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CASE STDY

Forecasting epidemic spread of SARS-CoV-2 using ARIMA model (Case study: Iran)

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ABSTRACT

Currently, the pandemic caused by a novel coronavirus, namely severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is one of the most serious issues worldwide. SARS-CoV-2 was first observed in Wuhan, China, on December 31, 2019; this disease has been rapidly spreading worldwide. Iran was the first Middle East country to report a coronavirus death, it has been severely affected. Therefore, it is crucial to forecast the pandemic spread in Iran. This study aims to develop a prediction model for the daily total confirmed cases, total confirmed new cases, total deaths, total new deaths, growth rate in confirmed cases, and growth rate in deaths. The model utilizes SARS-CoV-2 daily data, which are mainly collected from the official website of the European Centre for Disease Prevention and Control from February 20 to May 04, 2020 and other appropriated references. Autoregressive integrated moving average (ARIMA) is employed to forecast the trend of the pandemic spread. The ARIMA model predicts that Iran can easily exhibit an increase in the daily total confirmed cases and the total deaths, while the daily total confirmed new cases, total new deaths, and growth rate in confirmed cases/deaths becomes stable in the near future. This study predicts that Iran can control the SARS-CoV-2 disease in the near future. The ARIMA model can rapidly aid in forecasting patients and rendering a better preparedness plan in Iran.

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INTRODUCTION

In late December 2019, cases of patients with pneumonia of unknown etiology were reported in Wuhan city, China, with clinical symptoms considerably similar to those of common cold. Later, Chinese scientists found that pneumonia is caused by a novel coronavirus (Huang *et al.,* 2020). Clinical features of this disease include fever, cough, respiratory symptoms, as well as difficulty in breathing. However, in more severe cases, patients can suffer from severe acute respiratory syndrome (SARS), kidney failure, lung damage, and even death (Sohrabi *et al.,* 2020; Xu *et al.,* 2020). On February 11, 2020, the WHO named this disease as "coronavirus disease 2019", which is abbreviated "COVID-19". Then, the International Committee on Taxonomy of Viruses officially referred to it as "severe acute respiratory syndrome coronavirus 2" (SARS-CoV-2) (WHO, 2020a). The novel coronavirus has been identified by an official name, which can contribute to not only communication but also scientific studies. The family of coronaviruses (CoV) can cause diseases ranging from common cold to more severe illnesses, such as SARS and Middle East Respiratory Syndrome (MERS-CoV) (Shereen *et al.,* 2020). Previous studies have demonstrated that SARS-CoV and MERS-CoV infections spread from civet cats and dromedary camels to humans, respectively. CoV has been presenting in humans and several animals, namely cats, bats, camels, and cattle (Hassan *et al.,* 2020). Animal CoV hardly can be transmitted to humans and subsequently spread between humans such as in the case of MERS-CoV and SARS-CoV (WHO, 2020b). Although compared to MERS-CoV and SARS-CoV, SARS-CoV-2 is highly contagious, it exhibits a low mortality rate (Liu *et al.,* 2020). SARS-CoV-2 is rapidly spreading worldwide. According to the WHO COVID-19 situation report-104 released on May 03, 2020, more than 3.3 million people have been infected, and 238,268 have died from SARS-CoV-2 since its inception in January. SARS-CoV-2 cases have been confirmed in more than 200 countries and territories, with 3,349,786 confirmed cases (WHO, 2020c). Currently, SARS-CoV-2 is a serious problem worldwide, especially in the United States, the United Kingdom, Spain, and Italy. Iran was the first Middle East country to report a coronavirus death. On February 19, 2020, two patients tested positive for SARS-CoV-2 in Qom city. Then, the illness rapidly spread in all 31 provinces of Iran (Abdi, 2020). Up to May 04, 2020, the total confirmed cases amounted to 97,424, with 6,203 deaths (ECDC, 2020). By the time of this article submission (May 04, 2020), Iran ranked tenth with respect to the number of people affected by SARS CoV-2 (Worldometers, 2020). Hence, it is crucial to prepare healthcare services just in case there is no specific treatment for this disease, and it spreads considerably (Raoofi *et al.,* 2020). Undoubtedly, statistical forecasting models are useful for the control and prediction of this global pandemic (Chintalapudi *et al.,* 2020; Roosa *et al.,* 2020; Gao *et al.,* 2020). In the study, autoregressive integrated moving average (ARIMA) can aid in forecasting the trend of this pandemic spread. Typically, the ARIMA model, also known as the Box–Jenkins methodology (Box and Jenkins, 1976), is employed for forecasting and analysis (Sun and Koch, 2001; Adebiyi *et al.,* 2014; Alsharif *et al.,* 2019). This study aims to develop a prediction model for the daily total confirmed cases (TCC), total confirmed new cases (TCNC), total deaths (TD), total new deaths (TND), growth rate in confirmed cases (GRCC), and growth rate in deaths (GRD), which can undoubtedly aid the healthcare system in providing services for future patients. This study is conducted in 2020.

