis in Table 1 assumed that intercity transport was free in the country of 60 million people. If cities in the country are quarantined within themselves, what the consequences will be is explored in this section. In other scenario analysis simulated the mathematical model of the outbreak through cities with different populations. The time limit and quarantine measures implemented since the epidemic first started have been accepted as the 20th day. The transfer rate is 0.3, reproduction number 3.031, erlang mean rate 3.335.

Table 2. Quarantine day numbers needed for cities with different populations to reset pandemic cases

Population number	**A city 100000**	**B city 200000**	**C city 500000**	**D city 1000000**
Number of pandemic-ending days	**180 days**	**240 days**	**350 days**	**450 days**
Number of exposed individuals	0	0	0	0
Number of infectious individuals	0	0	0	0
Number of individuals who have recovered and become immune	29150	40410	58420	73260
Number of deaths individuals	190.6	264.3	382.1	479.3

It was initially assumed that 10 people had coronavirus. The number of days the number of infected patients has reset has been investigated. Simulation results are given in Table 2. According to the results, the less the population is held, the shorter the pandemic will end. The number of deceased in A city of 100000 was estimated at 190.6 as the pandemic would end after 180 days. However, in the D city of 1000000, it appears that 450 days of pandemic will last and 479.3 people will pass away. Thus, the separate quarantine of cities in the country will allow the process to be easily controlled. In fact, the implementation of quarantine operations on a district and neighbourhood basis within cities all over the country can ensure that the outbreak is over as soon as possible. If the measures are taken on the 20th day, the pandemic has been brought under control in 180 days (6 months) in a city or district with a population of 100,000, the number of cases has been reset and normalization has begun. But in A city of 1000000 people, it will last for over a year, like 450 days. This is why the pandemic outbreak, which will last for a year or two, could be brought under control in a very short time, with cities prohibiting county-by-district entrances and implementing quarantine operations. In this case it is very important that normalisation is switched as soon as possible. Considering this situation in terms of economics, education and socio-cultural, taking measures early in the long term and dividing the process into small populations will be the healthiest solution and way of fighting.

3.4. Taguchi Analysis Results

In this study, the Taguchi method was used to optimize the parameters (transmission rate, taking measures and population number) affecting the pandemic process. The transmisson rate was 0.2, 0.3 and 0.4, the 10th day, 20th day and 30th day for the taking measures, and the 200000, 500000 and 1000000 values were taken as the population number (Table 3). The numbering of the samples showing the levels of the pandemic parameters and the simulation setup selected using the Taguchi L9 orthogonal array are given in Table 4. The values given here are entered into the Minitab program. Taguchi analysis was performed with 9 different values. In this study, the minimum objective function was defined.

Table 3. Pandemic parameters and levels used in the study

Parameter	Degrees of freedom	Level 1	Level 2	Level 3
Transmission rate	2	0.2	0.3	0.4
Taking measures	2	10	20	30
Population	2	200000	500000	1000000
Total SD	6			

Table 4. Selected parameters and levels using Taguchi orthogonal L9 array

Orthogonal array	Simulation no	Transmisson rate	Taking measures	Population
111	1	0.2	10	200000
122	2	0.2	20	500000
133	3	0.2	30	1000000
212	4	0.3	10	500000
223	5	0.3	20	1000000
231	6	0.3	30	200000
313	7	0.4	10	1000000
321	8	0.4	20	200000
332	9	0.4	30	500000

3.4.1. Optimization Work for the Pandemic

The calculated death toll values for 9 different scenarios were entered into the Minitab 18 program. Then, ANOVA analyzes were performed using the Taguchi method. Table 5 shows the number of deaths obtained and the calculated S/N ratios. The largest average S/N ratio shows the smallest number of deaths. According to the average S/N ratio analysis given in Fig. 5a, the least number of deaths (optimal condition), the transmission rate of 0.2 where the highest average S/N ratios were obtained, the 10th day of taking precautions, and the population number 100000 were obtained. The ANOVA method allows us to test the importance of all the main factors and their interactions with each other. In this study, the ANOVA method was applied using the mean S/N values to define the contribution of each of the pandemic parameters. With the ANOVA results given in Table 6, the effect rates of the parameters on the deceased were obtained. These percentages are given in Fig. 5b. At the end of the pandemic process, it was obtained that the effect of the transmission rate was 35%, the effect of the taking of the measures was 33.7% and the effect of the population number was 24%. According to this result, the order of importance of the parameters affecting the duration of the pandemic was obtained as the transmission rate> taking of the measures> the number of population. The most important parameter in the pandemic process is the transmission rate. According to the S/N ratio response result table in Table 7, it is seen that the most important parameter (Rank number 1) is the transmission rate.

