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SARIMA model-based forecasting required number of COVID-19 vaccines globally and empirical analysis of peoples’ view towards the vaccines

Amer Malki, El-Sayed Atlama, Aboul Ella Hassanien, Ashraf Ewis, Guesh Dagnew, Ibrahim Gad

Department of Computer Science, Tanta University, Tanta, Egypt
Faculty of Computers and Artificial Intelligence, Cairo University, Cairo, Egypt
Department of Public Health and Occupational Medicine, Faculty of Medicine, Minia University, El-Minia, Egypt
Department of Public Health, Faculty of Health Sciences – AlQunfudah, Umm AlQura University, Mecca, Saudi Arabia
College of Computer Science and Engineering, Taibah University, Yanbu, Saudi Arabia
Department of Computer Science, Institute of Technology, Dire Dawa University, Ethiopia

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Abstract Recent studies regarding COVID-19 show a growing tendency to talk about the COVID-19 Pandemic on online channels. With the recent release of the Pfizer vaccine of COVID-19, people keep posting many rumors regarding the safety concerns of the Vaccine, especially among older people. Due to the rapid spread of the COVID-19 virus and the worldwide Pandemic developed, the rush to develop the COVID-19 Vaccine has become an alarming priority in health care services worldwide. In this research work, we have systematically evaluated people’s views towards the COVID-19 Vaccine, and shreds of evidence are supported empirically. The study mainly focuses on the empirical evidence and intensive discussions on what is currently known about the mechanism of action, efficacy, and toxicity of the most promising vaccines (Moderna), (Pfizer/BioNtech), (Astrazenac/Oxford), and (Sputnik V) against COVID-19. Our study’s primary objective is to provide an analysis of the questionnaire regarding people’s opinions, preferences, and acceptance of the COVID-19 vaccines. We have created an online questionnaire using a google form to collect data from various countries supposed to employ COVID-19 vaccines. The questionnaires were distributed to people in many Arab and foreign countries such as Egypt, Saudi Arabia, India, England, China, and Japan. A total of 516 responses were returned and analyzed using statistical, and Seasonal Autoregressive Integrated Moving Average (SARIMA) approaches. The SARIMA model is used to predict the total number of vaccines in the next few days. To attain the most accurate
1. Introduction

In 2020, COVID-19 was announced as a global Pandemic by the World Health Organization (WHO) [1,2]. Domain experts confirm that it is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), leading to a global Pandemic that can affect individuals’ health and imposed a significant burden on the World’s health systems, economy, and social impacts. On March 11, 2020, the World Health Organization (WHO) declared COVID19 as a worldwide Pandemic. By the end of May 2020, COVID-19 spread over 215 countries and/or territories to infect around 5 million people had been infected with death for more than 300,000 worldwide [3].

Globally according to WHO, on March 4, 2021, there have been about 115,899,053 confirmed cases of COVID-19, with 2,573,907 death cases [1,4].

To date, the Ministry of Health (MOH) of the Kingdom of Saudi Arabia (KSA) reported that there are 368,708 confirmed cases of COVID-19, including 6,514 deaths [5]. The KSA implemented preventive measures in all public facilities, mosques, universities, malls, markets, and workplaces, which began with social distancing, putting on masks, and imposing financial fines on violators of the preventive measures [6,7].

COVID-19 is still spreading very quickly across nations and among humans leading to morbidities and mortalities, especially among the high-risk groups, such as the elderly and those with compromised and comorbidities medical conditions (e.g., heart, lung, immunity diseases, diabetes mellitus, etc.). However, the COVID-19 related infections, serious complications, deaths, and a wide range of consequences can be prevented by finding specific treatments and/or developing effective vaccines [8–10].

Since the beginning of the COVID-19 Pandemic, all the WHO partners are working together to respond to the Pandemic, track it, provide facilities and protocols for critical interventions, and distribute vital medical supplies to those who need them [6,7,11]. Additionally, they raced to develop and deploy safe and effective vaccines and specific remedies. Vaccines are prepared medical treatments that are administered to high-risk individuals to protect them against infections. The vaccines the body’s natural defense mechanisms in the immune system to realize, attack, and contain or destroy the viruses and bacteria they target. Therefore, the targeted illness becomes preventable if the body is exposed to its microorganisms later [12,13].

Recently, several vaccines have been announced that they are expected to contribute to reducing the numbers of infected people, creating community immunity against the COVID-19, which leads to alleviating pressure on the health systems. Among these most promising vaccines are the novel mRNA vaccines BNT162b2 (Pfizer/BioNtech), mRNA-1273 (Moderna), and the DNA vaccines ChAdOx1nCoV-19 (AstraZeneca/Oxford) and rAd26/rAd5 (SputnikV) vaccines, while other vaccines are on the way [14–16].

