Turkish Journal of Clinics and Laboratory

To cite this article: Yapar D. Forecasting for the number of the COVID-19 cases with Brown's linear exponential smoothing method: Comparison of the growth trends with 15, 30 and 60 days forecasts. Turk J Clin Lab 2022; 2: 232-241.

Original Article

Forecasting for the number of the COVID-19 cases with Brown's linear exponential smoothing method: Comparison of the growth trends with 15, 30 and 60 days forecasts

Brown'ın doğrusal üstel düzleştirme yöntemiyle COVID-19 vaka sayılarının tahmin edilmesi: 15, 30 ve 60 günlük tahminlerle büyüme eğilimlerinin karşılaştırılması

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ABSTRACT

Aim: The aim of this study was to estimate the number of the COVID-19 cases for the 15, 30 and 60-days with the ideal forecasting analysis methods by using the daily data of the Turkey, Germany, Brazil, United Arab Emirates (UAE) and United Kingdom (UK).

Material and Methods: The data were reached from the Our World in Data COVID-19 dataset. The forecasts for the cumulative cases for 15, 30, and 60 days periods to 19 February 2022 were made. The most commonly used methods for forecasting are explanatory techniques and time series algorithms. The exponential smoothing method (Brown's linear trend) was used for the five countries.

Results: The analyses showed that five countries have followed a similar epidemic curve. For 60-day forecasts, it was estimated respectively that 10,322,701, 22,434,809, 9,552,781, 16,937,127, and 767,819 total cases would be in Turkey, Brazil, Germany, the UK, and the UAE until February 19. For 30-day forecasts, it was estimated respectively that 12,809,392, 28,752,324, 12,655,999, 18,857,395, and 905,537 total cases would be in Turkey, Brazil, Germany, the UK, and the UAE until February 19. For 15-day forecasts, it was estimated respectively that 13,635,838, 29,678,270, 14,241,248, 20,006,207, and 885,958 total cases would be in Turkey, Brazil, Germany, the UK, and the UAE until February 19.

Conclusion: The short-time forecasting methods will help to plan the necessary interventions to control the pandemic, and to see whether health resources such as allocated health personnel and intensive care units are sufficient.

Keywords: COVID-19; pandemic; forecasting methods; exponential smoothing method; Brown's linear trend

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Recevied: 24.04.2022 accepted: 13.06.2022
Doi: 10.18663/tjcl.1108320

ÖZ

Amaç: Bu çalışmanın amacı, Türkiye, Almanya, Brezilya, Birleşik Arap Emirlikleri (BAE) ve Birleşik Krallık'ın günlük verilerini kullanarak ideal tahmin yöntemleri ile 15, 30 ve 60 günlük COVID-19 vaka sayılarını tahmin etmektir.

Gereç ve Yöntemler: Verilere Our World in Data COVID-19 veri setinden ulaşılmıştır. 19 Şubat 2022 tarihine kadar 15, 30 ve 60 günlük dönemler için kümülatif vaka sayıları tahmin edilmiştir. Tahmin için en yaygın kullanılan yöntemler açıklayıcı teknikler ve zaman serisi algoritmalarıdır. Beş ülke için üstel düzleştirme yöntemi (Brown'ın doğrusal trendi) kullanılmıştır.

Bulgular: Analizler, beş ülkenin benzer bir salgın eğrisi izlediğini gösterdi. Türkiye, Brezilya, Almanya, Birleşik Krallık ve BAE için 60 günlük tahminlerde 19 Şubat'a kadar sırasıyla 10.322.701, 22.434.809, 9.552.781, 16.937.127 ve 767.819 toplam vakanın olacağı tahmin edildi. Türkiye, Brezilya, Almanya, Birleşik Krallık ve BAE için 30 günlük tahminlerde sırasıyla 12.809.392, 28.752.324, 12.655.999, 18.857.395 ve 905.537, 15 günlük tahminlerde ise sırasıyla 13.635.838, 29.678.270, 14.241.248, 20.006.207 ve 885.958 toplam vaka sayısına ulaşılacağı tahmin edilmiştir.

Sonuç: Uygun yöntemler ile yapılan kısa süreli tahminler, pandemiyi kontrol altına almak gerekli müdahaleleri planlamaya, ayrılan sağlık personeli ve yoğun bakım üniteleri gibi sağlık kaynaklarının yeterli olup olmadığını görmeye yardımcı olacaktır.

Anahtar kelimeler: COVID-19; pandemi; tahmin yöntemleri; üstel düzleştirme yöntemeleri; Brown'ın doğrusal trendi

Introduction

Novel coronavirus (2019-nCoV) or the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a serious public health crisis that has been going on for more than 2 years and now it has spread to more than 200 countries around the world [1]. Unfortunately, the number of cases in the world exceeded 410 million and the number of deaths exceeded 5.8 million (14.02.2022) [2, 3]. 2019-nCoV is transmitted through droplets, especially generated during coughing and sneezing by infected patients. Clinical features of coronavirus disease 2019 (COVID-19) are range from asymptomatic to acute respiratory distress syndrome, multiple organ dysfunction, and death [4]. Mortality is higher in the older age group and those with chronic diseases such as diabetes mellitus, cardiovascular disease and cancer. To prevent and control the spread of this epidemic, lots of strategies are needed. Current prevention efforts regarding masks, hand hygiene, and physical distance are still the most reliable methods of protection, and attention should be paid to the resistance of the community to adaptation. The need to vaccinate the entire population against the SARS-CoV-2 virus is urgent and vaccination will likely be the most effective way to control the pandemic. As of February 2022, WHO listed a total of 337 vaccines, of which 195 are in the preclinical phase and 142 are in the clinical phase [5]. Vaccination against COVID-19 has now started in 218 locations covering 95% of the world's population and only 62% of the world population has received at least one dose of a COVID-19 vaccine [6].

The creations of web-based databases such as the Johns Hopkins University-Coronavirus Resource Center (JHU-CRC), Our World in Data and the Worldometer-Coronavirus, which contain current data have been helped us to follow up the course of the disease in the countries and also in the World to date [1-3]. But these databases contain descriptive data and graphics mostly. Predicting the size of infection in the countries by modeling daily changes about the process according to the data obtained at the moment, will help us with the measures that must be taken. Estimating the trend of the epidemic is very important because of the causes such as the allocation of medical resources and the regulation of production activities. So, we can learn more clearly the effectiveness of measures taken by governments and individuals and how long they must be. The double exponential smoothing, quadratic trend, and logistic growth model are the commonly used ones. In the literatüre, these methods were used and performed well in many different areas such as tourism, health, economy, and production [7-9].