MATERIALS AND METHODS

Data source

The daily total confirmed cases/new cases, as well as total deaths/new deaths, of SARS-CoV-2 from February 20 (day 1) to May 04, 2020 (day 75) in Iran were collected from the official website of the European Centre for Disease Prevention and Control (ECDC, 2020). Then, data were utilized to build the ARIMA model. Next, the ARIMA model was applied to predict the trend of TCC, TCNC, TD, TND, GRCC, and GRD from May 05 (day 76) to May 24 (day 95).

Autoregressive Integrated Moving Average (ARIMA) models

ARIMA was first formed by Box and Jenkins, (1976). The general equation of successive differences at the d_{th} difference of X_t is briefly expressed as Eqs. 1, 2 and 3.

$$\Delta^d X_t = (1 - B)^d X_t, \quad (1)$$

Where, d is the different order, and B is the

backshift operator. The successive difference at one-time lag equals according to Eq. 2.

$$\Delta^1 X_t = (1 - B)X_t = X_t - X_{t-1} \quad (2)$$

In this situation, the general non-seasonal ARIMA (*p, d, q*) is as Eq. 3.

$$\Phi_p(B)W_t = \theta_q(B)e_t \quad (3)$$

Where, $\Phi_p(B)$ is an auto-regressive operator of order *p*, $\theta_q(B)$ is a moving average operator of order *q*, and $W_t = \Delta d X_t$

Model selection criteria

To select the appropriate parameter that can be applied to the ARIMA model, two model selection criteria were applied as; i) Akaike's information criterion (AIC) (Akaike, 1974) and ii) the Ljung–Box-Q statistic test (Ljung and Box, 1978). According to Akaike, (1974) and Mohammed *et al.* (2015), a good model exhibits the lowest AIC. As described by Akaike (1974), AIC is expressed as Eq. 4.

$$AIC=-2 * \ln(L)+2 * k \quad (4)$$

Where, L: the value of the likelihood and k; the number of estimated parameters.

The Ljung–Box statistic tests whether the residuals form a random sequence of numbers. If the statistic is significant, then the residuals are not completely random, and the selected model does not capture all of the structure in the data (Mohamad, 2012; Clement, 2014). The test statistic is defined as Eq. 5.

$$Q = T(T+2)\sum_{K=1}^{s}\frac{rk\,\hat{}\,2}{T-K}, \quad (5)$$

Where, T: number of observations, s: length of coefficients to test autocorrelation, r_k: Autocorrelation coefficient (for lag k). Microsoft Excel was utilized to build the database of daily SARS-CoV-2, and Statgraphics Centurion 18 software was used to build the ARIMA model.