The KSA is one of the countries that provided the Vaccine to citizens, and on December 17, 2020, the MOH reported providing the first COVID-19 vaccination to an old-aged Saudi woman. Four hundred forty thousand six hundred eighteen vaccinated doses were provided, and over 1 million people have registered to receive the COVID-19 Vaccine [17].

However, after several COVID-19 vaccines have become available, there are various degrees of acceptance among the populations of different countries to take these newly-developed COVID-19 vaccines. A systemic review study in Jordan found different vaccine acceptance rates among countries with high acceptance in Ecuador (97%), Malaysia (94.3%), Indonesia (93.3%), and China (91.3%). In contrary, other countries showed lower acceptance rates e.g., Kuwait (23.6%), Jordan (28.4%), Italy (53.7%), Russia (54.9%), Poland (56.3%), United States (56.9%), and France (58.9%) [17,12].

A recent study in the United Kingdom showed that about (71.7%) are willing to be vaccinated, (16.6%) was very unsure while 11.7% were strongly hesitant to receive the vaccine [18]. Similarly, a survey study was conducted in KSA before any COVID-19 vaccine is available and showed that (64.7%) of the participants were willing to take the COVID-19 vaccine, and (28.2%) were “not sure” while about (7%) are refusing to be vaccinated [19].

According to the Food and Drug Administration, those COVID-19 vaccines provide strong protection against COVID-19 approximately in about 10 days of the first dose [12,16,20]. Moreover, most people are planning to get vaccinated with COVID-19 vaccines. But some may want more information about COVID-19 vaccines, including the process for developing and authorizing these vaccines and information about their safety and effectiveness. People may have previous experiences that affect their trust and confidence in the health system. By taking time to listen to their concerns and answer their questions, we can help people become confident in their decision to be vaccinated. Moreover, when you decide to get vaccinated and share the reasons why you did, you can have a powerful influence on your family and community. Strong confidence in the vaccines within communities leads to more people getting vaccinated, which leads to fewer COVID-19 illnesses, hospitalizations, and deaths [21,22].

The current COVID-19 pandemic has affected all aspects of life and its global effects are beyond accounting. Therefore, the COVID-19 related data are huge and accumulating giving the opportunity to all researchers in different fields to search and study in the nature, effects and consequences of the pandemic. Engineering, artificial intelligence and information technology are not away from the world’s concerns. New and hot research
The COVID-19 virus is a messenger RNA virus that is similar to the common cold virus. The COVID-19 virus enters lung type II alveolar cells, enterocytes of the small intestine, arterial and venous endothelial cells, and smooth muscle cells of the vasculature via its S-spike protein binding the ACE2 receptor of the target cells. Variances in the expression of the ACE2 receptor may be partly responsible for differential susceptibility to infections by sex and ethnic group [32].

Mutations in the S-Spike protein have been associated with differences in the virulence of COVID-19 subtypes [33]. It is against this S-protein that current vaccines have been developed to address the target. There is little knowledge of post-infection immunity to SARS-CoV-2 with cases being reported of reinfection. This finding may be a result of the rapid mutation of the COVID-19 virus implying the potential need for continuous vaccine development yearly as is the case of flu vaccine [34,35].

However, as the epidemic has spread, inaccurate information about COVID-19 has become widely available and transmitted, including material that underestimates the severity of the pandemic and information that minimizes the negative repercussions of the pandemic [36–39]. In an effort to fight the virus, several researchers are attempting to accelerate the research and production of COVID-19 vaccinations as quickly as possible [40–42]. In pre-clinical research now, around 195 vaccines are being tested, with a further 144 vaccines in clinical development as of February 18, 2022 [43].

Previous researchers were focused on discussing the advantage and side effects of different vaccines, emphasizing their safety and efficacy in preventing COVID-19 infection. However, those researches did not consider the people's feelings, fears, opinions, and acceptance of the newly developed vaccines. Our study's primary objective is to provide an analysis of the questionnaire regarding people's opinions, preferences, and acceptance of the COVID-19 vaccines.