The rapidly growing number of infected cases in worldwide shows that we are confronted with exponential growth. It is necessary to consider this growth pattern according to the stages of the outbreak, it is difficult to predict the dynamics of the outbreak in the early stages. When outbreaks are considered in the long term, exponential growth can not go on, so it shows a logistical growth pattern [10]. It is a more accurate and reliable approach to make short-term forecasts instead of long-term

forecasts to predict the trend of the COVID-19 pandemic. The purpose of this study is to report the current status of COVID-19 and to estimate the size of the COVID-19 pandemic for the next 15, 30, and 60 days with the ideal forecasting analysis methods by using the latest daily data of the Turkey and four countries (Germany, Brazil, the UK and UAE).

Methods

Daily confirmed cumulative cases

The dataset of the study consisted of the cumulative number of daily COVID-19 confirmed cases that were reached from the Our World in Data COVID-19 dataset [1]. It has included the daily cumulative COVID-19 positive infections since the date of 01 June 2020. A total of 614 measurements (time-series length) from 01 June 2020 to 04 February 2022 for 15-days forecasts, a total of 599 measurements from 01 June 2020 to 20 January 2022 for 30-days forecasts, a total of 569 measurements from 01 June 2020 to 21 December 2021 for 60-days forecasts, were used. Fifteen-day forecasts have been made for 05 February 2022 to 19 February 2022. Thirty-day forecasts have been made for 21 January 2022 to 19 February 2022. Sixty-day forecasts have been made for 22 December 2021 to 19 February 2022.

The growth pattern of COVID-19 outbreak attack period and Forecasting cumulative COVID-19 infections per day with Brown's exponential smoothing time-series model

Most the epidemics of infectious disease are characterized by an exponential growth at the beginning of the attack [11]. The cumulative number of cases increased exponentially during the early stages of the epidemic are observed [12]. During this period, the disease spreads rapidly. This period is divided into two parts in itself. The rate of increase of cases until turning point is always above the previous day. After the turning point, the number of cases continues to rise, but the rate of increase has slowed. The maturation phase of attack period is the period when the number of cases reaches saturation and draw a plateau [10-13].

The forecasting models and epidemic curves have established with used the cumulative number of COVID-19 cases diagnosed and reported daily by countries from1 June 2020 up to December 2022. Time-series analyses are widely used in various fields such as tourism, economy, and health. One of the time series methods that is used in forecasting is Brown's exponential smoothing method. This study describes the accuracy of Brown's exponential smoothing time series forecasting model in the COVID-19 pandemic next 15, 30 and 60 days. The formulation of exponential smoothing forecasting methods was described in the 1950s by Brown and Holt [14-16].

The basic idea of smoothing models is to construct forecasts of future observations as weighted averages of past observations. In this method, the more recent observations are carrying increased weight in determining forecasts than observations in the distant past. In general, the Brown's linear exponential smoothing approach to forecasting makes use of an exponentially weighted average of past observations to make forecasting, with the weights declining over time [17]. The exponential growth is that the outbreak growth rate, the number of confirmed cases in each generation increases as the population gets larger Brown's linear exponential smoothing method was performed to estimate the cumulative number of diagnosed COVID-19 infections and 95% prediction intervals per day for 15, 30 and 60-days

Statistical analysis

Statistical analysis was performed by IBM SPSS Statistics for Windows, Version 25.0. Throughout the calculations, model screate some error parameters to keeptrack of the variation in the models. The models were chosen by optimizing the parameters and measures of accuracy, including the meanabsolute percentage error (MAPE). The models can be used since the MAPE values are less than 50% (<10%: highly accurate forecast, 11% to 20%: good forecast, 21%-50%:reasonable forecast) [17].

Results

Turkey

The total reported cases are nearly 14 million (2, 18). To 19 February 2022, there are 13.434.130 reported cases from Turkey(1) (Table 1). To date, Turkey has followed the same epidemic curve as Brazil, Germany and the UK (Figure 1). For 60-day forecasts, 10,322,701 (95% CI: 4,982,139 - 15,663,263) total cases were estimated in Turkey until February 19. For 30-day forecasts, 12,809,392 (95% CI: 10,820,458 - 14,798,326) total cases were estimated in Turkey until February 19. For 15-day forecasts, 13,635,838 (95% CI: 12,857,209 - 14,414,467) total cases were estimated in Turkey until February 19 (Table 1, Figure 1).

Brazil

As of February 19, 2022, there have been 28,177,367 confirmed COVID-19 cases in Brazil (1). For 60-day forecasts, 22,434,809 (95% CI: 15,165,676 - 29,703,942) total cases were estimated in Brazil until February 19. For 30-day forecasts, 28,752,324 (95% CI: 25,807,035 - 31,697,613) total cases were estimated in Brazil until February 19. For 15-day forecasts, 29,678,270 (95% CI: 28,449,180 - 30,907,359) total cases were estimated in Brazil until February 19 (Table 2, Figure 1).

Germany

As of February 19, 2022, there have been 13,605,445 confirmed COVID-19 cases in Germany (1). For 60-day forecasts, 9,552,781 (95% CI: 6,817,655 - 12,287,907) total cases were estimated in

Table 1. Forecasts for Turkey by using Brown's linear exponential smoothing method

