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Mathematical Modeling Skills for Data on the Spread of the COVID-19 and Some Observations Using Statistical Models: Case Study of Arab Countries

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Abstract

The deadly Corona virus continued to spread at an insane speed through new modifications and resistance to incomplete vaccinations all over the world, and there was a need to expand the field of use of mathematical models, especially random ones, to show the path and scope of spread of suspected, recovered and deceased Corona virus patients, in addition to the number of people who were infected. Test them, and what are the chances of obtaining herd immunity to gain long-term immunity for citizens. This study leads, through the general random model, to a better estimate of the extent of the spread, and the consequences of this epidemic in the future. The researcher proposed the development of a random mathematical model with the significance of eight parameters in order to contain the dynamic behavior of COVID-19 infection by tracking a sample of data for a previous year, which allowed the researcher to form the general extended form of the proposed mathematical model; Then, the positive discussion of the results and the extent covered by the proposed model. In order to study the process of local stability and global stability of the proposed model, the researcher needs to conduct a simulation and alignment process in order to study the standard and non-standard finite differences schemes with the use of some results of illustrations through ready-made computer programs that show us the possible reason for the rapid spread of COVID-19, and its future risks to lives, money, and the community life of individuals.

Keywords

Extended, Gamma Distribution, Mathematical Modeling, Machine Learning Modeling, Statistical Modeling, Statistical Methods, COVID-19, Arab Countries, Statistical Modeling Software

1. Introduction

Humanity is living in a difficult stage in the history of the world, and the indicators fully suggest that it is a stage that will pass and go on despite its continuation, cruelty, bitterness and difficulty, and until today the world is searching for an effective treatment for the "Corona" virus, and there is no treatment in sight soon, and quarantine and social distancing have been adopted, in order to reducing the chances of infection with the disease and controlling the windows of its spread [1].

Common datasets for statistical analysis include census data, public health data, social media data, image data, and other public sector data that make use of real-world forecasts. Statistical modeling is the use of mathematical models and statistical assumptions to generate sample data and make predictions about the real world. A statistical model is a set of probability distributions over a set of all possible outcomes of an experiment. Several statistical models have been developed to make predictions, according to some combinatorial criteria such as minimizing mean squared error. Statistical models excel even when they are based on a subset of information available to clinicians (who, for example, can also interview people). Furthermore, statistical models do not need to be perfect to be superior but may be 'inappropriate'—as when linear formulation is based on ad hoc (but directionally correct) or intuitive weights. Paul Meehl influential 1954 book surveyed about 20 studies comparing such predictions—from important human outcomes to those of clinical experts who had access to exactly the same information on which the statistical prediction was based. The human expert was by no means superior [2].

Statistical modeling refers to the data science process of applying statistical analysis to data sets. A statistical model is a mathematical relationship between one or more random variables and other nonrandom variables. Applying statistical modeling to raw data helps data scientists approach data analysis in a strategic manner, providing intuitive visualizations that help identify relationships between variables and make predictions. Statistical models, usually consisting of a set of probability distributions, are used to describe patterns of variance that random variables or data may display. The stability of such models is often described by group theory. Although the mathematical concept of a set is relatively simple, the ideas of set theory provide a very convenient way to describe how statistical models change when random variables are transformed [3].

Statistical models describe the mathematical functional relationship between input and output variables. So it is data driven. Models usually have a deterministic and random component. The form of the imperative part of the relationship may be linear or non-linear. Linear terms may include consistent terms useful in describing seasonal variation, and linear terms may also be included to account for simple trends [9].

Statistical models usually have a descriptive objective rather than a mechanical one. The parameters in these models are directly estimated by selecting them in a way that best fits a particular data set. Thus, any given statistical model is not very general in application to different systems. The structure of these models may be useful in a variety of different contexts. Specialists in building sequential probabilistic models of the spread of the epidemic and the accumulation of consequences wonder what if we were wrong in finding models from which reliable decisions emerge, and if the decision was wrong, we are faced with two possibilities [1, 3].

2. Methods

2.1. Mathematical Modeling

Much like statistical modeling, mathematical modeling translates real-world problems into traceable mathematical formulas whose analysis provides insight, results, and direction that are useful to the original application. However, unlike statistical modeling, mathematical modeling includes static models that represent a realistic phenomenon in mathematical form. Once a mathematical model is formulated, it does not require change. Statistical models are flexible and can, with the help of machine learning, incorporate emerging new patterns and trends, and will adapt to new data entry. Statistical models are needed capable of separating three types of change, namely, non-uniform variance due to measurement error, systematic state variability due to situational influences and interaction between person and situation, and systematic change of traits which can be due to events, maturity and other causes [4].

2.2. Statistical Modeling

Is a subfield of mathematics that searches for relationships between variables in order to predict an outcome? Statistical models are based on parameter estimation, are usually applied to smaller sets of data with fewer attributes, and require the human designer to understand the relationships between variables before input. Statistical modeling serves as one solution to the data discovery challenge facing big data management systems. It always works to monitor the validity of statistical models with which the user can visualize predictions along with actual results and see how the predictions diverge from real life.

In particular, statistical models closed under the category of fixed transformations are called. This invariance often has important implications for the inferential problems associated with the model. The principle of invariance asserts that when a problem is stationary under a set of transformations, the solution to the problem must also be stationary. Applications of this principle occur in both estimation problems and hypothesis testing. For example, maximum likelihood estimators and probability ratio tests are stable solutions to inference problems when the model is stationary [5].

2.3. Machine Learning Modeling

Is a subfield of computer science and artificial intelligence that involves building systems that can learn from data rather than explicitly programmed instructions. Machine learning models search for hidden patterns in the data independently of all assumptions, so the predictive power is usually very strong. Machine learning requires little human input and works well with a large number of attributes and observations.

Statistical models usually have a descriptive objective rather than a mechanical one. The parameters within these models are directly estimated by selecting them in a way that best fits a given data set. Thus, any given statistical model is not very general in application to different systems. The structure of these models may be useful in a variety of different contexts. Regression models, which assume a certain mathematical relationship between variables and assume that errors in the data take a certain shape, are widely applied [6].

Stochastic models and the current corona crisis: Stochastic models consist of infinite possibilities, and the stochastic component(s) of the statistical model are described by probability distributions that can take a wide range of functions. It is really limited only by the numerical methods available for simulating population dynamics. Statistical models emerge from two intertwined components: a deterministic model that describes the deterministic biological process and a stochastic component that describes how random variance affects the process. The deterministic component typically, but not always, constitutes the biological process of sufficient interest by professionals.