3. The Framework of the Proposed Methodology

This study proposed a two-way approach analysis, namely descriptive statistics for the questionnaire data and the SARIMA model to forecast the total number of vaccines in the next few days. The study comprises 516 respondents' views in various countries. An online questionnaire was administered to collect various information, including demographic information, four types of vaccines, such as Pfizer/BioNTech, Moderna, AstraZeneca/Oxford, and SputnikV vaccines. Fig. 1 shows the main steps of the proposed framework. The first step of the proposed framework is to understand the problem well. We have two parts to analyze (1) the questionnaire data and (2) the vaccinations dataset. The questionnaire questions are designed and translated into English to analyze questionnaire data, and then we distributed online among the respondents found in various countries. The questionnaire data are collected and preprocessed through the Google platform. The analysis steps are done using tables and figures to show participants' opinion regarding the different types of vaccines. Similarly, the vaccination dataset is collected from WHO and Github websites. Then it is preprocessed and split into training and testing sets. The SARIMA model is trained and tested using the training set and testing set, respectively. Finally,
the model is used to forecast the total number of vaccinations required in the upcoming days.

3.1. Seasonal ARIMA Model

The Autoregressive Integrated Moving Average (ARIMA) and SARIMA are the most widely used statistical models for many time-series forecasting problems [44]. The seasonal SARIMA \((p, d, q) \times (P, D, Q)\) model is an extension to ARIMA \((p, d, q)\) model that explicitly supports the direct modeling of the seasonal component of a time series data. The SARIMA method has seven parameters. The first three trend modeling of the seasonal component of a time series data. The SARIMA has seven parameters. The first three trend parameters represented as \((p, d, q)\) describes the non-seasonal part and four of the seasonal parameters represented as \((P, D, Q, s)\) deals with the seasonal part of the model [45,46]. The mathematical formula of the SARIMA model is shown in Eq. 1.

\[
\phi_p(B)\phi_p(B^s)W_t = \theta_q(B)\Theta_Q(B^s)\omega_t
\]  
(1)

The terms of Eq. 1 can be written as:

- non-seasonal AR: \(\phi_p(B) = 1 - \phi_1B - \phi_2B^2 - \cdots - \phi_pB^p\),
- seasonal AR: \(\Phi_P(B^s) = 1 - \Phi_1B^s - \Phi_2B^{2s} - \cdots - \Phi_PB^{Ps}\),
- non-seasonal MA: \(\theta_q(B) = 1 - \theta_1B - \theta_2B^2 - \cdots - \theta_qB^q\),
- seasonal MA: \(\Theta_Q(B^s) = 1 - \Theta_1B^s - \Theta_2B^{2s} - \cdots - \Theta_QB^{Qs}\).

The most known metric widely used to select the best fitted models is Akaike’s Information Criterion (AIC). The Akaike’s Information Criterion (AIC) is presented in Eq. 2 [47,48].

\[
AIC = -2\log(L) + 2k
\]  
(2)

where \(k\) refers to the total number of estimated SARIMA’s parameters and \(L\) is the maximum value of the likelihood function for the model. It is experimentally proved that the best forecasting model is the one with the minimum AIC value [49].

4. Experimental Results and Evaluations

4.1. Questionnaires Analysis

The questionnaire regarding vaccination was designed and released on the Google cloud platform, and the final answers were stored in a CSV format. Likert-type survey was prepared and written in two languages namely Arabic and English and distributed to people in many countries such as Egypt, Saudi Arabia, Morocco, Ethiopia, Afghanistan, India, China, and Japan. These countries were selected because of the availability of respondents. The online version of the designed questionnaire can be accessed from the following links: Arabic version Link: https://forms.gle/WMA3dmJqyrSS1ce9 and English version Link: https://forms.gle/Pb4o8GcbvmwMBppe7.

4.1.1. Dataset Description

This section describes the collected dataset using questionnaires. Data acquisition is conducted online with the help of Google forms that were distributed to people/respondents in many countries such as Egypt, Saudi Arabia, Ethiopia, India, China, and Japan. A total of 516 responses were returned and analyzed using various statistical approaches. The questionnaire contains queries related to the 4 types of vaccines such as Pfizer/BioNTech, Moderna, AstraZeneca/Oxford, and SputnikV vaccines. Table 1 summarizes the responses for the following columns: ‘Country’, ‘Sex’, ‘Academic level’, ‘Age’, and ‘what is the nature of your job?’ toward the different types
vaccines. In the column namely country, the highest number of respondents are from Saudi Arabia followed by Egypt. Also, the majority are females, 307, followed by males of 209. In the academic level feature, the highest number of respondents are from University Students of 380 followed by Ph.D. and then Masters degree holders. Others are a category where if candidates are higher than Ph.D., they are grouped into a group named "Other" for anonymity at the formal education status of the respondents. Finally, most of the respondents, do not work in the medical field, and a few numbers are in the medical field.

