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A View on technology and controls for epidemic preparedness and the growth of COVID-19 disease in Saudi Arabia

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Authors' Contribution | **Almeneem, H.A.A** & **W. M. Asiri** designed the experiments, **I. A. S. Mohamed** and **Ab. M. Mohammad** explained the results, statistically analyzed the data.

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ABSTRACT **Review Process: Peer review**

This work emphasizes that the best chance of ending the pandemic lies in the Measures that can help us respond to these epidemic threats more effectively than before in the scope of protection from epidemic risks that we were not aware of before the outbreak of the disease, which is to benefit from the study of previous experiences. The work show the importance of technology about how to prepare for and handle any pandemic by discussing a successful case from the past. We examine Saudi Arabia's COVID-19 pandemic response experiences. We proposed a case evolution study from the southern region of Jazan to demonstrate the consequences of these techniques. Data on the daily Jazan COVID-19 infection curve collected from July 1st to September 30th, 2020, was processed using multiple Python software modules, such as encoder-decoder LSTM, 1D-CNN, and Complex network analysis of time series to identify changes within the infection curve's structure. A Gaussian modeling study was performed to compare the data movement with the protection from epidemic risks computed by stratification based on the data group.The network analysis shows that hubs are stable while medium and low-degree nodes are unstable. Also, from the perspective of Gaussian modeling, the COVID-19 infection curve parts indicate that the pandemic in Saudi Arabia is about to peak and move into the second (declining) half of the bell-shaped distribution.Technology in many areas and internet access make Saudi Arabia's social separation strategies a pandemic-eradication success story.

Keywords: Coronavirus, adequate preparedness, visibility graph, normal distribution.

INTRODUCTION In addition to vaccines, there are other steps we can take to better prepare for epidemic threats than we have in the past. One of these steps is to use the analysis of prior experiences to protect us from epidemic risks that we were unaware of prior to the disease's outbreak.In this study, when COVID-19 reaction experiences were examined to draw lessons, it was determined that Saudi Arabia is setting the standard for all other countries in terms of implementing preventive measures.Saudi Arabia is the second-largest Arab country, home to almost 34 million people, of which 0.37 percent are not Saudi citizens(General authority of statistics, Kingdom of Saudi Arabia, 2020). The demand for healthcare services in Saudi Arabia, where more than 0.60 percent of the population is under 35, is increasing consistently (Alfetni *et al.*, 2022). We look at the daily real-time growth rates for detected cases of COVID-19 in the Jazan area from July 1, 2020, to September 30, 2020, as a time series to show how the control measures changed the number of infected cases. Figure 1 shows the overall infection curve for the southern Saudi Arabian region of JAZAN as an example. Recently, researchers have developed through the application of a variety of time series analysis tools, including statistical techniques, machine learning (ML), and deep learning, the ability to reduce time series features into manageable scales, which can then be used to predict how a system will change over time (Deng, 2014). Avci *et al.* (2018) created 1D Convolutional Neural Networks or 1D CNNs, a modified form of 2D CNNs, and explored that 1D CNNs have advantages over their 2D counterparts, making them the best choice for processing 1D Data values in a number of applications (Kiranyaz *et al.*, 2021). According to Vanessaet al., 2021 complex networks are frequently utilized because they are effective in simulating the relationship between each factor or node analysis. The authors presented a number of algorithms that have been proposed in the literature to map univariate and multivariate time series into the complex network domain.We suggest using one of the non-parametric or computational models, the encoder-decoder LSTM multi-step forecasting model, and one of the one-dimensional convolutional neural networks (1D-CNN) as deep learning approaches based on multi-step forecasting in addition to Gaussian modelingin analyzing our data series.

OBJECTIVES: The objectives of this study were as follows: (1) Apply technology in how to prepare and deal with any pandemic by discussing a successful case from the past. (2)Studying the experiences of responding to the Covid-19 pandemic in the Kingdom of Saudi Arabia.

MATERIALS AND METHODS: Data resources: Information about COVID-19 instances in Jazan was acquired from the Ministry of Health in Saudi Arabia. Data were obtained from (https://sehhty.com/sa-covid , 2020) covering the period from July 1st, 2020 to September 30th, 2020. Daily time series summary tables and daily case reports make up the dataset.