The random component of models is usually included by adding a random variable to some or all of the input parameters. In many cases, a random variable will have a mean of zero to reduce the risk of introducing bias. The scattering or scattering of the random variable must be determined. The random variable must be chosen from some form of distribution—this is often a normal distribution with random variables chosen to be independent of each other. This is not always true and errors may have other distress. Statistical models include estimation of parameters, usually from some form of regression. Statistical models take the form of regression, then the regression coefficients are estimated using standard regression methods. The parameters do not necessarily have any direct environmental or biological explanation, so they do not represent any mechanism [7].

The deterministic model may be relatively straightforward, such as exponential population growth; it can include a description of multiple groups, such as paired predator and prey models; or it may explicitly describe the structure within a population, such as the dynamics of size structure.

The stochastic component of a statistical model is often thought of as an "error" term that allows for variance around a deterministic model. However, while it is true for pure observational error, it can introduce stochasticity in parameters and variables that generate population dynamics that are not found in deterministic models, as a result, a statistical model describing a biological process necessarily includes an accurate statement of both the random and deterministic components [8].

An alternative view of statistical models is that they are much more than descriptive, by providing a way to separate the potential effects of complex interactions from limited observations. This is one of the goals of hierarchical Bayes methods where data on uncontrolled variables are used to estimate interactions at different levels or scales in the system. The idea is to consider a hierarchy of processes in which the probability distribution at one level of the process depends on the components at the other levels. Using conditional probability arguments multiple times allows a Bayesian update to build a complex model from simpler conditional relationships. The suffix distribution can be very complex, but it is possible to obtain using the Markov Chain Monte Carlo method where the simulated Markov chain has the same stationary distribution as the suffixed distribution required by the hierarchical Bayes model. See Clark and Gelfand (2006) for a variety of applications of this methodology to health problems and epidemics [9].

2.4. Statistical Modeling Algorithm

The first step in developing a statistical model is to collect data, which can be obtained from spreadsheets, databases, data lakes, or the cloud. The most common statistical modeling methods for analyzing this data are categorized as either supervised learning or unsupervised learning. Some examples of commonly used statistical models include stochastic or deterministic models such as time series, logistic regression, regression models, classification models, and decision trees. There are three main types of statistical models: parametric, nonparametric, and quasi-parametric:

1) Time Series Models and Forecasting: Use cases include forecasting, modeling time series, and discovering the causal effect relationship between variables. It is summarized in the type of predictive statistical models that analyze the relationship between a dependent and independent variable. Common regression models include logistic, polynomial, and linear regression models.

2) Classification models: a type of machine learning in which an algorithm analyzes an existing, large, and complex set of known data points as a means of understanding the data and then classifies it appropriately; Common models include

Decision Trees, Naive Bayes, Nearest Neighbors, Random Forests, and Neural Network Models, which are commonly used in artificial intelligence.

Includes unsupervised learning techniques

3) Clustering Algorithms and Association Rules: It means grouping a specified number of data points into a specified number of groups based on certain similarities.

4) Reinforcement learning models: The area of deep learning that is concerned with iterating models over many trials, rewarding movements that lead to positive outcomes and penalizing steps that lead to undesirable outcomes, thus training the algorithm to learn the optimal process.

5) Parametric Probability Distribution Models: A family of probability distributions with a specified number of parameters.

6) Nonparametric Probability Distribution Models: Models in which the number and nature of parameters are a priori flexible and not fixed.

7) Semi-parametric Probability Distribution Models: The parameter contains a finite-dimensional component (parametric) and an infinite-dimensional component (non-parametric).

The evaluation of quality of fit tests and diagnosis of the Mathematical model is done through the core of good statistical practice, which is the origin of modern statistics, where the quality of fit is generally the basis and most important element in the processes of building the preferred model, we suggest the use of the Anderson-Darling test as a comprehensive test, and we will see this better in practical applications, supported Using components of seamless tests in an exploratory data analysis method. This will help in diagnosing the type of deviation from the assumed distribution, accordingly a set of basic tests such as chi-square tests, EDF tests, series tests, and others are performed [10].

Table 1. The number of active cases of the COVID-19 pandemic, reported active cases and deaths in the Arab countries (alphabetical order) (https://www.worldometers.info/coronavirus/#countries)

Country	Total Cases	Total Recovered	Total Deaths	Active Cases	Total Tests	Population
Algeria	211,662	145,350	6,111	60,201	230,861	44,981,074
Bahrain	277,856	276,148	1,394	314	7,513,731	1,785,818
Comoros	4,548	4,324	151	73		896,027
Djibouti	13,508	13,294	188	26	248,627	1,008,512
Egypt	364,033	302,259	20,770	41,004	3,693,367	105,088,625
Iraq	2,084,961	2,050,960	23,903	10,098	16,451,108	41,509,921
Jordan	981,767	907,386	11,787	62,594	12,450,089	10,347,811
Kuwait	413,524	410,746	2,465	313	5,456,590	4,360,736
Lebanon	679,625	634,994	8,785	35,846	4,795,578	6,781,746
Libya	375,468	356,814	5,499	13,155	1,930,533	7,004,702
Mauritania	39,584	37,973	842	769	515,803	4,823,905
Morocco	950,643	933,049	14,788	2,806	10,506,174	37,535,330
Oman	304,612	300,047	4,113	452	25,000,000	5,291,809
Palestine	432,265	424,172	4,554	3,539	2,758,039	5,270,549
Qatar	244,387	241,566	611	2,210	3,027,701	2,807,805
Saudi Arabia	549,955	539,082	8,845	2,028	31,741,301	35,587,827
Somalia	23,051	12,325	1,331	9,395	262,138	16,525,276
Sudan	44,170	35,786	3,200	5,184	238,579	45,309,430
Syria	48,709	29,850	2,782	16,077	113,162	18,106,919
Tunisia	718,443	691,640	25,401	1,402	3,198,939	11,995,247
UAE	742,376	737,400	2,149	2,827	102,805,056	10,061,048
Yemen	10,034	6,917	1,955	1,162	265,253	30,762,982

3. Results

A number of statistical models can be derived depending on how the randomness is presented. If the randomness affects how states are observed, but not the dynamics underlying them, then it is referred to as an 'observation error'. Many statistical models based on logistic growth have to be solved numerically. To reflect this, and the general fact that biologically motivated statistical models rarely have analytic solutions, the discussion below focuses on numerical methods. Statistical models aim to find associations, but the researcher has to decide whether it is a coincidence or a cause.