Table 5. Number of deaths in the pandemic process and calculated S/N ratio

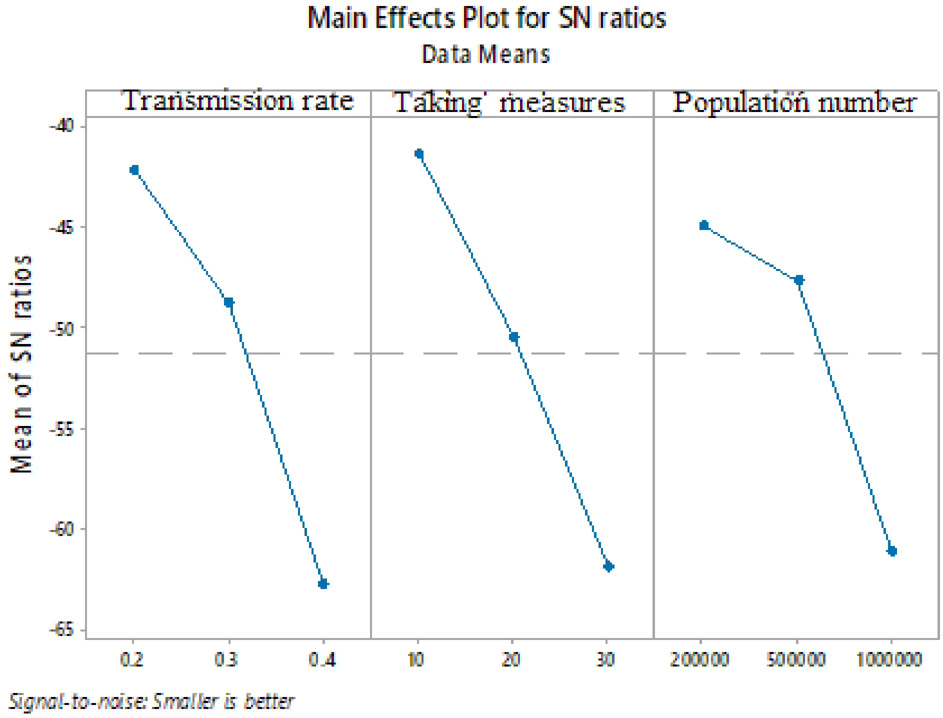
Orthogonal array	Number of deaths	S/N ratio	Standard deviation
111	12.03	-21.6053	0.01000
122	137.30	-42.7536	1.12694
133	1295	-62.2454	1.0000
212	55.35	-34.8624	0.0100
223	477.17	-53.5734	0.15275
231	795.30	-58.0106	1.12694
313	2421.00	-67.6799	1.0000
321	577.17	-55.2260	0.15275
332	1884.00	-65.5016	1.0000