Turkey			Model for 60-days (Fist Day: 01 June 2020; Time series length=569)			Model for 30-days (Fist Day: 01 June 2020; Time series length=599)			Model for 15-days (Fist Day: 01 June 2020; Time series length=614)			Real reported number of total cases*
No	Forecast days		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		
				Lower	Upper		Lower	Upper		Lower	Upper	
1#	570.	22.12.21	9227855	9156316	9299394							*9228835*
31	600.	21.01.22	9784556	7693015	11876097	10803877	10733990	10873763				*10808770*
32	601.	22.01.22	9803113	7616954	11989271	10873033	10772461	10973604				*10881626*
33	602.	23.01.22	9821669	7539507	12103832	10942188	10806537	11077840				*10947129*
34	603.	24.01.22	9840226	7460694	12219758	11011344	10836860	11185828				*11014152*
35	604.	25.01.22	9858783	7380535	12337031	11080500	10863832	11297167				*11090493*
36	605.	26.01.22	9877340	7299046	12455633	11149655	10887735	11411575				*11167927*
37	606.	27.01.22	9895896	7216247	12575546	11218811	10908785	11528837				*11250107*
38	607.	28.01.22	9914453	7132152	12696754	11287967	10927152	11648782				*11343693*
39	608.	29.01.22	9933010	7046780	12819240	11357122	10942977	11771267				*11438476*
40	609.	30.01.22	9951566	6960144	12942989	11426278	10956382	11896174				*11526621*
41	610.	31.01.22	9970123	6872261	13067985	11495434	10967469	12023398				*11619882*
42	611.	01.02.22	9988680	6783144	13194216	11564589	10976331	12152848				*11722483*
43	612.	02.02.22	10007237	6692808	13321665	11633745	10983047	12284443				*11833165*
44	613.	03.02.22	10025793	6601266	13450321	11702901	10987690	12418111				*11940695*
45	614.	04.02.22	10044350	6508531	13580170	11772057	10990326	12553787				*12051852*
46	615.	05.02.22	10062907	6414615	13711198	11841212	10991014	12691411	12154971	12085854	12224089	*12150567*
47	616.	06.02.22	10081463	6319532	13843395	11910368	10989808	12830928	12260747	12161063	12360432	*12238501*
48	617.	07.02.22	10100020	6223293	13976747	11979524	10986758	12972289	12366524	12231890	12501157	*12335015*
49	618.	08.02.22	10118577	6125909	14111245	12048679	10981911	13115447	12472300	12298975	12645625	*12446111*
50	619.	09.02.22	10137134	6027392	14246875	12117835	10975310	13260361	12578076	12362717	12793435	*12554674*
51	620.	10.02.22	10155690	5927753	14383628	12186991	10966993	13406988	12683852	12423397	12944307	*12653276*
52	621.	11.02.22	10174247	5827001	14521493	12256146	10956999	13555294	12789628	12481229	13098028	*12748341*
53	622.	12.02.22	10192804	5725148	14660459	12325302	10945363	13705241	12895405	12536384	13254426	*12834534*
54	623.	13.02.22	10211360	5622204	14800517	12394458	10932117	13856799	13001181	12589003	13413359	*12908321*
55	624.	14.02.22	10229917	5518177	14941657	12463614	10917292	14009935	13106957	12639205	13574709	*12984953*
56	625.	15.02.22	10248474	5413078	15083870	12532769	10900918	14164620	13212733	12687096	13738371	*13079683*
57	626.	16.02.22	10267031	5306916	15227145	12601925	10883022	14320828	13318509	12732765	13904254	*13173859*
58	627.	17.02.22	10285587	5199699	15371475	12671081	10863630	14478531	13424286	12776293	14072279	*13266265*
59	628.	18.02.22	10304144	5091438	15516850	12740236	10842768	14637705	13530062	12817752	14242371	*13353676*
60	629.	19.02.22	**10322701**	**4982139**	**15663263**	**12809392**	**10820458**	**14798326**	**13635838**	**12857209**	**14414467**	*13434130*
Goodness of fit criteria			R-squared=1, RMSE=36422, MAPE=0.24			R-squared=1, RMSE=35584, MAPE=0.23			R-squared=1, RMSE=35194, MAPE=0.23			

** Our World in Data COVID-19 dataset; The actual total case numbers are in italics. # Forecasts between 2 and 30 are not shown to fit the table on the page. Accurate predictions at 95% CI are in **bold**.*

Germany until February 19. For 30-day forecasts, 12,655,999 (95% CI: 11,086,846 -14,225,151) total cases were estimated in Germany until February 19. For 15-day forecasts, 14,241,248 (95% CI: 13,436,096 - 15,046,400) total cases were estimated in Germnay until February 19 (Table 3, Figure 1).

The United Kingdom

As of February 19, 2022, there have been 18,628,487 confirmed COVID-19 cases in the UK (1). For 60-day forecasts, 16,937,127 (95% CI: 15,341,510 - 18,532,744) total cases were estimated in the UK until February 19. For 30-day forecasts, 18,857,395 (95% CI: 17,735,483 - 19,979,308) total cases were estimated in the UK until February 19. For 15-day forecasts, 20,006,207 (95% CI: 19,294,358 - 20,718,056) total cases were estimated in the UK until February 19 (Table 4, Figure 1).

The United Arab Emirates

As of February 19, 2022, there have been 873,882 confirmed COVID-19 cases in the UAE (1). For 60-day forecasts, 767,819 (95% CI: 708,962 - 826,675) total cases were estimated in the UAE until February 19. For 30-day forecasts, 905,537 (95% CI: 881,211 - 929,863) total cases were estimated in the UAE until February 19. For 15-day forecasts, 885,958 (95% CI: 876,767 - 895,148) total cases were estimated in the UAE until February 19 (Table 5, Figure 1). The epidemic curve of the UAE was in the maturation phase of exponential growth last five months and draw a plateau (Figure 1). However, with the increase in the total number of cases in the last 2 months, it has been observed that the plateau has broken (Figure 1). It was found that forecasts failed to predict this rapid change.