Fig. 2 presents the distribution of different diseases that are related to COVID-19. The responses to the question can be summarized as follows: the large majority of those who completed the questionnaires do not suffer from chronic diseases. The majority of the respondents are found to be suffered from blood pressure and heart diseases. Moreover, Fig. 2 shows that a small number of people are also suffering from Chronic bronchitis during the Pandemic and the majority of them have two or one chronic diseases.

Table 1 The participants' demographic information.

| Country         | Frequency | Percentage |
|-----------------|-----------|------------|
| Saudi Arabia    | 381       | 73.84      |
| Egypt           | 93        | 18.02      |
| China           | 11        | 2.13       |
| Afghanistan     | 10        | 1.94       |
| Japan           | 3         | 0.58       |
| Yemen           | 2         | 0.39       |
| India           | 2         | 0.39       |
| Tunisia         | 2         | 0.39       |
| Ethiopia        | 2         | 0.39       |
| Jordan          | 2         | 0.39       |
| Libya           | 2         | 0.39       |
| Germany         | 1         | 0.19       |
| Morocco         | 1         | 0.19       |
| Albania         | 1         | 0.19       |
| Kazakhstan      | 1         | 0.19       |
| Iraq            | 1         | 0.19       |
| Bahrain         | 1         | 0.19       |
| Bahrain         | 1         | 0.19       |
| Kuwait          | 1         | 0.19       |
| Jordan          | 2         | 0.39       |
| Saudi Arabia    | 381       | 73.84      |
| Egypt           | 93        | 18.02      |
| China           | 11        | 2.13       |
| Afghanistan     | 10        | 1.94       |
| Japan           | 3         | 0.58       |
| Yemen           | 2         | 0.39       |
| India           | 2         | 0.39       |
| Tunisia         | 2         | 0.39       |
| Ethiopia        | 2         | 0.39       |
| Jordan          | 2         | 0.39       |
| Libya           | 2         | 0.39       |
| Germany         | 1         | 0.19       |
| Morocco         | 1         | 0.19       |
| Albania         | 1         | 0.19       |
| Kazakhstan      | 1         | 0.19       |
| Iraq            | 1         | 0.19       |
| Bahrain         | 1         | 0.19       |

4.1.2. Data Analysis

Fig. 4 shows participants’ responses to the question "Do you take the flu vaccine annually?". Most of the participants are not taking the flu vaccine annually followed by respondents are taking the vaccine once in some years. Besides, fifteen respondents said, they take the flu vaccine annually.

Fig. 5 shows participants’ answers to the question "Do you have an idea of the type of vaccines officially approved in your country?", Most of the participants are not have any information about the type of vaccines officially approved in their country followed by maybe. Additionally, the number of participants which are known the type of vaccines is 105.

Fig. 6 demonstrates participants’ answers to the question "Did you take the vaccine until the time of the questionnaire?". Most of the participants are not take the vaccine until the time of the questionnaire followed by only the first dose. Also, the number of participants who have taken the second dose of vaccine until the time of the questionnaire is zero.

Fig. 7 shows the participants’ answers to the question "In your opinion, what is the best way to deal with the vaccine in your country?". Most of the participants, 193 respondents, have answered, the choice is left for everyone whether to take the vaccine or not. Next, 153 respondents believe that vaccination should be imposed on everyone after the effectiveness of the vaccine is proven and 91 respondents reply saying "I do not know". Lastly, 35 participants believe that there should not be an obligation to impose the vaccination.

Fig. 8 shows the participants’ answers to the question "In your opinion, to what extent do others in your country need the vaccine?". The Majority of the respondents, 258, gave an answer saying "All people may need it after proven successful in clinical trials" followed by "I do not know" of 148 respondents. 87 of the respondents reply saying only infected people may need". Moreover, 23 respondents have answered saying that "No one needs it", that they show their pessimistic view towards the vaccine.

Fig. 9 shows the participants’ answers to the question "What is your opinion about the approved vaccines? (American vaccine (Pfizer- Moderna))". The majority of the participants, 210, towards the question remains "Neutral". Moreover, 153 respondents believe that they "agree" that the vaccine is approved and 89 respondents reply they still are "strongly agree" with the approval of the vaccine. Lastly, 8 respondents are replying, they "strongly disagree" towards the approval of the vaccine.

Fig. 10 shows the answers of participants to the question "What is your opinion about the approved vaccines? (European vaccine (Oxford - Astrazeneca))". The majority of the participants, 243, still remains "Neutral" followed by "Agree"
by 130 respondents and 77 respondents answered "Strongly agree" that the European vaccine is properly approved. Besides, 9 participants gave "Strongly disagree" towards the proper approval of the European vaccine.