An internally validated form does not equal a valid expectation. The need for external validation of QSAR models is discussed for external validation, a set of particles not used in model development is evaluated. In other words, reliability and probability are not interchangeable concepts. Statistical models do not explain the reason for the existence of the association, and therefore the researcher needs to weight the results to reach a conclusion.

As with the imperative form, there are many options available. If the response variable (that is, the event described by the probability distribution) is continuous and takes values between negative infinity and positive infinity (referred to as the domain), then the normal distribution may be a suitable choice. If a continuous response variable can only take positive values, a log-normal distribution or a gamma distribution might be a good choice. When the response variable is discrete, such as count data. The choice of the probability distribution should reflect whether the response variable is continuous or discrete, the domain of the stochastic process, how well the shape of the distribution reflects the stochastic process, and in some cases probability distributions emerge directly from the assumptions of the stochastic process.

Uppercase letters denote a random variable (Y), lowercase letters denote the realized value of the random variable (y); The function $f()$ denotes either a probability mass function (for discrete random variables) or a probability density function (for continuous random variables); The symbol "|" represents The statement is "given", and lowercase letters indicate the parameters of the distribution . Thus, the notation f (Y = y | $\alpha, m, n, p, k, \lambda, \gamma$) is read as "the probability mass (or intensity) that a random variable Y will take in a given realization y, for parameters $\alpha, m, n, p, k, \lambda, \gamma$.

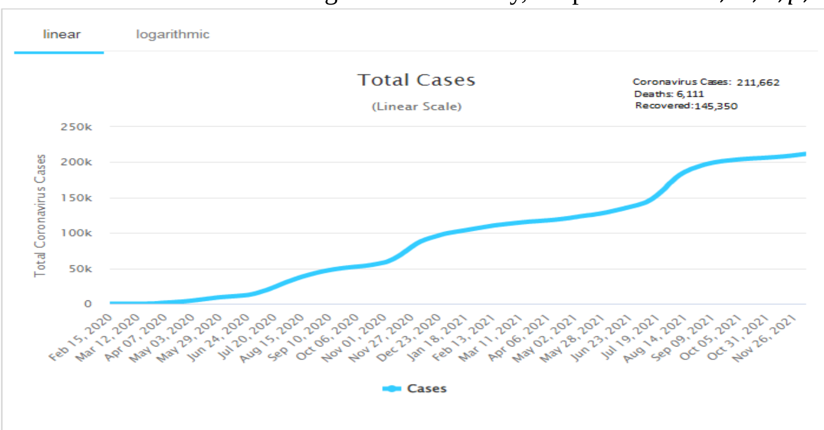

Figure 1. The number of active cases of the COVID-19 pandemic in Algeria.

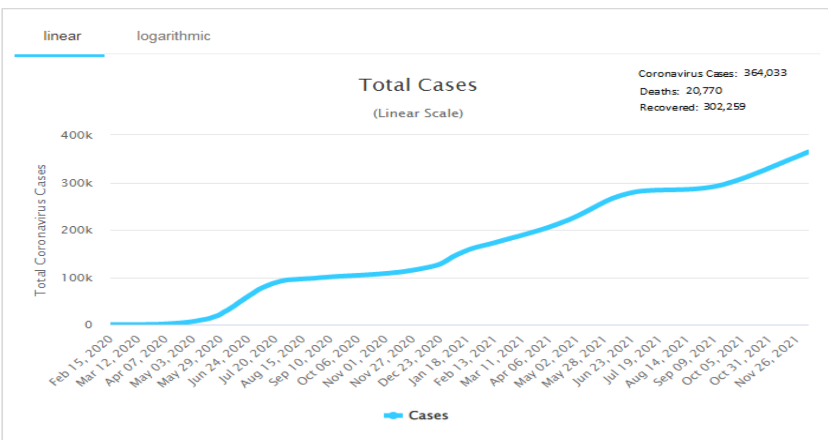

Figure 2. The number of active cases of the COVID-19 pandemic in Egypt.

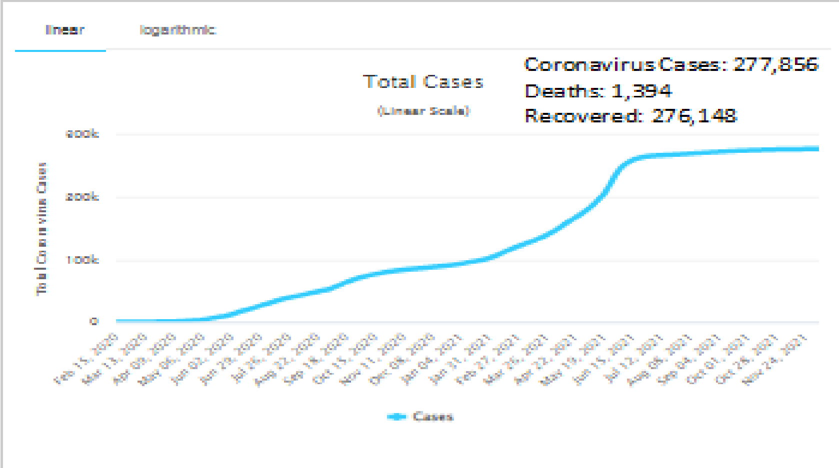

Figure 3. The number of active cases of the COVID-19 pandemic in Bahrain.

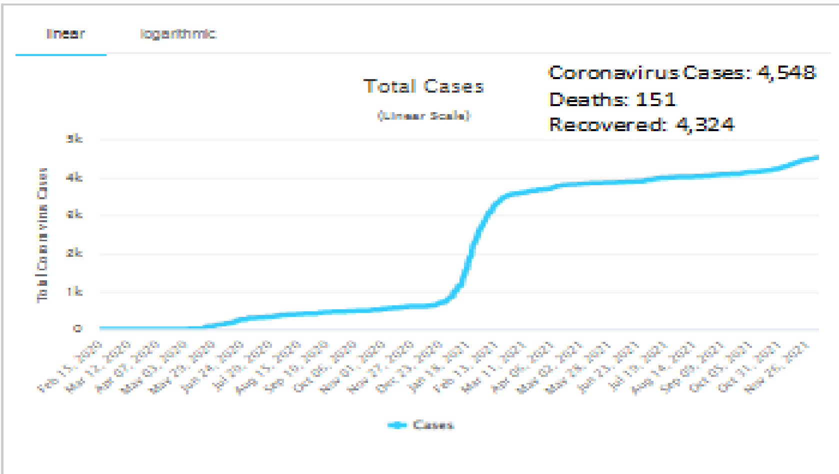

Figure 4. The number of active cases of the COVID-19 pandemic in Comoros.