RESULTS AND DISCUSSION

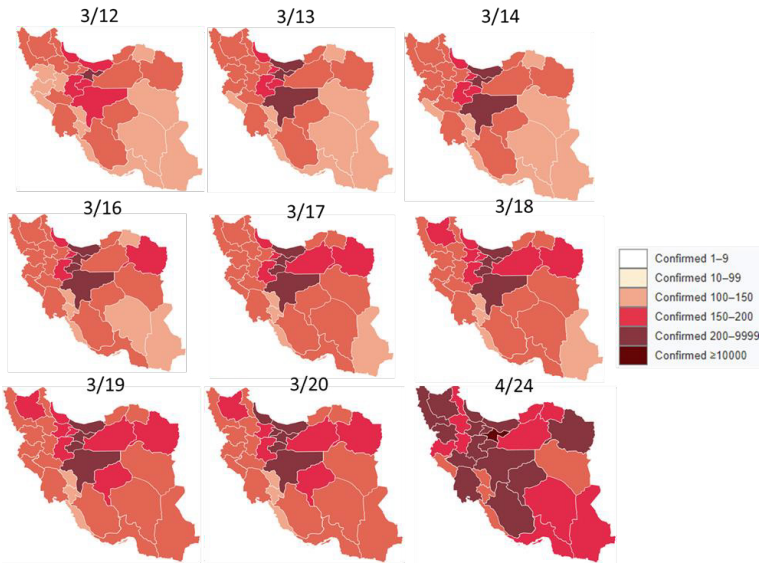
During the 2019–20 coronavirus pandemic, Iran reported its first confirmed cases of SARS-CoV-2 infections on 19 February 2020 in Qom. The virus may have been brought to the country by a merchant from Qom who had travelled to China. In response to the coronavirus the government cancelled public events and Friday prayers; closed schools, universities, shopping centers, bazaars, and holy shrines; and banned festival celebrations. Economic measures were also announced to help families and businesses (Fig. 1). In addition, the statics of deaths, recoveries and active cases due to the Covid-19 in Iran is shown in Fig. 2.

All criteria assessment confirmed the goodness-of-fit for the fitted ARIMA model (Table 1). As the p-value for the Ljung–Box test > 0.05, the hypothesis that the series is random at the 95.0% confidence level would not be rejected. Therefore, these selected models are probably adequate for the data.

Fig. 3 shows the trend observed for all variables from February 20 to May 24. Table 2 also shows the forecast for 20 days (from May 05 to May 24) with the 95% confidence interval for different variables. From Table 2, Iran could easily exhibit an upward trend for TCC and TD, while the other variables such as TCNC, TND, GRCC, and GRD, possibly became stable. Iran is hopeful to control this pandemic at the end of May 2020.

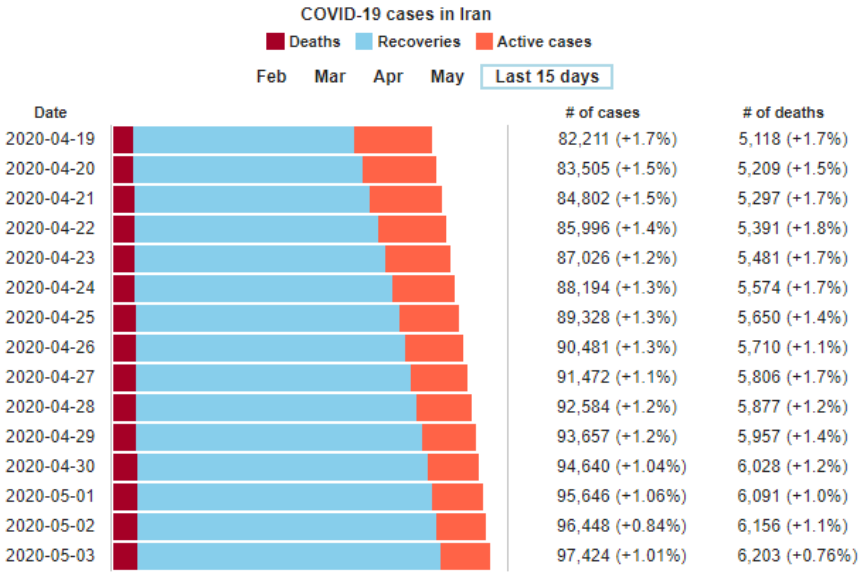
Moftakhar *et al.* (2020) has utilized ARIMA model and forecasted that an exponential increase in the TCNC. Moreover, the result reported by Moftakhar and Seif (2020) revealed an exponential increase in the TCC. In other words, this study demonstrated a stable in all variables (except for TCC and TD) (Table 3). The difference in the number of observations was mainly related to the considerable difference in these predictions. The ARIMA model not only requires few data inputs but also does not assume knowledge of any underlying model or relationships as in some other techniques (Meyler *et al.,* 1998). However, with a small sample size, forecast results are not reliable. In addition, the use of the ARIMA model for predicting time series relies on past values of the series as well as previous error terms; thus, the accuracy of past data inputs must be enhance.