Fig. 11 shows the answers of participants to the question "What is your opinion about the approved vaccines? (Russian vaccine (Sputnik))". The majority of the respondents, 257, have answered being "Neutral" followed by "Agree" by 109 respondents. Moreover, 59 respondents gave "Strongly agree" for the same question, and 13 of the respondents answered "Strongly disagree".

Fig. 12 shows the answers of participants to the question "What is your opinion about the approved vaccines? (Chinese vaccine (Sinovac))". Majority of the participants answer "Neutral" of 237 followed by "Agree" of 96 then "Strongly agree" of 55. Besides, the number of participants which are answer "Strongly disagree" is 30.

Fig. 13 shows the answers of respondents to the question "What is your opinion about the approved vaccines? (Indian vaccine)". The majority of the respondents, 246, gave a neutral answer towards the specified question followed by "Agree" by 95 respondents. Moreover, 32 respondents replied "Strongly
agree” to the question followed by 28 respondents who have answered strongly disagree.

Tables 3–5 present the answers of participants to the question “If you mind or hesitate to take the vaccine, or even decide to take it, but you have reservations that will not prevent you from taking it in the end, what is the reason or reasons that make you not encouraged to take the vaccine?”.

This is a very important question and we would like to analyze the answers using the proposed statistical approaches. The majority of the respondents, 205, answered the specified question by “I am afraid that side effects of the serum will appear, which are not announced now” followed by “The possibility that the vaccine will lose its effectiveness against new strains of the virus” by 177 respondents. Moreover, 181 respondents
replied, "I am afraid that taking the vaccine can affect the genetics for life". Furthermore, 118 respondents replied, "Not long enough has passed to know the safety of the vaccine".

Figs. 14 shows the correlation matrix for the questions. It depicts that majority of the questions are related to each others.

4.2. SARIMA Analysis

This section illustrates the experiments to predict the total number of vaccines in many countries. The following python packages such as scikit-learn and Stat are needed for the experiments to be conducted. To perform the experimentations, we have selected Google's colab environment, which has the necessary libraries. The vaccinations dataset is assembled starting from January 3rd, 2021 to the present time from known data repositories such as WHO and Github [1,50]. The dataset consists of 127 countries that have started reporting vaccinations. The total number of vaccine doses is 11,537,618,404 over the globe and the current rate of vaccine production is about 129.10/second or 11,154,051 each day. That is about 148.25 doses per hundred people i.e. 7.85 billion and the number of people completed vaccination is 3,289,529,390 [51]. To attain the most accurate forecast, the parameters of the SARIMA model are investigated using a grid search approach [46,27]. Finally, the best SARIMA model’s parameters are estimated and used to forecast the total number of vaccination for the next 30 days. Table 6 shows a sample of the total number of vaccinations globally starting from January 3rd, 2021. Table 7 shows a summary of the number of countries for each vaccine.

In this work, the SARIMA model is used to predict the total number of vaccines in the next few days. The model learns with the first part of the data set then tested using the last part of the data set. For the SARIMA model, a collection of parameters are set up and initialized with values. The grid search technique can be used to determine the optimal models that have the lowest AIC [47]. Next, the best fitted SARIMA model is selected based on the most suitable combination of parameters, which is the one that minimizes the AIC. Table 8 presents the results of the SARIMA model's diagnostic test with p-values ≤ 0.05, indicating the smallest values of the AIC metric.

In this experiment, we have observed that the model parameters vary from one to another country. The SARIMA model \((p,d,q) \times (P,D,Q)\) works fine for different time series data. Since the collected daily data consisted of a few months, the value of \(s\) is assigned to be 12. To train and test the best fitted SARIMA model, we have split the vaccination data into training and validating datasets based on the 70% and 30% ratio for training and validation. The training set starting from 2020–12-29 to 2022–01-01 and the testing set is from 2022–01-01 to the current day.

Table 9 presents the AIC, MAPE, MAE, and RMSE values of different forecasting SARIMA models. The following combinations \((1,0,1) \times (1,0,0,1)\) have the minimum AIC values.

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**Table 2** Question: Do you intend to take the vaccine when it is available?

| Answer                              | Count |
|-------------------------------------|-------|
| I will wait until I see the result with others | 295   |
| I'm not sure                        | 168   |
| Yes                                 | 27    |
| No                                  | 19    |
| I don't think it’s necessary        | 3     |
| I will wait till prove no side effect and its efficiency | 2     |

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![Fig. 6 Question: Did you take the vaccine until the time of the questionnaire?](image)
Fig. 7  Question: In your opinion, what is the best way to deal with the vaccine in your country?