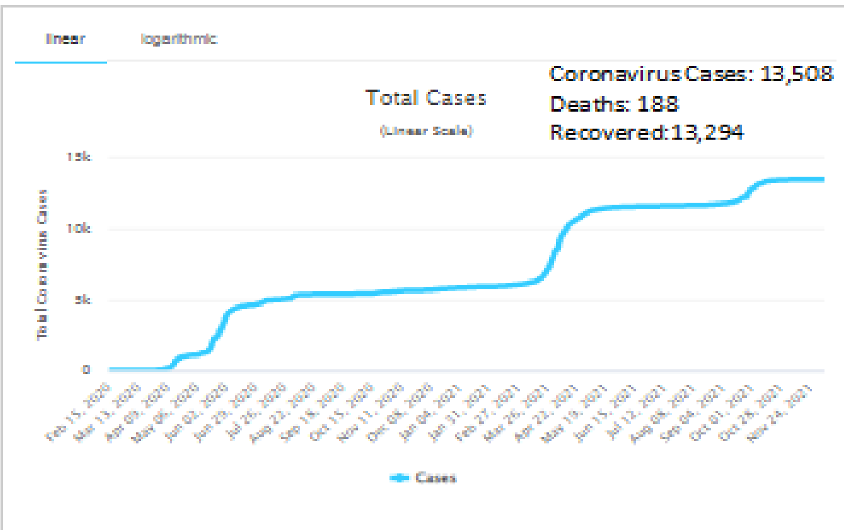

Figure 5. The number of active cases of the COVID-19 pandemic in Djibouti.

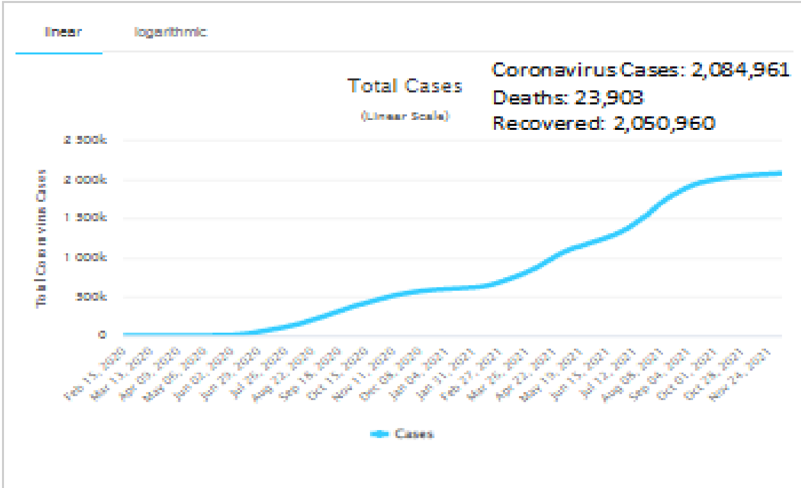

Figure 6. The number of active cases of the COVID-19 pandemic in Iraq.

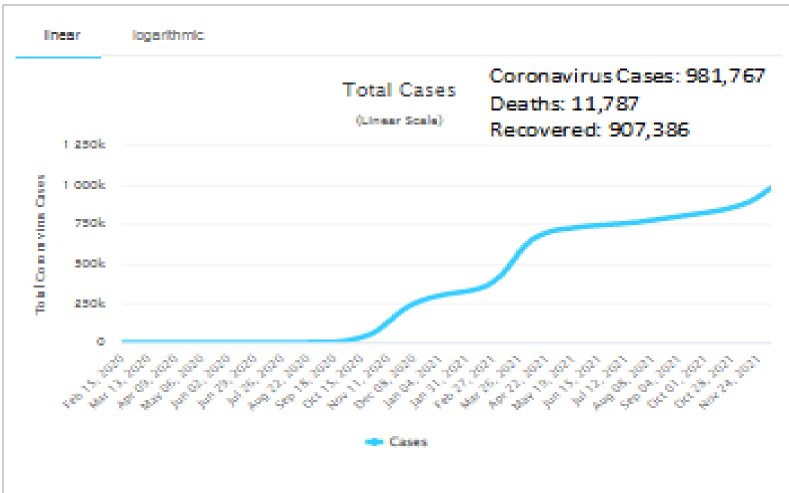

Figure 7. The number of active cases of the COVID-19 pandemic in Jordan.

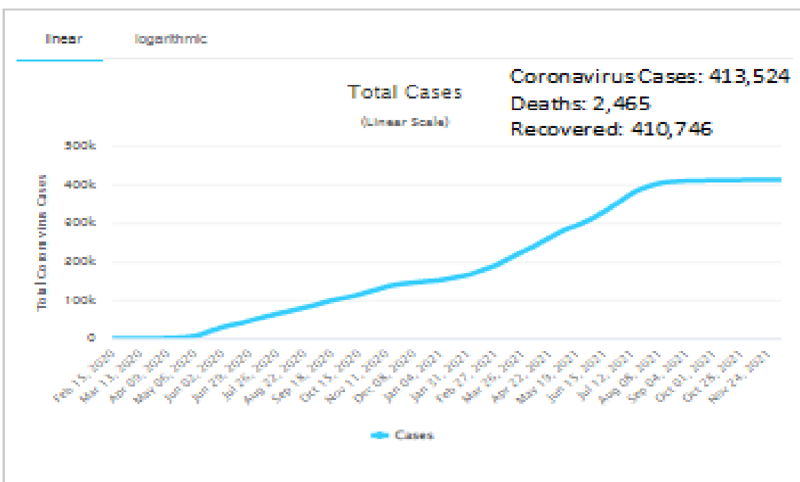

Figure 8. The number of active cases of the COVID-19 pandemic in Kuwait.