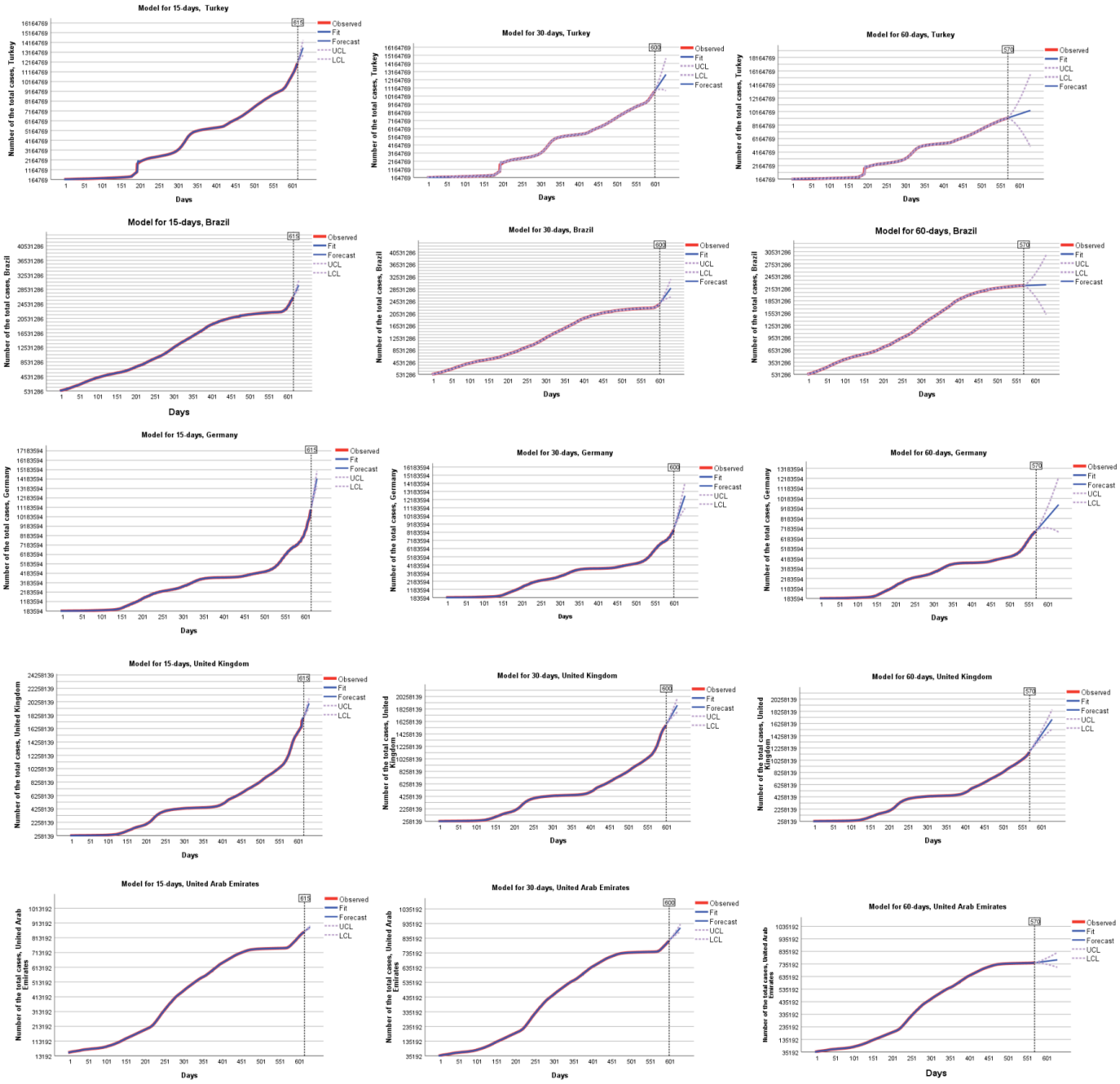

Figure 1. Forecasts cases with the Brown's linear exponential smoothing method

Table 2. Forecasts for Brazil by using Brown's linear exponential smoothing method

Brazil			Model for 60-days (Fist Day: 01 June 2020; Time series length=569)			Model for 30-days (Fist Day: 01 June 2020; Time series length=599)			Model for 15-days (Fist Day: 01 June 2020; Time series length=614)			Real reported number of total cases*
No	Forecast days		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		
				Lower	Upper		Lower	Upper		Lower	Upper	
1 #	570.	22.12.21	22227447	22195090	22259803							*22227169*
31	600.	21.01.22	22332885	19589434	25076336	23767133	23733659	23800606				*23766499*
32	601.	22.01.22	22336400	19462113	25210686	23939036	23867240	24010832				*23931609*
33	602.	23.01.22	22339914	19332776	25347053	24110939	23992939	24228939				*24054405*
34	603.	24.01.22	22343429	19201453	25485404	24282842	24111833	24453851				*24142032*
35	604.	25.01.22	22346943	19068174	25625712	24454745	24224679	24684812				*24342322*
36	605.	26.01.22	22350458	18932966	25767950	24626648	24332032	24921265				*24560093*
37	606.	27.01.22	22353973	18795856	25912090	24798551	24434320	25162783				*24789795*
38	607.	28.01.22	22357487	18656868	26058106	24970455	24531885	25409025				*25050601*
39	608.	29.01.22	22361002	18516027	26205976	25142358	24625008	25659708				*25256198*
40	609.	30.01.22	22364516	18373358	26355675	25314261	24713925	25914597				*25360647*
41	610.	31.01.22	22368031	18228881	26507181	25486164	24798840	26173488				*25463530*
42	611.	01.02.22	22371546	18082620	26660472	25658067	24879927	26436207				*25634781*
43	612.	02.02.22	22375060	17934595	26815526	25829970	24957342	26702598				*25820745*
44	613.	03.02.22	22378575	17784826	26972324	26001874	25031222	26972525				*26107894*
45	614.	04.02.22	22382089	17633333	27130846	26173777	25101690	27245864				*26326454*
46	615.	05.02.22	22385604	17480135	27291073	26345680	25168856	27522504	26549998	26512436	26587560	*26484546*
47	616.	06.02.22	22389119	17325251	27452987	26517583	25232821	27802345	26773446	26692125	26854768	*26546399*
48	617.	07.02.22	22392633	17168697	27616569	26689486	25293678	28085294	26996894	26862696	27131092	*26616014*
49	618.	08.02.22	22396148	17010492	27781804	26861389	25351512	28371267	27220342	27025415	27415269	*26793497*
50	619.	09.02.22	22399663	16850652	27948673	27033293	25406399	28660186	27443790	27181162	27706418	*26972914*
51	620.	10.02.22	22403177	16689194	28117161	27205196	25458413	28951978	27667238	27330582	28003894	*27135550*
52	621.	11.02.22	22406692	16526132	28287252	27377099	25507621	29246577	27890686	27474170	28307202	*27299336*
53	622.	12.02.22	22410206	16361482	28458931	27549002	25554085	29543918	28114134	27612320	28615947	*27434286*
54	623.	13.02.22	22413721	16195260	28632182	27720905	25597865	29843945	28337582	27745359	28929805	*27492904*
55	624.	14.02.22	22417236	16027479	28806993	27892808	25639015	30146602	28561030	27873558	29248502	*27552267*
56	625.	15.02.22	22420750	15858153	28983347	28064711	25677587	30451836	28784478	27997151	29571805	*27677468*
57	626.	16.02.22	22424265	15687297	29161233	28236615	25713630	30759599	29007926	28116341	29899510	*27819996*
58	627.	17.02.22	22427779	15514924	29340635	28408518	25747190	31069845	29231374	28231307	30231441	*27940119*
59	628.	18.02.22	22431294	15341046	29521543	28580421	25778312	31382530	29454822	28342206	30567438	*28072238*
60	629.	19.02.22	**22434809**	**15165676**	**29703942**	**28752324**	**25807035**	**31697613**	29678270	28449180	30907359	*28177367*
Goodness of fit criteria			R-squared=1, RMSE=16473, MAPE=0.18			R-squared=1, RMSE=17044, MAPE=0.17			R-squared=1, RMSE=19126, MAPE=0.17			

** Our World in Data COVID-19 dataset; The actual total case numbers are in italics. # Forecasts between 2 and 30 are not shown to fit the table on the page. Accurate predictions at 95% CI are in **bold**.*