The number of TCNC, TND, GRCC, and GRD might become stable in the near future. This result may be related to the good control and quarantine by the Iran government, including the closure of nonessential businesses as well as travel ban between cities. Although the spread of the virus is affected by several factors, which may govern the predictions, ARIMA is one of the most suitable



Disease	COVID-19
Virus strain	SARS-CoV-2
Location	Iran
First outbreak	Wuhan, Hubei, China (initial reports)
Index case	Qom
Arrival date	19 February 2020
Confirmed cases	97,424
Recovered	78,422
Deaths	6,203

Fig. 1: 2020 coronavirus pandemic in Iran (MHME, 2020)
Last Updated on the 24 April 2020



Date	# of cases	# of deaths
2020-04-19	82,211 (+1.7%)	5,118 (+1.7%)
2020-04-20	83,505 (+1.5%)	5,209 (+1.5%)
2020-04-21	84,802 (+1.5%)	5,297 (+1.7%)
2020-04-22	85,996 (+1.4%)	5,391 (+1.8%)
2020-04-23	87,026 (+1.2%)	5,481 (+1.7%)
2020-04-24	88,194 (+1.3%)	5,574 (+1.7%)
2020-04-25	89,328 (+1.3%)	5,650 (+1.4%)
2020-04-26	90,481 (+1.3%)	5,710 (+1.1%)
2020-04-27	91,472 (+1.1%)	5,806 (+1.7%)
2020-04-28	92,584 (+1.2%)	5,877 (+1.2%)
2020-04-29	93,657 (+1.2%)	5,957 (+1.4%)
2020-04-30	94,640 (+1.04%)	6,028 (+1.2%)
2020-05-01	95,646 (+1.06%)	6,091 (+1.0%)
2020-05-02	96,448 (+0.84%)	6,156 (+1.1%)
2020-05-03	97,424 (+1.01%)	6,203 (+0.76%)

Fig. 2: The statics of deaths, recoveries and active cases due to the Covid-19 in Iran (MHME, 2020)

Table 1: Results of the Ljung-Box test and AIC value of each ARIMA model

Selected ARIMA model	AIC	p-value	Selected ARIMA model	AIC	p-value
Total confirmed cases ARIMA (0,2,0)	10.8911	0.11	Total new deaths ARIMA (0,1,0)	4.6111	0.12
Total confirmed new cases ARIMA (0,1,0)	10.8637	0.11	Growth rate in confirmed cases ARIMA (2,1,1)	8.3736	0.42
Total deaths ARIMA (1,1,0)	4.6112	0.12	Growth rate in deaths ARIMA (1,0,0)	7.7829	0.48