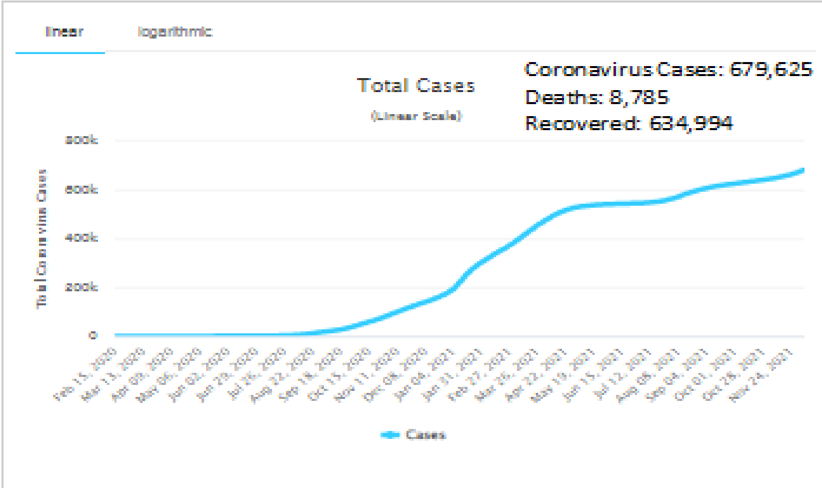

Figure 9. The number of active cases of the COVID-19 pandemic in Lebanon.

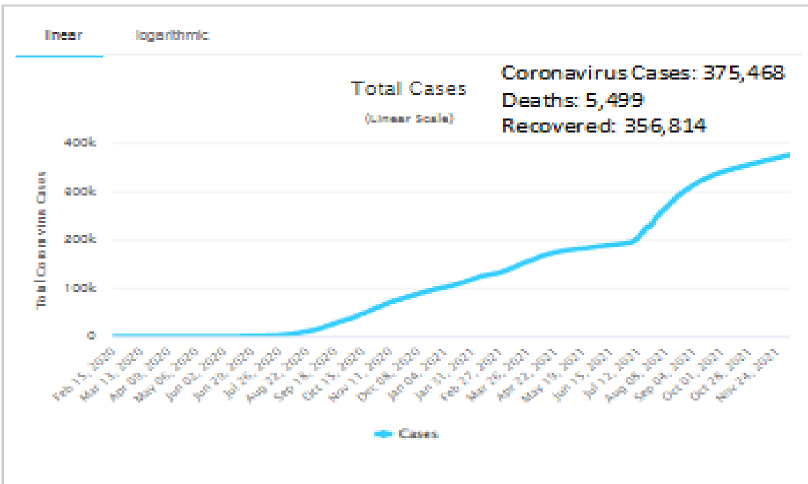

Figure 10. The number of active cases of the COVID-19 pandemic in Libya.

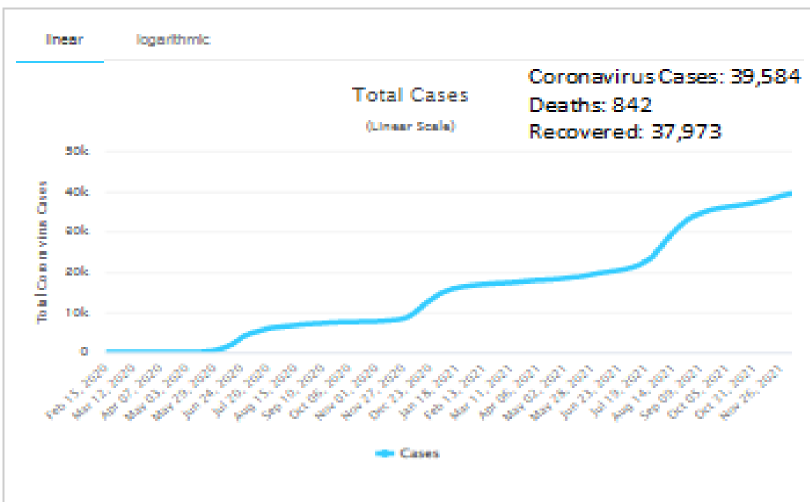

Figure 11. The number of active cases of the COVID-19 pandemic in Mauritania.

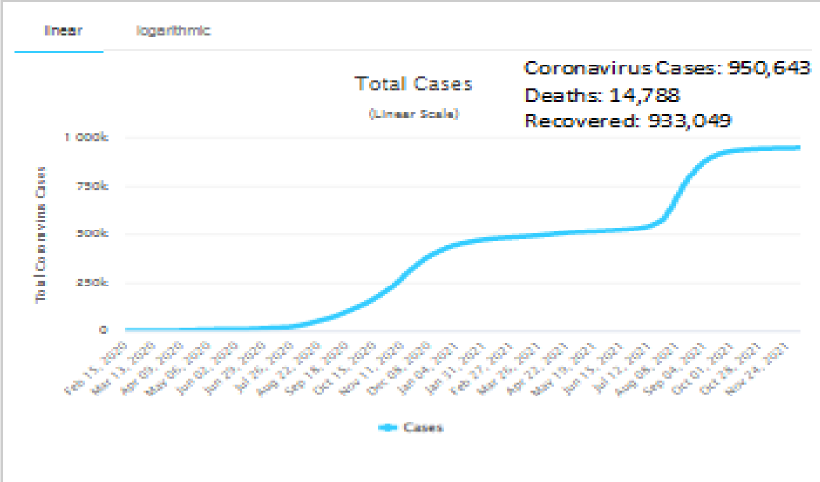

Figure 12. The number of active cases of the COVID-19 pandemic in Morocco.

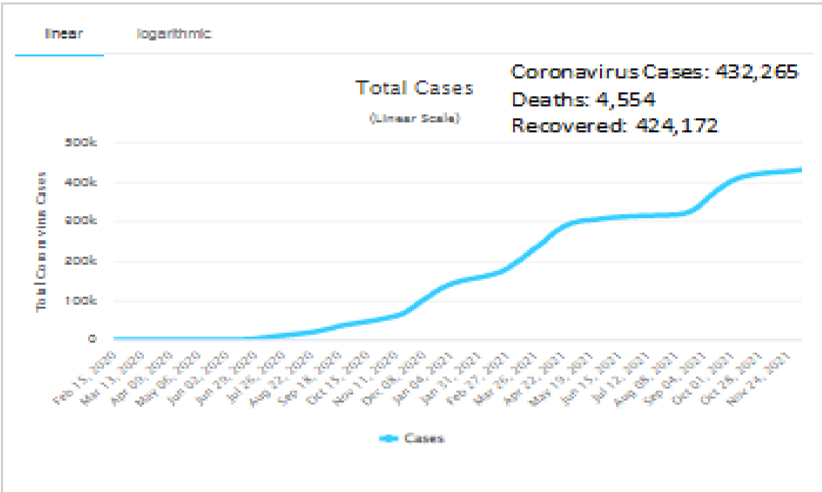

Figure 13. The number of active cases of the COVID-19 pandemic in Palestine.