Table 3. Forecasts for Germany by using Brown's linear exponential smoothing method

Germany			Model for 60-days (Fist Day: 01 June 2020; Time series length=569)			Model for 30-days (Fist Day: 01 June 2020; Time series length=599)			Model for 15-days (Fist Day: 01 June 2020; Time series length=614)			Real reported number of total cases*
No	Forecast days		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		
				Lower	Upper		Lower	Upper		Lower	Upper	
1#	570.	22.12.21	6940625	6922517	6958733							*6943750*
31	600.	21.01.22	8268840	7224961	9312719	8640337	8618248	8662427				*8635461*
32	601.	22.01.22	8313114	7220232	9405995	8778808	8735347	8822270				*8716804*
33	602.	23.01.22	8357387	7214759	9500015	8917279	8848518	8986041				*8773030*
34	603.	24.01.22	8401661	7208555	9594768	9055751	8958239	9153262				*8909503*
35	604.	25.01.22	8445935	7201628	9690242	9194222	9064867	9323577				*9088672*
36	605.	26.01.22	8490209	7193989	9786429	9332693	9168670	9496716				*9317280*
37	606.	27.01.22	8534483	7185648	9883318	9471164	9269858	9672469				*9477603*
38	607.	28.01.22	8578757	7176614	9980899	9609635	9368603	9850667				*9661657*
39	608.	29.01.22	8623030	7166895	10079165	9748106	9465044	10031168				*9774847*
40	609.	30.01.22	8667304	7156502	10178107	9886577	9559302	10213853				*9846032*
41	610.	31.01.22	8711578	7145440	10277716	10025048	9651477	10398619				*10025463*
42	611.	01.02.22	8755852	7133719	10377984	10163519	9741661	10585377				*10236740*
43	612.	02.02.22	8800126	7121347	10478905	10301990	9829931	10774049				*10474992*
44	613.	03.02.22	8844400	7108330	10580469	10440461	9916358	10964565				*10723644*
45	614.	04.02.22	8888673	7094676	10682671	10578933	10001005	11156860				*10938030*
46	615.	05.02.22	8932947	7080392	10785503	10717404	10083929	11350879	11158507	11131173	11185840	*11065146*
47	616.	06.02.22	8977221	7065484	10888958	10855875	10165180	11546569	11378702	11322157	11435248	*11147509*
48	617.	07.02.22	9021495	7049959	10993030	10994346	10244808	11743883	11598898	11507419	11690377	*11198886*
49	618.	08.02.22	9065769	7033824	11097714	11132817	10322856	11942778	11819094	11687698	11950490	*11579518*
50	619.	09.02.22	9110043	7017084	11203001	11271288	10399363	12143213	12039290	11863532	12215048	*11832331*
51	620.	10.02.22	9154316	6999745	11308888	11409759	10474367	12345151	12259486	12035318	12483654	*12068411*
52	621.	11.02.22	9198590	6981813	11415367	11548230	10547903	12548557	12479681	12203366	12755997	*12274653*
53	622.	12.02.22	9242864	6963294	11522434	11686701	10620003	12753399	12699877	12367925	13031830	*12391463*
54	623.	13.02.22	9287138	6944193	11630083	11825172	10690698	12959646	12920073	12529199	13310947	*12454304*
55	624.	14.02.22	9331412	6924516	11738308	11963643	10760017	13167270	13140269	12687363	13593175	*12628843*
56	625.	15.02.22	9375685	6904267	11847104	12102114	10827985	13376244	13360465	12842563	13878367	*12692053*
57	626.	16.02.22	9419959	6883451	11956467	12240586	10894629	13586542	13580661	12994929	14166392	*13093881*
58	627.	17.02.22	9464233	6862074	12066392	12379057	10959972	13798141	13800856	13144574	14457139	*13309040*
59	628.	18.02.22	9508507	6840141	12176873	12517528	11024037	14011018	14021052	13291600	14750505	*13491802*
60	629.	19.02.22	9552781	6817655	12287907	**12655999**	**11086846**	**14225151**	**14241248**	**13436096**	**15046400**	*13605445*
Goodness of fit criteria			R-squared=1, RMSE=9219, MAPE=0.24			R-squared=1, RMSE=11247, MAPE=0.24			R-squared=1, RMSE=13918, MAPE=0.25			

** Our World in Data COVID-19 dataset; The actual total case numbers are in italics. # Forecasts between 2 and 30 are not shown to fit the table on the page. Accurate predictions at 95% CI are in **bold**.*

Table 4. Forecasts for United Kingdom by using Brown's linear exponential smoothing method