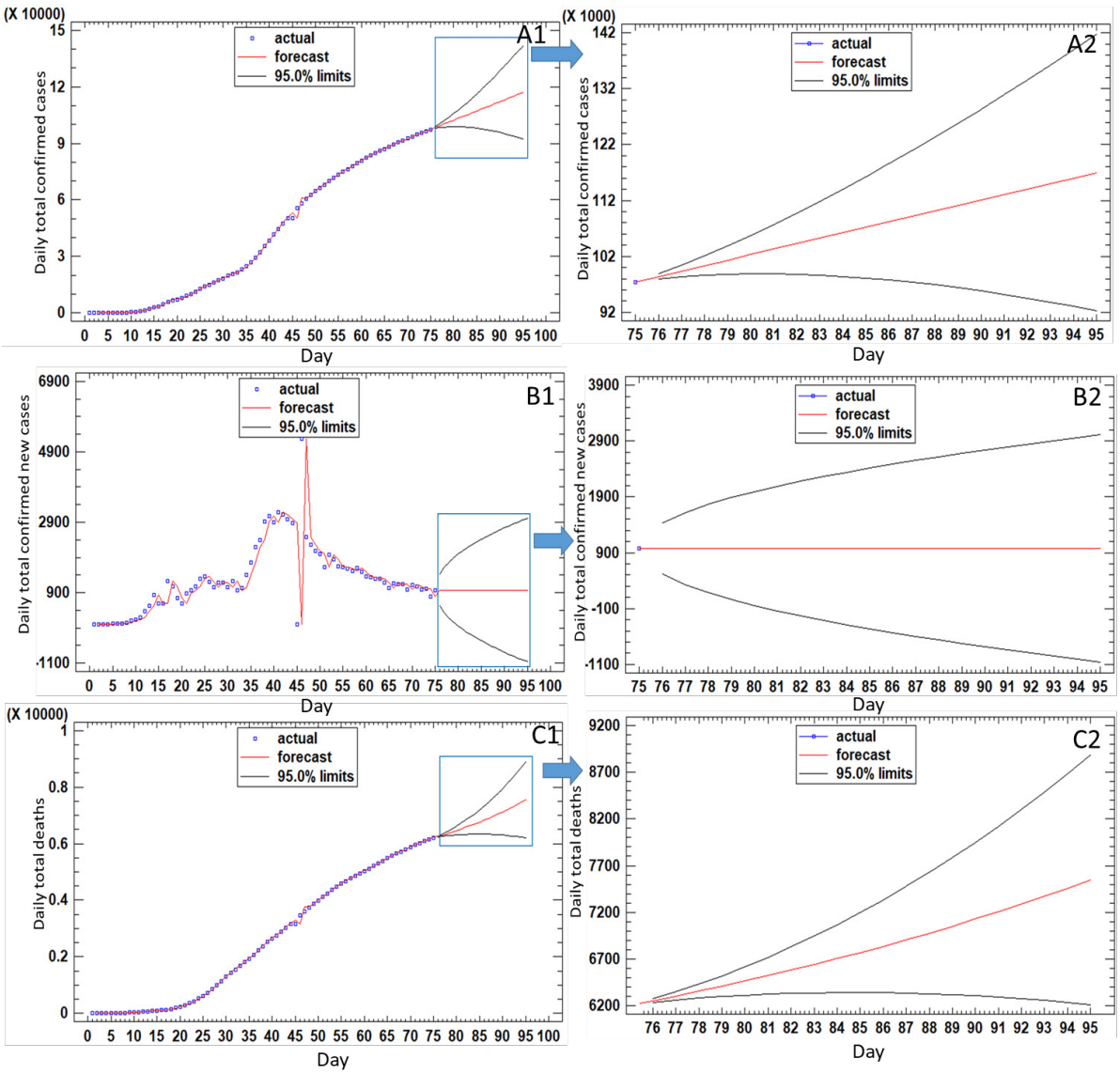


Fig. 3: Time sequence plot displays for confirmed cases (A1, A2), confirmed new cases (B1, B2), deaths (C1, C2), new deaths (D1, D2), growth rate in confirmed cases (E1, E2), growth rate in deaths (F1, F2) include the forecasts with 95% limits