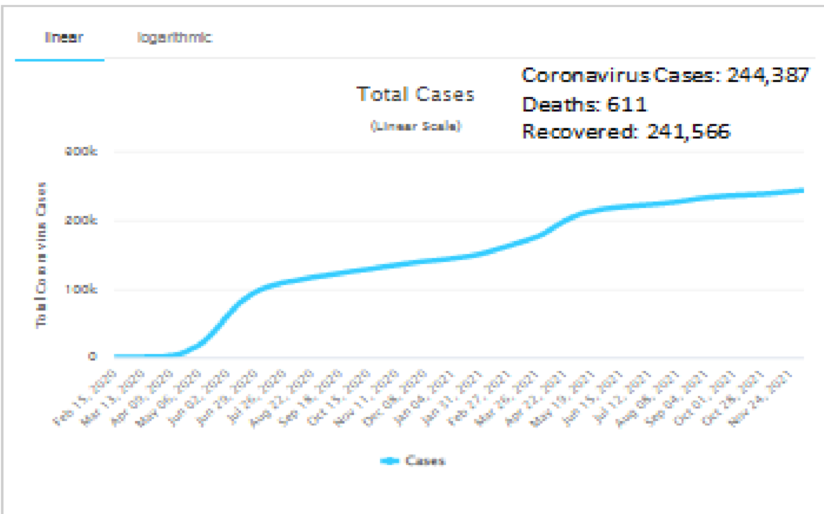

Figure 14. The number of active cases of the COVID-19 pandemic in Qatar.

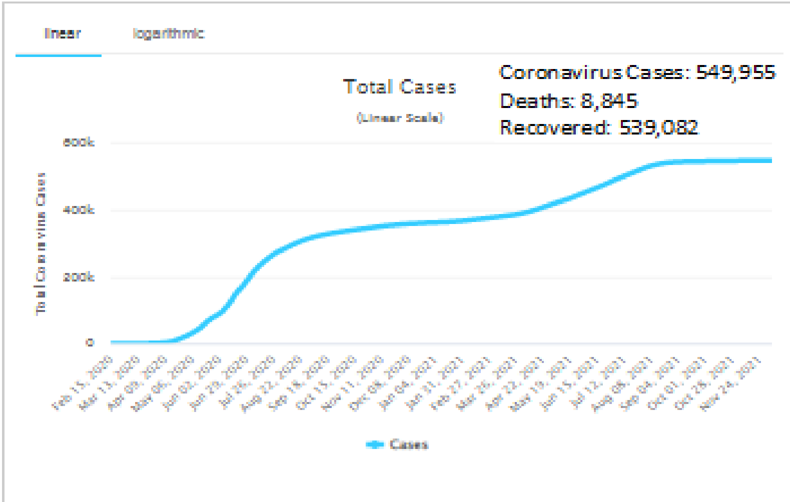

Figure 15. The number of active cases of the COVID-19 pandemic in Saudi Arabia.

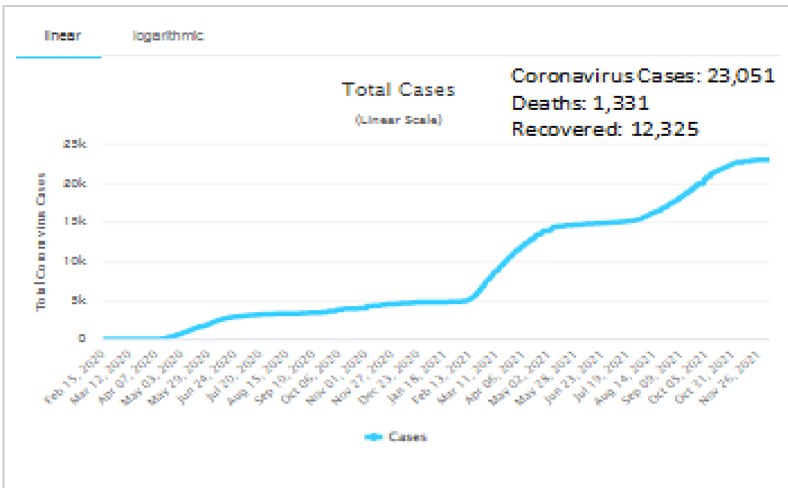

Figure 16. The number of active cases of the COVID-19 pandemic in Somalia.

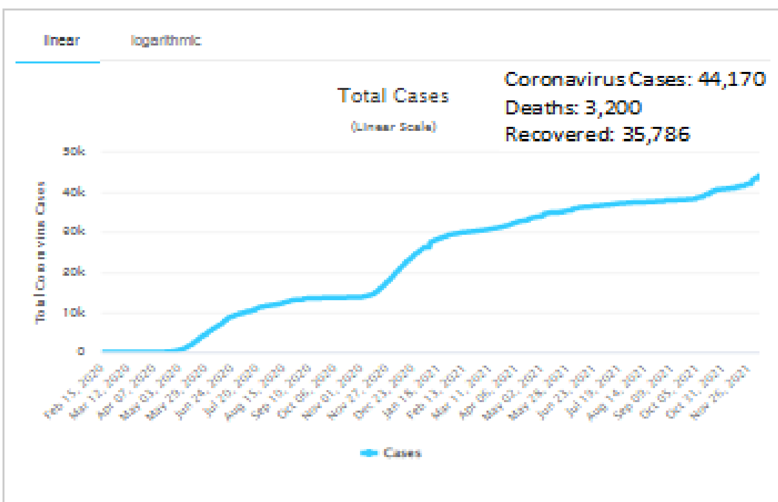

Figure 17. The number of active cases of the COVID-19 pandemic in Sudan.