Fig. 8  Question: In your opinion, to what extent do others in your country need the vaccine?
as given in Table 9. Therefore, this combination of the parameters $\theta(1,0,1) \times (1,0,0,1)$ is considered to be the best model produced for the SARIMA model. Table 10 presents the forecasting values with lower and upper confidence limits that are calculated using the best SARIMA model for the period from 2022-01-01 to the current day. Fig. 15 shows the observed or training set from 2020-12-29 to 2022-01-01 and the testing set from 2022-01-01 to present-day and values for one step ahead forecasting is represented by the red line. In Fig. 16, the predicted values marked in the red line, real values marked

**Fig. 9** Question: What is your opinion towards the approved vaccines? (American vaccine (Pfizer- Moderna)).

**Fig. 10** Question: What is your opinion about the approved vaccines? (European vaccine (Oxford - Astrazeneca)).
Fig. 11  Question: What is your opinion about the approved vaccines? (Russian vaccine (Sputnik)).

Fig. 12  Question: What is your opinion about the approved vaccines? (Chinese vaccine (Sinovac)).
Table 3  Question: What is the reason or reasons that make you not encouraged to take the vaccine?  

| Question: what is the reason or reasons that make you not encouraged to take the vaccine? | Frequency |
|---|---|
| I am afraid that side effects of the serum will appear, which are not announced now | 205 |
| There is no reservation about taking the vaccine | 92 |
| I had Corona previously. Currently, I do not need the vaccine | 42 |
| There is no need for the vaccine because the virus’s spread is receding | 27 |
| I am not one of the people who meet the conditions for taking the vaccine | 27 |
| I am generally not satisfied with the vaccine | 26 |
| The vaccine has not been tested in enough people | 25 |
| I think the coronavirus is greatly amplified to serve the vaccine manufacturers | 20 |
| The vaccine was quickly produced. This reduces the credibility of the producing companies | 14 |
| Coronavirus is a plot and the vaccine is part of it | 9 |
| There is no need for the vaccine because most of the infected people recover from the virus | 7 |
| I don’t think I will catch the virus | 9 |
| There is no need for the vaccine because more people in the country are infected with the virus | 5 |
| There are no published scientific studies on the vaccine | 5 |
| I heard that the vaccine contains aluminum, which damages the mind | 3 |

Table 4  Question: what is the reason or reasons that make you not encouraged to take the vaccine?  

| what is the reason or reasons that make you not encouraged to take the vaccine? | Frequency |
|---|---|
| The possibility that the vaccine will lose its effectiveness against new strains of the virus | 177 |
| I do not want to suffer from the side effects mentioned in medical research | 153 |
| I fear that the immunity acquired from the vaccine does not last long | 63 |
| I heard that people took the vaccine and then they infected by the virus again | 49 |
| I heard about deaths due to the vaccine | 43 |
| I heard that people took the vaccine and then developed side effects such as fatigue, joint pain, headache, and high temperature. | 21 |
| I have an excessive sensitivity to food or medicine | 10 |
in blue line and grey shading area are used for the confidence intervals with lower and upper confidence limits.

Table 10 shows the forecasted values of total vaccination for next 30 days using SARIMA\((1, 0, 1) \times (1, 0, 0, 1)\) model with 95% CI, lower and upper confidence limits. Although the increasing trend is noticeable, the best model performs better for the testing set. The forecast performance is generally satisfactory when the MSE and RMSE values for the testing set are 0.0153414, and 0.12386, respectively.

Fig. 17 shows the increase of total cases, the number of people vaccinated, people fully vaccinated, and total vaccinations for the world from 2021–01–01 to the current time. Also, Fig. 18 shows a comparison between the increase of total cases and total vaccinations for the world from 2021–01–01 to the current time. From this figure, it is clear that the average number of vaccine doses being administered across the United States per day is now averaging 2 million. The United States as a whole is averaging 19 new daily cases per 100,000 people.

| Table 5 | What is the reason or reasons that make you not encouraged to take the vaccine? |
|---------|-----------------------------------------------------------------------------|
| What is the reason or reasons that make you not encouraged to take the vaccine? | Frequency |
| I am afraid that taking the vaccine will affect your genetics for life | 181 |
| Not long enough has passed to know the safety of the vaccine | 118 |
| I fear that the vaccine itself may cause disease | 92 |
| I don’t like acupuncture | 72 |
| I do not trust the health policy in the country | 21 |
| I have chronic diseases, so I am afraid that I will be harmed by the vaccine | 20 |
| The vaccine has not been tested on Arab peoples, and it is not a requirement that the results apply to other ethnicities | 12 |
Thus, several other limits will remain in place, including safety and cleaning protocols at gyms and personal care services like salons and spas.