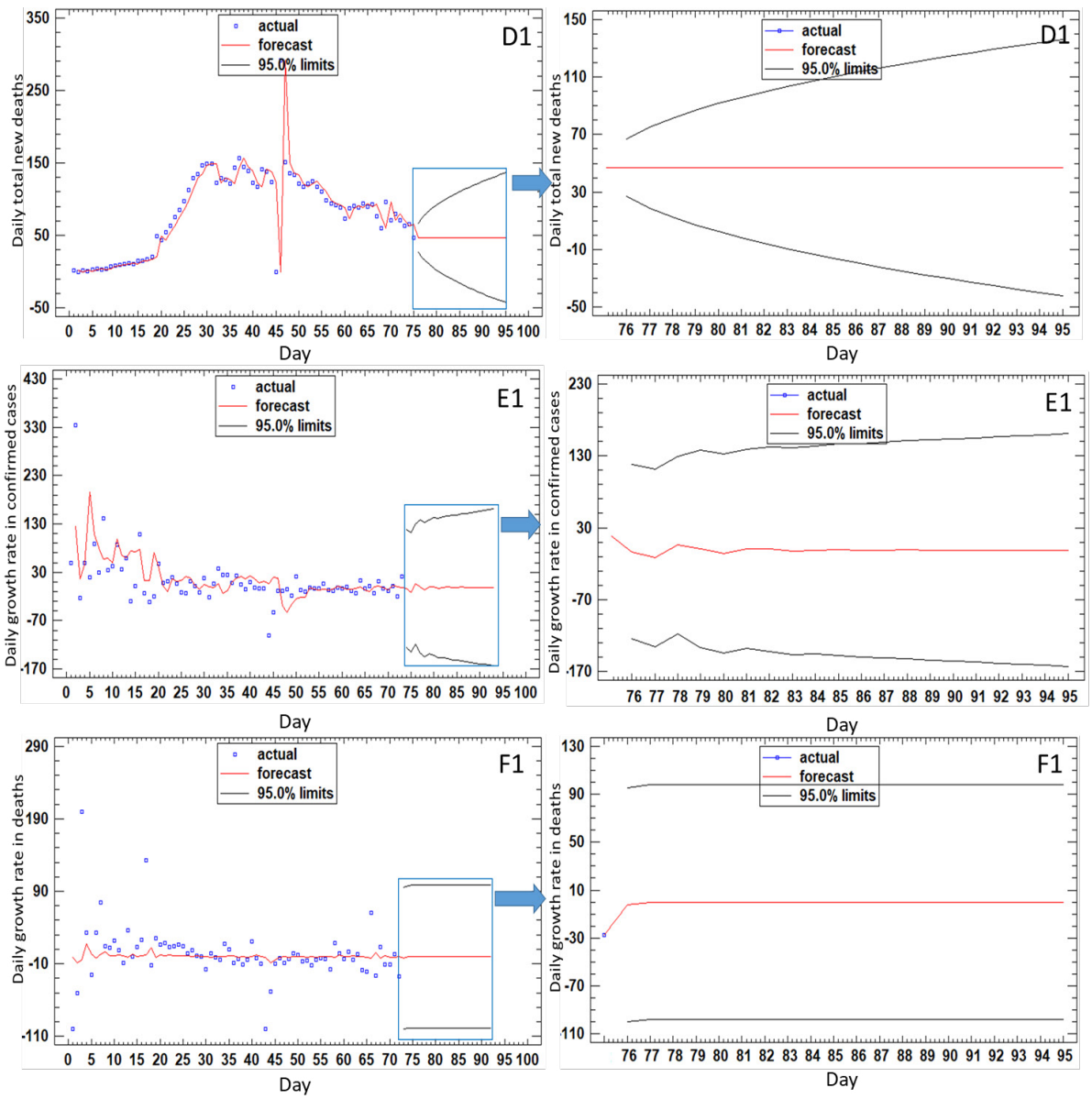


Fig. 3: Time sequence plot displays for confirmed cases (A1, A2), confirmed new cases (B1, B2), deaths (C1, C2), new deaths (D1, D2), growth rate in confirmed cases (E1, E2), growth rate in deaths (F1, F2) include the forecasts with 95% limits

models (Moftakhar and Seif, 2020). In fact, ARIMA models have been successfully utilized to estimate the incidence and prevalence of SARS-CoV-2. Chintalapudi *et al.* (2020) and Ceylan (2020) used the ARIMA to predict the epidemiological trend of COVID-SARS-CoV-2 in Italy, Spain, and France. Moftakhar *et al.* (2020) used the ARIMA and artificial neural networks (ANNs) to predict the daily total