United Kingdom			Model for 60-days (Fist Day: 01 June 2020; Time series length=569)			Model for 30-days (Fist Day: 01 June 2020; Time series length=599)			Model for 15-days (Fist Day: 01 June 2020; Time series length=614)			Real reported number of total cases*
No	Forecast days		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		
				Lower	Upper		Lower	Upper		Lower	Upper	
1#	570.	22.12.21	11654269	11647713	11660825							*11670349*
31	600.	21.01.22	14340468	13739476	14941460	15758107	15746569	15769645				*15747291*
32	601.	22.01.22	14430008	13800273	15059743	15864979	15839179	15890779				*15822720*
33	602.	23.01.22	14519548	13860626	15178470	15971851	15928680	16015022				*15897520*
34	603.	24.01.22	14609088	13920542	15297634	16078723	16015527	16141919				*15992837*
35	604.	25.01.22	14698628	13980027	15417229	16185595	16100027	16271163				*16087344*
36	605.	26.01.22	14788168	14039087	15537249	16292467	16182402	16402532				*16189420*
37	606.	27.01.22	14877708	14097728	15657688	16399339	16262820	16535858				*16286017*
38	607.	28.01.22	14967248	14155956	15778540	16506211	16341416	16671006				*16374927*
39	608.	29.01.22	15056788	14213775	15899800	16613083	16418300	16807866				*16447070*
40	609.	30.01.22	15146328	14271192	16021464	16719955	16493564	16946346				*16509469*
41	610.	31.01.22	15235868	14328210	16143525	16826827	16567287	17086367				*17357945*
42	611.	01.02.22	15325408	14384836	16265979	16933699	16639538	17227860				*17470812*
43	612.	02.02.22	15414948	14441073	16388822	17040571	16710376	17370766				*17558231*
44	613.	03.02.22	15504488	14496926	16512049	17147443	16779855	17515031				*17651284*
45	614.	04.02.22	15594027	14552400	16635655	17254315	16848022	17660608				*17733624*
46	615.	05.02.22	15683567	14607498	16759637	17361187	16914921	17807454	17920403	17852874	17987932	*17793738*
47	616.	06.02.22	15773107	14662225	16883990	17468059	16980590	17955529	18069389	17973962	18164816	*17847064*
48	617.	07.02.22	15862647	14716584	17008710	17574931	17045064	18104798	18218375	18091075	18345675	*17911386*
49	618.	08.02.22	15952187	14770580	17133795	17681803	17108378	18255228	18367361	18204807	18529915	*17978020*
50	619.	09.02.22	16041727	14824215	17259239	17788675	17170560	18406790	18516347	18315529	18717165	*18045697*
51	620.	10.02.22	16131267	14877495	17385040	17895547	17231639	18559455	18665333	18423497	18907169	*18208217*
52	621.	11.02.22	16220807	14930421	17511194	18002419	17291641	18713198	18814319	18528907	19099731	*18266881*
53	622.	12.02.22	16310347	14982998	17637697	18109291	17350589	18867993	18963305	18631912	19294698	*18312381*
54	623.	13.02.22	16399887	15035228	17764546	18216163	17408507	19023819	19112291	18732641	19491941	*18353596*
55	624.	14.02.22	16489427	15087115	17891739	18323035	17465416	19180654	19261277	18831201	19691354	*18394995*
56	625.	15.02.22	16578967	15138662	18019272	18429907	17521336	19338479	19410263	18927684	19892842	*18441179*
57	626.	16.02.22	16668507	15189872	18147142	18536779	17576285	19497274	19559249	19022173	20096325	*18495270*
58	627.	17.02.22	16758047	15240749	18275346	18643651	17630281	19657021	19708235	19114740	20301731	*18546995*
59	628.	18.02.22	16847587	15291293	18403881	18750523	17683342	19817705	19857221	19205448	20508994	*18594476*
60	629.	19.02.22	16937127	15341510	18532744	**18857395**	**17735483**	**19979308**	20006207	19294358	20718056	*18628487*
Goodness of fit criteria			R-squared=1, RMSE=3337, MAPE=0.09			R-squared=1, RMSE=5874, MAPE=0.09			R-squared=1, RMSE=34386, MAPE=0.13			

** Our World in Data COVID-19 dataset; The actual total case numbers are in italics. # Forecasts between 2 and 30 are not shown to fit the table on the page. Accurate predictions at 95% CI are in **bold**.*

Table 5. Forecasts for United Arab Emirates by using Brown's linear exponential smoothing method

United Arab Emirates			Model for 60-days (Fist Day: 01 June 2020; Time series length=569)			Model for 30-days (Fist Day: 01 June 2020; Time series length=599)			Model for 15-days (Fist Day: 01 June 2020; Time series length=614)			Real reported number of total cases*
No	Forecast Days		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		Forecasts	95% CI for Forecasts		
				Lower	Upper		Lower	Upper		Lower	Upper	
1#	570.	22.12.21	745258	744788	745727							*745555*
31	600.	21.01.22	756729	734131	779328	819888	819414	820363				*819866*
32	601.	22.01.22	757112	733461	780762	822842	822016	823667				*822886*
33	602.	23.01.22	757494	732776	782212	825795	824562	827028				*825699*
34	603.	24.01.22	757877	732075	783678	828749	827058	830439				*828328*
35	604.	25.01.22	758259	731359	785159	831702	829509	833895				*830832*
36	605.	26.01.22	758641	730628	786655	834655	831918	837393				*833201*
37	606.	27.01.22	759024	729881	788166	837609	834289	840929				*835839*
38	607.	28.01.22	759406	729120	789692	840562	836624	844501				*838384*
39	608.	29.01.22	759788	728345	791232	843516	838925	848107				*840739*
40	609.	30.01.22	760171	727554	792787	846469	841193	851745				*843030*
41	610.	31.01.22	760553	726750	794356	849422	843430	855415				*845058*
42	611.	01.02.22	760936	725932	795939	852376	845638	859114				*847142*
43	612.	02.02.22	761318	725100	797536	855329	847817	862841				*849305*
44	613.	03.02.22	761700	724254	799147	858283	849969	866596				*851537*
45	614.	04.02.22	762083	723394	800771	861236	852094	870378				*853651*
46	615.	05.02.22	762465	722521	802409	864189	854193	874186	855810	855338	856281	*855642*
47	616.	06.02.22	762848	721635	804060	867143	856267	878018	857963	857139	858788	*857657*
48	617.	07.02.22	763230	720735	805724	870096	858317	881875	860116	858882	861351	*859361*
49	618.	08.02.22	763612	719823	807402	873049	860343	885756	862270	860576	863964	*860976*
50	619.	09.02.22	763995	718898	809092	876003	862346	889660	864423	862224	866623	*862514*
51	620.	10.02.22	764377	717960	810795	878956	864327	893586	866577	863830	869323	*864102*
52	621.	11.02.22	764759	717009	812510	881910	866285	897534	868730	865398	872062	*865576*
53	622.	12.02.22	765142	716046	814238	884863	868222	901504	870884	866929	874838	*866971*
54	623.	13.02.22	765524	715070	815978	887816	870138	905495	873037	868426	877648	*868237*
55	624.	14.02.22	765907	714082	817731	890770	872033	909507	875190	869890	880491	*869428*
56	625.	15.02.22	766289	713082	819496	893723	873907	913539	877344	871323	883364	*870358*
57	626.	16.02.22	766671	712070	821273	896677	875762	917591	879497	872726	886268	*871315*
58	627.	17.02.22	767054	711046	823062	899630	877598	921662	881651	874101	889201	*872210*
59	628.	18.02.22	767436	710009	824863	902583	879413	925753	883804	875447	892161	*873092*
60	629.	19.02.22	767819	708962	826675	905537	881211	929863	885958	876767	895148	*873882*
Goodness of fit criteria			R-squared=1, RMSE=238, MAPE=0.06			R-squared=1, RMSE=241, MAPE=0.06			R-squared=1, RMSE=240, MAPE=0.06			

** Our World in Data COVID-19 dataset; The actual total case numbers are in italics. # Forecasts between 2 and 30 are not shown to fit the table on the page. Accurate predictions at 95% CI are in **bold**.*

Discussion

The aim of this study is to estimate the size of the COVID-19 pandemic for the 15, 30, and 60 days with the ideal forecasting analysis methods by using the daily reported cumulative cases of Germany, Brazil, UAE, UK and Turkey. When the literature was examined, similar studies were found that predicted the COVID-19 epidemic trends [17, 19-22].