5. Discussions

The current research work investigates that the four types of vaccines evaluated and compared here all have the ability to minimize infections or the presence of clinical symptoms. Perhaps, more importantly, the Moderna, AstraZeneca/Oxford, and Pfizer/BioNTech vaccines all seem to be effective in preventing serious diseases with statistically no difference. The short time frame of evaluation however may skew the effectiveness of the vaccines upwards. The short time frame was most likely due to the rush to find a vaccine and the intense competition to influence one's market share. It is currently

Table 6  A sample of the total number of vaccinations globally.

| date       | location | total_vaccinations | people_vaccinated | people_fully_vaccinated |
|------------|----------|--------------------|-------------------|-------------------------|
| 2021-01-03 | World    | 13136211           | 8447382           | 22002                   |
| 2021-01-04 | World    | 13956533           | 9230059           | 22004                   |
| 2021-01-05 | World    | 15525472           | 9947630           | 22004                   |
| 2021-01-06 | World    | 16503120           | 10785570          | 22004                   |
| 2021-01-07 | World    | 17782014           | 12120502          | 24180                   |
| ...        | ...      | ...                | ...               | ...                     |
| 2022-04-24 | World    | 11531035191        | 5127697704        | 4635881860              |
| 2022-04-25 | World    | 11537618404        | 512870445         | 4637261223              |

Table 7  Summary of the number of countries for each vaccine.

| Vaccine          | Location                                                                 | Count |
|------------------|---------------------------------------------------------------------------|-------|
| Covaxin          | India                                                                     | 1     |
| EpiVacCorona     | Russia                                                                    | 1     |
| Johnson&Johnson  | South Africa, United States                                               | 2     |
| Moderna          | Austria, Belgium, Bulgaria, Canada, Czechia, Denmark, Estonia, Faeroe Islands, Finland, France, Germany, Greece, Guatemala, Honduras, Hungary, Iceland, Ireland, Israel, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Rwanda, Spain, Switzerland | 31    |
| Oxford/AstraZeneca| Anguilla, Argentina, Australia, Bahrain, Bangladesh, Barbados, Belize, Brazil, Dominican, Dominican Republic, El Salvador, Falkland Islands, Grenada, Guyana, Isle of Man, Jersey, Madeiras, Mauritius, Mexico, Moldova, Mongolia, Montserrat, Morocco, Myanmar, Nepal, Oman, Pakistan, Saint Helena, Saint Lucia, Saudi Arabia, Serbia, Seychelles, Slovenia, South Korea, Sri Lanka, Sweden, Trinidad and Tobago, Uruguay, United Arab Emirates, United Kingdom | 40    |
| Pfizer/BioNTech  | Albania, Andorra, Bermuda, Cayman Islands, Chile, Colombia, Costa Rica, Croatia, Cyprus, Ecuador, Gibraltar, Greenland, Guernsey, Hong Kong, Japan, Jordan, Kuwait, Lebanon, Malaysia, Malta, Monaco, New Zealand, Northern Cyprus, Panama, Qatar, Singapore, Slovakia, Turks and Caicos Islands | 28    |
| Sinopharm/Beijing| Cambodia, China, Egypt, Macao, Montenegro, Peru, Senegal, Zimbabwe         | 8     |
| Sinovac          | 'Azerbaijan, Indonesia, Philippines, Thailand, Turkey, Uruguay            | 6     |
| Sputnik V        | Algeria, Belarus, Bolivia, Iran, Kazakhstan, Paraguay, San Marino, Venezuela | 8     |

Table 8  Experimental results of the diagnostics test for different SARIMA models.

| (p,d,q)    | (P,D,Q,s) | AIC    | MAPE  | MAE   | MPE   | MSE   | RMSE  | Corr  | MinMax |
|------------|-----------|--------|-------|-------|-------|-------|-------|-------|--------|
| (1, 0, 1)  | (1, 0, 1)  | -4100.110704 | 0.100847 | 0.093766 | 0.100847 | 0.015765 | 0.125559 | 0.984079 | 0.086607 |
| (1, 0, 0)  | (1, 0, 1)  | -4100.093899 | 0.10103 | 0.093938 | 0.10103 | 0.015826 | 0.125801 | 0.984038 | 0.08674 |
| (1, 0, 0)  | (1, 0, 2)  | -4098.667835 | 0.158095 | 0.147153 | 0.158095 | 0.039055 | 0.197625 | 0.974083 | 0.125878 |
| (2, 0, 1)  | (1, 0, 1)  | -4087.89106 | 0.00885 | 0.007883 | 0.008159 | 0.000908 | 0.009893 | 0.999446 | 0.008739 |
unknown how long the antibody response will last against the S protein of the COVID-19 virus. COVID-19 an RNA virus has a very unstable genome and hence like the common cold the ability to distribute this vaccine over the others to rural areas and poorer countries [52]. This means that vaccines developed in one part of the World may not be as efficacious elsewhere. The best estimate is 6–8 months meaning that these vaccines will need to be administered every year in a similar fashion that the flu shot is given. The efficacy of the vaccines did not seem to be dependent on the technology used as the mRNA vaccines and the DNA-based vaccines seem equally efficacious. The side effects were relatively minor but quite common. Surprisingly, the side effects of the mRNA vaccines had a similar rate as the DNA vaccines excluding fever where the DNA-based vaccines were more common.