Table 6. ANOVA table for S/N ratios for the pandemic period

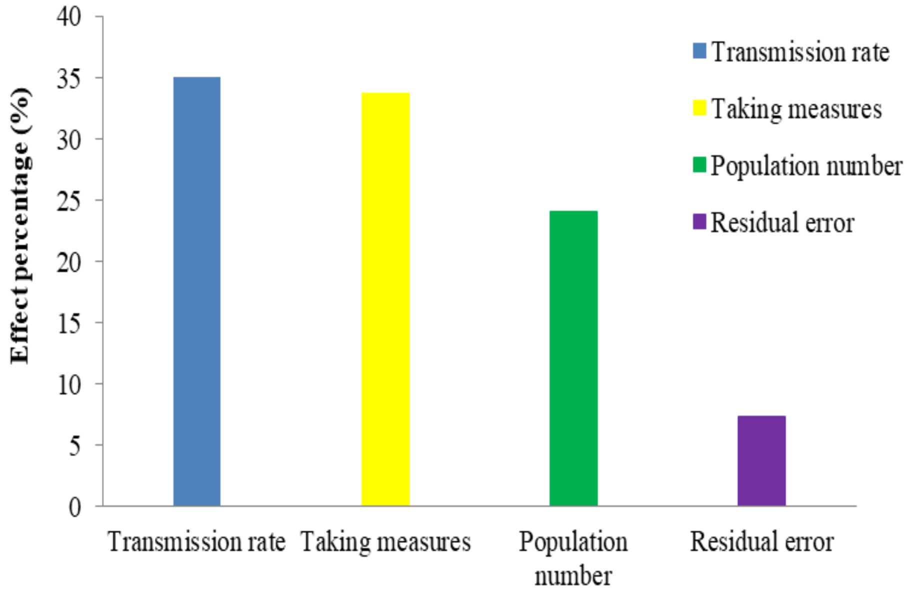
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Transmission rate	2	663.8	663.8	331.89	5.12	0.163
Taking measures	2	635.2	635.2	317.60	4.90	0.169
Population number	2	451.8	451.8	225.92	3.49	0.223
Residual Error	2	129.6	129.6	64.79		
Total	8	1880.4				

Table 7. Response table for signal to noise ratios

Level	Transmission rate	Taking measures	Population number
1	-42.20	-41.38	-44.95
2	-48.82	-50.52	-47.71
3	-62.80	-61.92	-61.17
Delta	20.60	20.54	16.22
Rank	1	2	3



(a)



(b)

Figure 5. a) Mean of S/N ratios for different pandemic parameters b) Percentage of effect of parameters on the number of deaths

The result graph of the optimum condition is given in Fig. 6. Optimum conditions were obtained as the transmission rate of 0.2, the taking of the measures to be taken at the 10th day and the population number as 100000. As seen in Fig. 6, it was determined that the pandemic ended on the 90th day, in other words, the number of infected patients was reset. Therefore, the parameters that can be controlled in the pandemic are the population number and the duration of the measures. According to the simulation and Taguchi analysis, the sooner precautions (quarantine, etc.) are taken in places with small populations (district, neighborhood, village, etc.), it will be possible to reset the number of infected patients before the pandemic process progresses too far. In this process, it is necessary to keep the process under control without exceeding the capacity of the health system, in order to carry out the process in a healthy way.