Table 2: Forecasting of daily total confirmed cases, total confirmed new cases, total deaths, total new deaths, growth rate in confirmed cases and deaths in Iran for the next 20 days according to ARIMA models with 95% CI

Date	Total confirmed cases ARIMA (0,2,0)	Total confirmed new cases ARIMA (0,1,0)	Total deaths ARIMA (1,1,0)	Total new deaths ARIMA (0,1,0)	Growth rate in confirmed cases ARIMA (2,1,1)	Growth rate in deaths ARIMA (1,0,0)
5/5	98400 (97938-98862	976 (521-1431)	6252 (6232-6271)	47 (27-67)	-4 (-125-118)	-2 (-100-95)
5/6	99376 (98343-100409	976 (332-1620)	6302 (6258-6346)	47 (19-75)	-12 (-135-112)	0 (-98-98)
5/7	100352 (98624-102080	976 (187-1765)	6354 (6279-6428)	47 (12-82)	6 (-118-130)	0 (-98-98)
5/8	101328 (98799-103858	976 (65-1887)	6407 (6296-6518)	47 (7-87)	1 (-137-138)	0 (-98-98)
5/9	102304 (98879-105729	976 (-42-1994)	6462 (6310-6614)	47 (2-92)	-6 (-144-133)	0 (-98-98)
5/10	103280 (98875-107686	976 (-140-2092)	6519 (6321-6717)	47 (-2-96)	0 (-138-139)	0 (-98-98)
5/11	104256 (98792-109720	976 (-229-2181)	6578 (6330-6827)	47 (-6-100)	0 (-142-143)	0 (-98-98)
5/12	105232 (98636-111828	976 (-312-2264)	6639 (6335-6943)	47 (-10-104)	-3 (-147-142)	0 (-98-98)
5/13	106208 (98412-114004	976 (-390-2342)	6702 (6338-7066)	47 (-13-107)	-1 (-146-144)	0 (-98-98)
5/14	107184 (98122-116246	976 (-464-2416)	6767 (6339-7196)	47 (-16-110)	0 (-148-147)	0 (-98-98)
5/15	108160 (97772-118548	976 (-535-2487)	6834 (6337-7332)	47 (-19-113)	-2 (-151-147)	0 (-98-98)
5/16	109136 (97362-120910	976 (-602-2554)	6904 (6332-7476)	47 (-22-116)	-1 (-152-149)	0 (-98-98)
5/17	110112 (96896-123329	976 (-666-2618)	6976 (6325-7626)	47 (-25-119)	-1 (-153-151)	0 (-98-98)
5/18	111088 (96375-125801	976 (-728-2680)	7050 (6316-7783)	47 (-28-122)	-1 (-155-152)	0 (-98-98)
5/19	112064 (95802-128326	976 (-788-2740)	7126 (6304-7948)	47 (-30-124)	-1 (-156-154)	0 (-98-98)
5/20	113040 (95178-130902	976 (-846-2798)	7205 (6290-8120)	47 (-33-127)	-1 (-157-155)	0 (-98-98)
5/21	114016 (94504-133528	976 (-902-2854)	7287 (6274-8299)	47 (-35-129)	-1 (-159-157)	0 (-98-98)
5/22	114992 (93783-136201	976 (-956-2908)	7371 (6255-8487)	47 (-38-132)	-1 (-161-158)	0 (-98-98)
5/23	115968 (93016-138920	976 (-1009-2961)	7458 (6234-8682)	47 (-40-134)	-1 (-162-160)	0 (-98-98)
5/24	116944 (92203-141685	976 (-1061-3013	7548 (6210-8886)	47 (-42-136)	-1 (-163-161)	0 (-98-98)