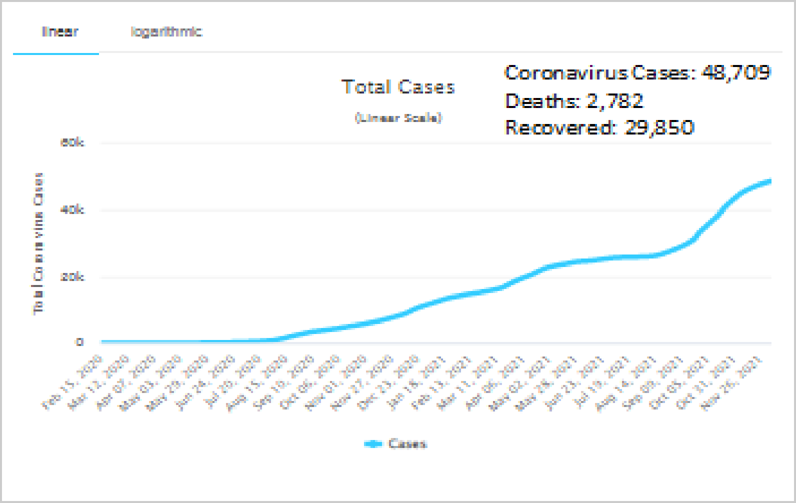

Figure 18. The number of active cases of the COVID-19 pandemic in Syria.

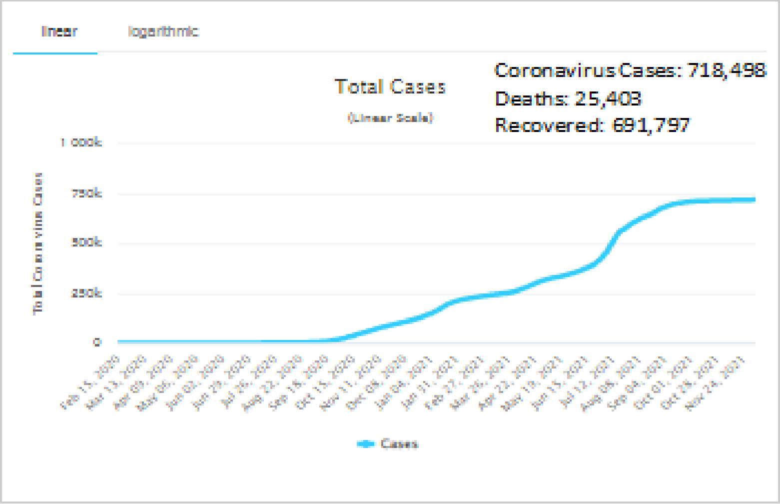

Figure 19. The number of active cases of the COVID-19 pandemic in Tunisia.

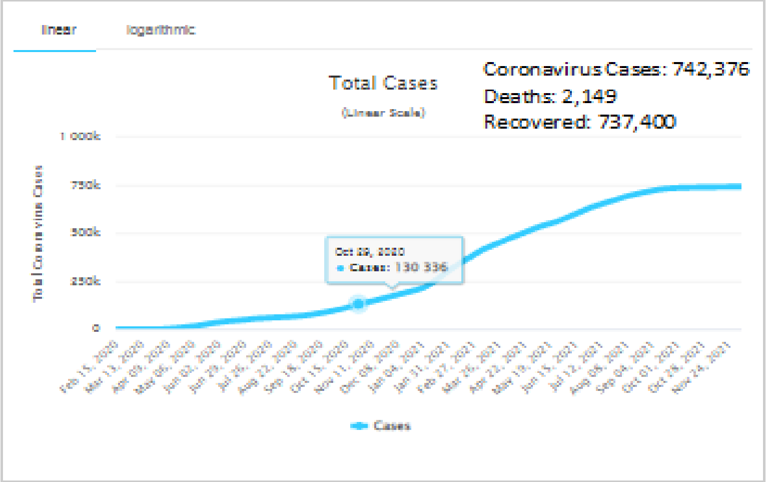

Figure 20. The number of active cases of the COVID-19 pandemic in UAE.

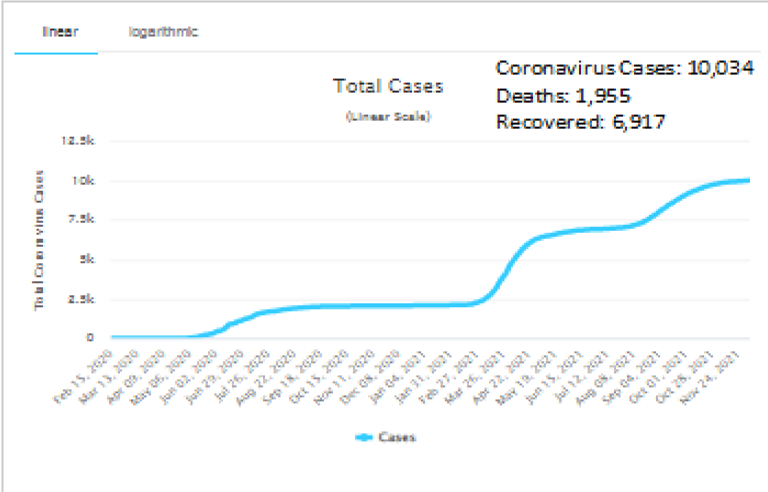

Figure 21. The number of active cases of the COVID-19 pandemic in Yemen.

4. Discussion

After browsing the data contained in Table 1 represent the number of active cases of the COVID-19 pandemic, reported active cases and deaths in the Arab countries (alphabetical order), it becomes clear that some graphs of the epidemic's spread process can be represented in each of the targeted Arab countries (from Figure 1 to Figure 21)), and the obtained shapes suggest the presence of one part of the modified exponential function $exp\{-\lambda x^{p-1}+\gamma x^{1-k}\}$, and two other parts From simple and advanced functions $x^{\alpha-1}[x^m+n]^{-r}$, and during the installation of these three functions, we can model the obtained data through the use of the probability density function proposed by the same researcher ([11],[12]), and it is possible to work on the operations of estimating the parameters in appropriate and efficient ways, and thus the probability density function for the random variable of the corona epidemic distribution in Arab countries can rewrite their general form in the form:

$$f_X(\alpha,m,n,p,k,\lambda,\gamma)=\frac{x^{\alpha-1}[x^m+n]^{-r}}{\Lambda_r(\alpha,m,n,p,k,\lambda,\gamma)}exp\{-\lambda x^{p-1}+\gamma x^{1-k}\}$$

The values of the parameters in the domain that make the integral of the extended gamma function are defined and convergent, which are defined by the form:

$$\Lambda_r(\alpha,m,n,p,k,\lambda,\gamma)=\int_0^{+\infty}x^{\alpha-1}[x^m+n]^{-r}\,exp\{-\lambda x^{p-1}+\gamma x^{1-k}\}dx$$

In connection with the functionality of the model, it is proposed to expand the study of statistical properties, reliability and severity functions, and to estimate distribution coefficients using various methods. And making sure that this new distribution model is suitable to accommodate diverse applications since it has a variety of shapes, especially for component life distribution where having displacement and intensity parameters is very important, where $a,b,c\in R^{+}$.