Most importantly serious adverse effects were relatively rare with the caveat there has only been a relatively short time frame. Indeed, the safety of these vaccines or their efficacy in those under the age of 16 and pregnant women is unknown. The risk for those with a history of allergies may also be elevated.

The Moderna vaccine must be stored at 45 F (- 7.2 C), the Pfizer/BioNTech vaccine at 94 F (-20 C), and the AstraZeneca/Oxford and Sputnik V vaccines to be stored at normal refrigeration temperature may play a large role in the ability to distribute this vaccine over the others to rural areas and poorer countries [53].

It is expected that the virulence of the COVID virus in terms of its ability to cause serious disease will decrease. This is due to a fundamental principle in microbiology that the more prevalent a microbe becomes, the less deadly it becomes. This, with the proven ability of these vaccines to limit serious disease is due to a fundamental principle in microbiology that the future, thinking that the Vaccine itself may cause death. The findings of this study can be summarized as follows.

The SARIMA model-based forecasting required number of COVID-19 vaccines globally and empirical analysis 12105
limiting serious consequences. Till now, the reported COVID-19 vaccines’ side effects are minor but quite common, and the serious adverse effects are relatively rare. However, most of the hesitant people will receive COVID-19 vaccines because of the vaccines’ theoretical advantages of preventing the disease and hoping for relieving the restrictions, easing the precautions, and ending up the Pandemic. Starting with vaccinating the community leaders, the famous and senior citizens, reporting the growing numbers of people receiving the vaccines, announcing incentives for those who will be vaccinated e.g. issuing the healthy passport will help the hesitant individuals to decide and apply to get COVID-19 vaccines.

6. Conclusion

In this research work, we have proposed an empirical study. In this analytical study, two approaches are followed namely questionnaire-based respondents view analysis on the currently produced and ongoing vaccination process and SARIMA model-based prediction and forecasting of the required number of vaccines for the next few days. Our study has provided an analysis of the questionnaire regarding people’s opinions, preferences, and acceptance of the COVID-19 vaccines. Four various types of vaccines have been considered and all four of the vaccines are evaluated. Experimental results indicate

Fig. 15  Comparison between the actual and predicted values for SARIMA model on vaccination datasets.

Fig. 16  The forecasted values for the total vaccination over the globe.
that it seems to be effective in either preventing infection or the symptoms of infection. Most importantly the Moderna, Astra-Zeneca/Oxford, and Pfizer/BioNtech vaccines seem to be effective and nearly equivalent in preventing serious disease due to COVID-19. All four vaccines seem relatively safe with the greatest risk being anaphylaxis, though rare can be life-threatening by causing blood clotting. Those at high risk are people over the age of 60 or people with moderate to severe chronic health conditions should be the first to receive these vaccines. Moreover, most of the participants are not have any information about the type of vaccines officially approved in their country followed by maybe. Additionally, the number

Fig. 17  A comparison between the increasing of total cases, the number of people vaccinated, people fully vaccinated, and total vaccinations.

Fig. 18  A comparison between the increasing of total cases and total vaccinations.
of participants which are known the type of vaccines is 105. SARIMA models have been investigated with a grid search method to attain the most accurate forecast and prediction. The combination of the parameters $(1, 0, 1) \times (1, 0, 0, 1)$ is considered to be the best SARIMA model because it has the lowest AIC values of $-179.35$ and the best Correlation coefficients of $0.998$. Future work could focus on applying the proposed model to four types of Vaccines through Twitter datasets and their effect on the COVID-19 virus. Also, it may concentrate on applying the suggested model to other countries around the world in order to forecast the total number of vaccines produced. Furthermore, there is an urgent need to do research into the efficiency of the available vaccines. More comprehensive deep learning models, which would be based on feature extraction obtained through enhanced optimization approaches, might be investigated by researchers in the future.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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