Table 3: Application of the ARIMA model studies to forecast the spread of SARS-CoV-2 in Iran

Parameter	Moftakhar *et al.* (2020)	Moftakhar and Seif (2020)	The present study
Database	41 days (February 19-March 30)	32 days (February 19-March 21)	75 days (February 20-May 04)
Forecasting	30 days (March 31-April 29)	30 days (March 22-April 20)	20 days (May 05-May 24)
Variables and model's parameter	TCNC (ARIMA (0,1,0))	TCC (ARIMA (0,1,0))	TCC (ARIMA (0,2,0)), TCNC (ARIMA (0,1,0)), TD (ARIMA (1,1,0)), TND (ARIMA (0,1,0)), GRCC (ARIMA (2,1,1)), and GRD (ARIMA (1,0,0))
Predictive trend	An exponential increase	An exponential increase	An increase in TCC and TD. TCNC, TND, GRCC, and GRD will become stable

confirmed new cases. The empirical results showed that ARIMA prediction was more accurate than ANNs. Several traditional methods for time-series analysis, namely ARIMA, assume that the series is generated from linear processes; hence, their result can be unreliable because of a majority of nonlinear real-world issues (Zhang *et al.,* 1998; Khashei *et al.,* 2009). However, ARIMA is typically used for analysis and prediction (Adebiyi *et al.,* 2014), and it is considered as the most efficient prediction technique in social science, with extensive use for time-series analysis (Patle *et al.,* 2015).

CONCLUSION

Coronavirus, which causes severe acute respiratory syndrome, is rapidly spreading worldwide. The severity of this pandemic is increasing in Iran. This is one of the pioneering studies focusing on the forecasting of the pandemic spread of SARS-CoV-2 in Iran. Forecasting results can be summarized as i) Based on Akaike's Information Criterion and the Ljung–Box-Q statistic test, the ARIMA models are probably adequate for data of the TCC (ARIMA (0,2,0), TCNC (ARIMA (0,1,0), TD (ARIMA (1,1,0), TND (ARIMA (0,1,0), GRCC (ARIMA (2,1,1), and GRD (ARIMA (1,0,0); ii) Iran may be successful in haltering the SARS-CoV-2 pandemic because the ARIMA model forecasts a stable in all variables in the near future. This result may be related to the strict control and quarantine by the Iran government. This study predicts that Iran can control this pandemic in the near future (at the end of May 2020); iii) Although Iran made some achievements toward the prevention of SARS-CoV-2, health officials need to make decisions to prevent its spread and decrease the number of new deaths in the future. Based on the study's predictions, public health politicians should pay more focus on the TD, TND; in addition, rapid infection control in health-care settings is mandatory for achieving success in containing SARS-CoV-2; iv) Although ARIMA exhibits few limitations, the prediction by this model might be useful for future strategies of health decisions. The study suggested that the ARIMA model is an easy-to-use modeling tool for the rapid forecasting of the spread of SARS-CoV-2.

AUTHOR CONTRIBUTIONS

T.T. Tran collected and statistical analysis the data, prepared the manuscript text. L.T. Pham and Q.X. Ngo have analyzed and interpreted the data, prepared the manuscript text, and manuscript edition. The final version of the manuscript was approved by all authors.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

AIC	Akaike's Information Criterion
ANNs	Artificial neural networks
ARIMA	Auto Regressive Integrated Moving Average
CI	Confidence Interval
CoV	Coronaviruses
COVID-19	Coronavirus disease 2019
ECDC	European Centre for Disease Prevention and Control
Eq	Equation
GRCC	Daily growth rate in confirmed cases
GRD	Daily growth rate in deaths
MERS-CoV	Middle East Respiratory Syndrome
SARS-CoV	Severe Acute Respiratory Syndrome
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
TCC	Daily total confirmed cases
TCNC	Daily total confirmed new cases
TD	Daily total deaths

TND	Daily total new deaths
WHO	World Health Organization

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