Statistical models for processing data obtained in accelerated predictive stability studies are described. The effect of data monitoring and approximation on the accuracy of hypothetical corona epidemic predictions obtained using different data processing methods that were derived for different cases, recoveries, active cases, and number of deaths was evaluated. The real results were compared with the predictive results using random equation models with the traditional methods that require the use of approved models to interact with the assumed results.

In most cases, it was found that the effect of censorship accuracy and approximation of the obtained data with field results was relatively insignificant. Classical methods based on time series and two-stage linear regression modeling with separate intercepts for each stress condition in the first stage were unsatisfactory, although imposing a common intercept in the first stage gave reliable results.

A simple model was found to estimate the proportions of active cases of the corona epidemic using limited data to provide an accurate and accurate estimate of the hypothetical time period in the near future, and despite the unexpected developments in the emergence of active and modified strains from strains that appeared until the last Omicron strain that appeared in South Africa, the finding the extended non-linear regression model to be slightly superior when additional data is available is consistent with some results confirmed by prediction methods using time series.

The absence of herd immunity was due to the spread of the Corona epidemic. It can be compared with the general situation of the spread of the epidemic in the world, which is shown in the following Figure 22:

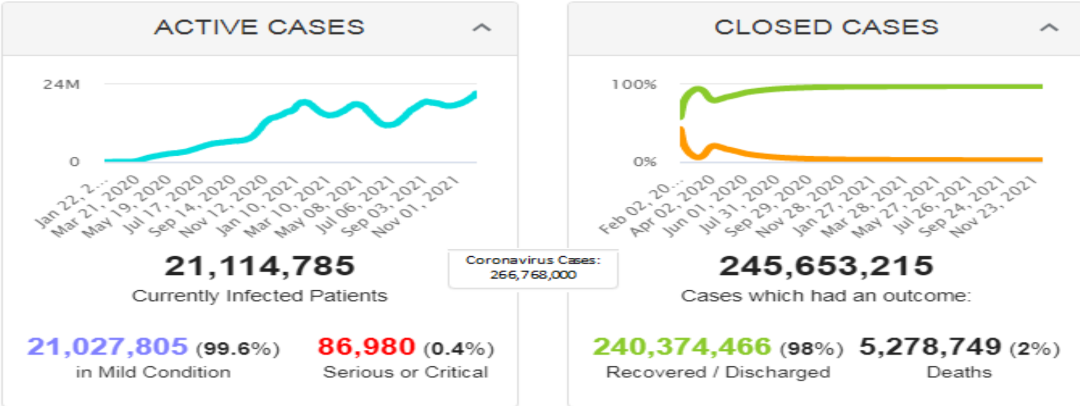

Figure 22. The number of active cases of the COVID-19 pandemic in Word.

The obtained figures represent a group of mixtures of exponential distributions, gamma distribution, and log-normal distribution, and they differ in contrast to the internal variables of each of the Arab countries, which are related to the number of population and financial capabilities that allow conducting daily examinations and expanding vaccination operations and health services that are required for each country through the Ministry of Health And the results of recovery, deaths, active cases, and vaccination rate level are in Table 1, which are results taken from the World Health Organization website Last updated: December 07, 2021, 07: 14 GMT (https://www.worldometers.info/coronavirus/#countries) .

It is clear from Figure 22 that there is some partial stability in the spread of the Corona epidemic and its negative consequences for the countries of the world, and these positive results can be attributed to the precautionary and health policies adopted in most Arab countries, especially the policies of error and distancing, and the social cultures that characterize these countries. In order to manage the proposed model in terms of eight parameters, we need to use advanced software that allows accurate calculations and dealing with ready-made algorithms associated with matching of fitting and simulation operations.

Mechanisms of Statistical Modeling Software

Statistical modeling software is specialized computer software that helps collect, organize, analyze, interpret, and model data statistically. Advanced statistics software should provide data mining, data import, analysis and reporting, automated data modeling and dissemination, data visualization, support for multiple platforms, forecasting capabilities, and an easy-to-use user interface with statistical features ranging from basic tabulation to multi-level models. Statistical software is available as proprietary, open source, public domain, and free software. Statistical models can vary at different levels, depending on their complexity, and a common flaw in statistical modeling is the use of the same data for model estimation and verification. This should be avoided as it usually gives an over-estimated effectiveness of the model. It is preferable to use one part of the data set for parameter estimation and another part for validation, provided that the two parts of the data are independent.

5. Conclusion

During the past two years of the outbreak of the contagious and dangerous Corona pandemic, the knowledge of its paths and developments in this epidemic has not stopped until now, but surprises continue from time to time, the last of which is the modified 'Omicron' strain, whose discovery is significantly different from the previous strains, biases in the data and the complexities of the basic dynamics of this The epidemic presents significant challenges in the mathematical modeling, and in particular the statistical part of the outbreak, and designing the preferred policy to deal with these sudden changes. The ongoing response to COVID-19 varies from strain to strain, which complicates matters and requires continued research, exploration, and collaboration between epidemiologists and others specializing in modeling with fitting and simulation.

This paper presents a toolkit of statistical and mathematical models other than simple dynamic equations and time series models to analyze the early stages of outbreaks and evaluate interventions, especially mortality, and active cases after treatment. We focus on estimating the curves of the basic probability distributions for each country as a mixture that forms the series and the expressive model for some parameters of the proposed complex distribution.

We recommend that we continue the study and research the presence of some known biases in the data for some cases, and the extent of the impact of non-curative interventions, that is, policies to deal with the pandemic, whether in terms of closure policy or social distancing policies among closed sub-population groups, in educational centers, markets and re-creational activities until immunity is obtained The herd's community transmission risks are brought under control.

Conflicts of Interest

The author declares that this article content has no conflict of interest.

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