This article purposed to make the most reliable predictions by modeling the trends of the outbreak in countries by using the proper forecasting methods. Of course, effective intervention to the outbreak which is made earlier can change these estimates. For example, China reduced the growth rate of outbreak under extreme measures about within 20 days [23]. One of the advantages of the short-term estimates for the outbreak is also to allow us to assess the impact of interventions, particularly those implemented. Also, the short-term forecasts of the outbreaks can help to lead the type and intensity of government interventions such as healthcare infrastructure needs for diagnosis, isolation of infectious individuals, and contact tracing activities.

The results showed that the exponential smoothing method (Brown's linear trend) is more proper for predictions in the exponential growth phases of the epidemic. The exponential growth can cause significant health and economic problems over the world in the absence of serious measures. There is no doubt that every government struggles to make effective interventions for minimizing the spread of disease. As a result, the spread rate of the outbreak has been tried to break by different interventions. This means that the possible bad scenario would not be sustained and that the outbreak would be controlled sooner or later.

The most critical question for pandemics is whether the outbreak growth will continue to rise exponentially and for how long. The most effective weapon in terms of herd immunity in the fight against pandemics is the vaccine. So, the need to vaccinate the entire population of countries against the SARS-CoV-2 virus is urgent and vaccination will likely be the most effective way to control the pandemic [24]. Among the five countries included in the study, The UAE was the only country that could reach the recommended immunization level in terms of herd immunity. Ninety-one percent of the UAE population has completed the initial COVID-19 vaccination protocol, 36.7% of whom received a booster dose. In the other four countries, Share of people who completed the initial COVID-19 vaccination protocol levels ranged from 60 to 70% (Figüre 2).

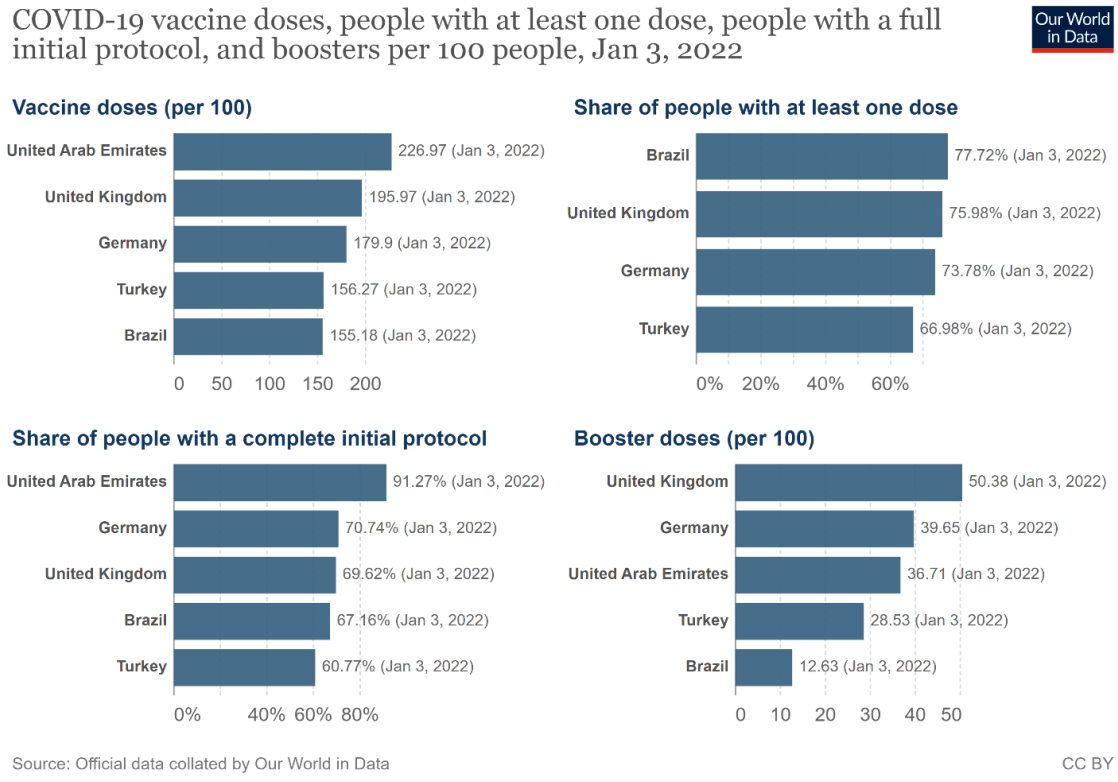

Figure 2. COVID-19 vaccine doses, people with at least one dose, people with a full initial protocol, and boosters per 100 people [6].

In this study, 60, 30 and 15-day cumulative case numbers were tried to be estimated by using the daily total case numbers of five countries as of 01 June 2020. When the 60-day estimates obtained by analyzing the 569-day total number of cases for 5 countries from 01 June 2020 to 22 December 2021 are analyzed, the estimates for only Turkey and Brazil have given an accurate result at the 95% confidence interval when compared with the actual number of cases. According to this forecast, it was estimated that 10,322,701 total cases (95% CI: 4,982,139 - 15,663,263) would be in Turkey and 22,434,809 total cases (95% CI: 15,165,676 - 29,703,942) would be in Brazil until 19 February 2022 for 60-day forecasts. However, it was seen that the forecasts were below the actual total number of cases due to the widening of the confidence interval as the estimated number of days increased. According to the data obtained from Our World in Data, for the date of 19 February 2022, Germany reached 13,605,445, UK 18,628,487, and UAE 873,882 cases [1]. However, in the 60-day forecasts, it was estimated that the total number of cases in the three countries would be 9,552,781, 16,937,127, and 767,819, respectively.

The real number of total cases reached after 60 days for these three countries was not within the confidence intervals of the forecasts. The 95% CI of the forecasts was considerably lower than the real reached number of cases. The important point of this study was to show that it was inconvenient to make a long process 60-day forecast for an event that is constantly intervened and tried to be controlled, such as a pandemic. Especially during the attack periods of the outbreak, there have been simultaneous serious interventions in the world and in our country. Especially since the beginning of 2022, vaccination rates have increased in many countries. Although the real number of cases for Turkey and Brazil was within the 95% confidence interval of the forecasts, the forecasts were found to be low like the other 3 countries. Therefore, no matter what method we use, it is quite difficult to accurately predict a 2-month period for a pandemic.