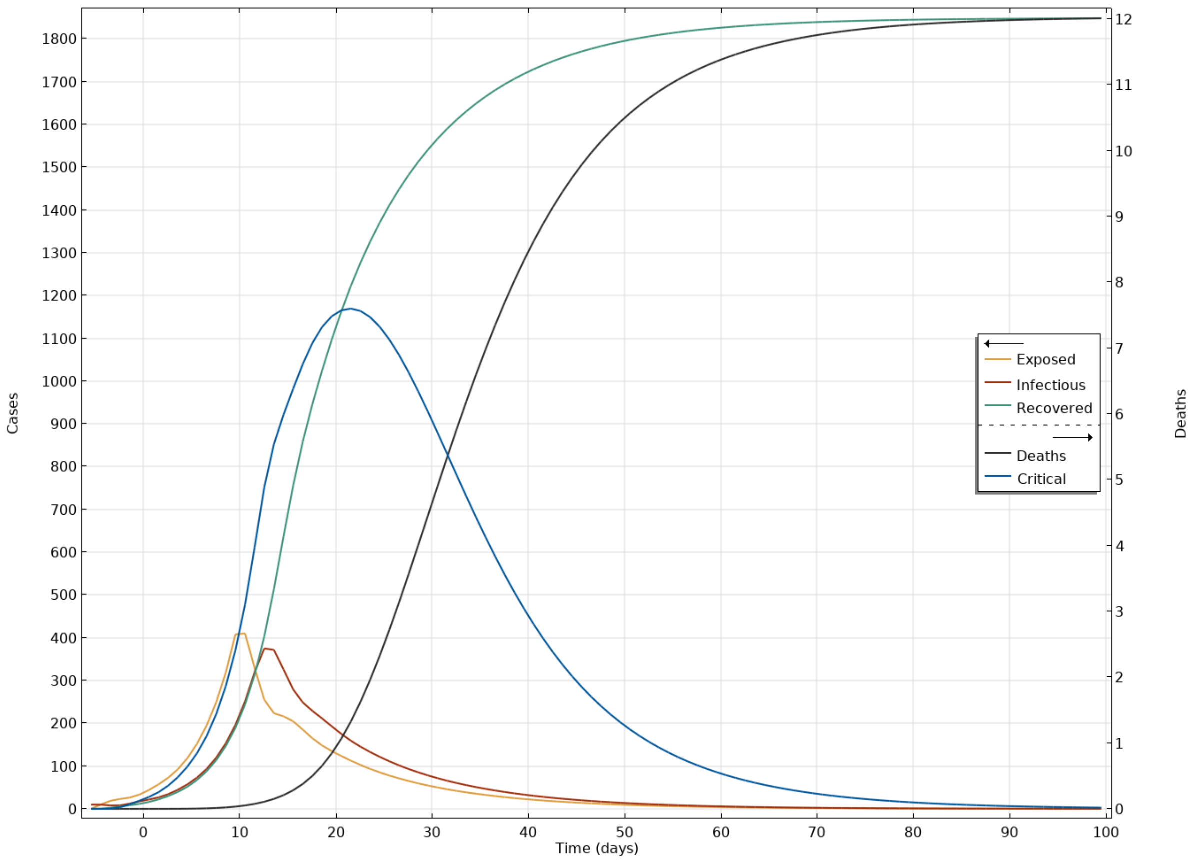


Figure 6. Simulation output curves of the optimum condition of the pandemic process

4.Conclusions

The fact that people were very vulnerable to the virus at the beginning of the epidemic, when vaccine and drug treatment were not yet fully known, shows that strict restrictions should be introduced that quickly extinguish the epidemic. If vaccination and proper treatment are not done, if new infected cases arise in the future, only a small fraction of the population will be immune by then, and the second epidemic will progress again with exponential growth in spread. This means that the society must be ready to act very quickly against a new epidemic at any time. Applying fewer restrictions produces more deaths in the first outbreak, but makes a larger portion of the population immune. If such a strategy is implemented, the population will need to protect the elderly at higher risk of death. However, it is necessary to take strict measures at the beginning of the epidemic and the same quarantine procedures should be applied as soon as possible in the second epidemic or other epidemics. Some countries were late in taking measures to gain natural immunity and the cost was heavy. What is important here, instead of waiting for people to become immune by spreading the epidemic, is to impose restrictions in each epidemic, to ensure quarantine and social distance, to comply with cleaning rules, and to encourage finding the right treatment and protective vaccine as soon as possible by investing in the field of medicine with a quick reflex.

In addition, while the number of infected patients will be reset in a shorter time by keeping the quarantine zones limited to fewer people and maintaining those areas, it will be difficult to control (keep under) the pandemic in more crowded populations with travels between districts or cities and will cause the process to prolong. According to the results of the analysis of the epidemic simulation, quarantine and measures should be taken as soon as possible when the epidemic begins. While taking precautions, dividing the cities within the country into regions (districts with smaller populations) and quarantining those regions completely can ensure that the epidemic process, which will take a year or two, is completely over in a short period of maybe two or three months.

The summary results obtained from the study can be listed as follows;

- When it is noticed that it is a symptom of an epidemic, the strictest measures should be taken as soon as possible.
- It should cut off the travel from other countries as soon as possible and cut the transportation between cities in the country and between the districts in the provinces. For healthy control, it is necessary to keep the population small and limited.
- It is also very important for the control of the process that the first disease appears to have a low rate of spread, that is, less contact with other people.

Author(s) Contributions

Authors read and approved the final version of the manuscript.

Competing Interests

The authors declare that they have no competing interests.

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