In The UAE, all three predictions were unsuccessful. It was noted that while the 60-day forecasts were below the real numbers, the 30 and 15-day forecasts were above the real case numbers. When the epidemic curve for UAE was examined, it was observed that the exponential growth was in the last stages and that more than 90% of the population was vaccinated which caused these estimates to differ from the actual number of cases. Therefore, The UAE is difficult to predict. Except for Germany, all 15-day forecasts were above the real number of cases. In this study, the most successful estimations, which had similar results to the real number of cases, were seen in the 30-day forecasts.

The spread of COVID-19 is strongly influenced by each country's national policy and healthcare access. Restriction and containment measures such as travel bans, border closing, trade controls, vaccination rate, and others were taken at different times in all countries have caused the consequences of epidemics to be not distributed equally, so the effects of the COVID-19 are currently quite uncertain. Different estimation methods can be used together to increase the reliability of the predictions by considering the good and bad scenarios.

Conclusion

In this study, it was predicted 15-day from 5 Feb 2022, 30-day from 21 Jan 2022, and 60-day forecasts from 22 Dec 2021 daily cumulative number of cases of COVID-19 outbreak by using Brown's linear exponential smoothing method. The aim was to estimate the short-term epidemic dynamics reliably and validly with the last data obtained. Although these short-term forecasts are not perfectly precise, they can make a serious contribution to managing the outbreak. Considering that the incubation period of the COVID-19 is 14 days on average, we can say that it is an ideal approach to make short-term predictions to see the effect of spreading-reducing interventions on the epidemic curve. The outbreaks cannot be left to their natural course, it is a condition that is intervened, making predictions longer than 1 month may mislead us. For the outbreak exponential growth period, making short-term forecasts such as 30-day or 15-day forecasts give a more accurate estimate instead of long-term forecasts such as 60 days. Finally, this study help that trend analysis will help to see if health resources such as healthcare staff and intensive care units are sufficient for the next few weeks.

Ethical Approval

Since all utilized data were publicly available, and no individual patient's data was collected, the ethical approval was not required.

Declaration of conflict of interest

The authors received no financial support for the research and/or authorship of this article. There is no conflict of interest

References

1. Our World in Data. Coronavirus Pandemic (COVID-19). https://ourworldindata.org/coronavirus#coronavirus-country-profiles. 2022. Access date: 15.03.2022.

2. COVID-19 Coronovirus Pandemic. https://www.worldometers.info/coronavirus/. 2022. Access date: 20.03.2022.
3. JHU-CSSE. Johns Hopkins. Coronavirus Resource Center. https://coronavirus.jhu.edu/map.html. 2022. Access date: 20.03.2022.
4. Guan W-j, Ni Z-y, Hu Y, et al. Clinical Characteristics of Coronavirus Disease 2019 in China N Engl J Med. 2020 Apr 30;382(18):1708-1720. (doi: 10.1056/NEJMoa2002032)
5. WHO. Draft landscape and tracker of COVID-19 candidate vaccines. 2022. https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines. Access date: 20.03.2022.
6. Our World in Data. Coronavirus (COVID-19) Vaccinations. https://ourworldindata.org/covid-vaccinations. 2022. Access date: 20.03.2022.
7. Montgomery DC, Johnson LA, Gardiner JS. Forecasting and time series analysis. 2 ed. New York: McGraw-Hill Companies; 1990.
8. Xiao H, Jiang X, Chen C, et al. Using time series analysis to forecast the health-related quality of life of post-menopausal women with non-metastatic ER+ breast cancer: A tutorial and case study. Res Social Adm Pharm 2019.
9. Yu G, Schwartz Z. Forecasting Short Time-Series Tourism Demand with Artificial Intelligence Models. Journal of Travel Research. 2006; 45: 194-203.
10. Viboud C, Simonsen L, Chowell G. A generalized-growth model to characterize the early ascending phase of infectious disease outbreaks. Epidemics 2016; 15: 27-37
11. Chowell G, Sattenspiel L, Bansal S, Viboud C. Mathematical models to characterize early epidemic growth: A review. Physics of life reviews 2016; 18: 66-97.
12. Chowell G, Viboud C, Hyman JM, Simonsen L. The Western Africa ebola virus disease epidemic exhibits both global exponential and local polynomial growth rates. PLoS currents. 2015; 7: 916803261.
13. Ayres R. Turning point: The end of exponential growth? Technological Forecasting and Social Change 2006; 73: 1188-203.
14. Brown, R.G. Statistical Forecasting for Inventory Control, McGraw-Hill: New York, NY. 1959.
15. Brown, R.G. Smoothing, Forecasting and Prediction of Discrete Time Series, Prentice-Hall: New Jersey. 1962.
16. Holt CC, Modigliani F, Muth JF, Simon HA, Bonini CP, Winters PR. Planning Production, Inventories, and Work Force, PrenticeHall: Englewood Cliffs, Chapter 14. 1960.
17. Yonar H, Yonar A, Tekindal MA, Tekindal M. Modeling and Forecasting for the number of cases of the COVID-19 pandemic with the Curve Estimation Models, the Box-Jenkins and Exponential Smoothing Methods. EJMO 2020; 4: 160-5.
18. .Johns Hopkins University Coronavirus Resource Center. Coronavirus COVID-19 Global Cases by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU). https://coronavirus.jhu.edu/map.html. 2022. Access date: 20.03.2022.
19. Abotaleb M, Makarovskikh T, Yonar H et al. Modeling Covid-19 Infection Cases and Vaccine in 5 Countries Highly Vaccinations. Turkish Journal of Mathematics and Computer Science 2020; 13: 403-17.
20. Li Q, Feng W, Quan Y-H. Trend and forecasting of the COVID-19 outbreak in China. Journal of Infection 2020; 80 :469-96.
21. Rajgor DD, Lee MH, Archuleta S, Bagdasarian N, Quek SC. The many estimates of the COVID-19 case fatality rate. Lancet Infect Dis. 202
22. Tekindal M, Yonar H, Yonar A et al. Analyzing COVID-19 outbreak for Turkey and Eight Country with Curve Estimation Models, Box-Jenkins (ARIMA), Brown Linear Exponential Smoothing Method, Autoregressive Distributed Lag (ARDL) and SEIR Models. Eurasian Journal of Veterinary Sciences. 2020; Covid-19 Special Issue: 142-55.
23. Remuzzi A, Remuzzi G. COVID-19 and Italy: what next? Lancet. 2020. (doi:10.1016/s0140-6736(20)30627-9).
24. Yapar D, Baran Aksakal N. COVID-19 döneminde aşılama. Çöl M, editör. Halk Sağlığı Bakışıyla COVID-19. 1. Baskı. Ankara: Türkiye Klinikleri; 2021. p.47-57.