Laboratories and variant-adapted COVID-19 booster vaccines: To prevent overcrowding, individuals created a profile, select the location for their checkup or the hospital where they received the vaccination, SARS-CoV-2, or Severe Acute Respiratory Syndrome Coronavirus, including Moderna and Pfizer. However, the persistent appearance of SARS-CoV-2 variants has diminished the vaccine's efficacy and necessitated replenishment shots after a minimum of three months. Furthermore, after the vaccine and booster doses have been administered to everyone, for the most vulnerable populations, there is one more booster dose, and for healthy individuals, annual boosters may not be necessary, and boosters may only be more appropriate if a more virulent variant emerges.

Technology-related bad habits: Online false information reduces confidence in scientific evidence and medical. Therefore, social media sites have come under intense pressure from public officials to stop the transmission of false information.

Online learning: Experiences and real-world applications have shown that distance learning offers high-quality instruction at all levels of school, university, and continuing education, as well as a useful way to teach in remote areas without access to traditional classrooms and lecture halls, whether resulting from wars or the outbreak of pandemics and epidemics such as the Corona pandemic.

Data representation and analysis: The first category of our proposed visualization analysis approach is statistical Gaussian modeling-based time-series analysis; as shown in figure 1. The second is a time-series study based on a complex network; that is, we convert the JAZAN cases of the COVID-19 curve time series into a complex network and then analyze the corresponding complex network rather than the time series. We choosed the crucial variable, new cases and loaded the series into with their original values and data length; the first column comprised for history an index. Data was turned into the requisite three-dimensional'samples, time-steps, features' shaSpe for processing by the 1D-CNN and ED-LSTM models. Python programming language, version 3.7 was used for these analyais. Python libraries, including:

1. Pandas Library – For reading Excel data.
2. Matplot Library – For visualizing the applied algorithms.
3. Numpy Library – For calculations.
4. Keras Library- For sequential model.

The results were analysied using a prediction model and the statistical metrics mean square error (MSE) and root mean square error (RMSE), which we explain separately (1) and (2).

$$MSE = \frac{1}{N}\sum_{t=1}^{N}[\hat{y}(t) - y(t)]^2 \quad (1)$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}[\hat{y}(t) - y(t)]^2} \quad (2)$$

where y(t) is the tested original data value and y^(t) is the predicted value.

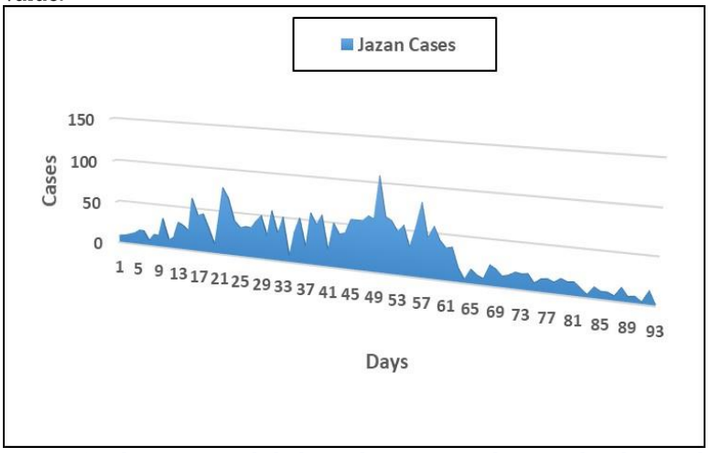

Figure 1: The estimated daily real-time growth rates for detected cases in COVID-19-affected territories between July 1st and September 30th, 2020.

RESULTS AND DISCUSSION: Impact of lockdowns: Despite the fact that the lockdown has been progressively eased, where: The ability of health care systems, the media, and social media to disseminate information and understanding about screening, testing, prevention, and policy across international borders has shown to be more successful in containing the disease's spread. Across the whole Kingdom, from north to south, Saudi Arabia has imposed extraordinary preventive and strict measures to either stop the virus's spread or mitigate its impacts if it occurs. After the lifting of the ban and returning to the office workplaces committed to wearing the cloth muzzle and bound to a physical distance by leaving a safe distance and limiting the gatherings, the active cases will then still decrease. Figure 2 shows an example in terms of the maximum and minimum number of confirmed cases for JAZAN in the southern region of Saudi Arabia between July and September 2020.

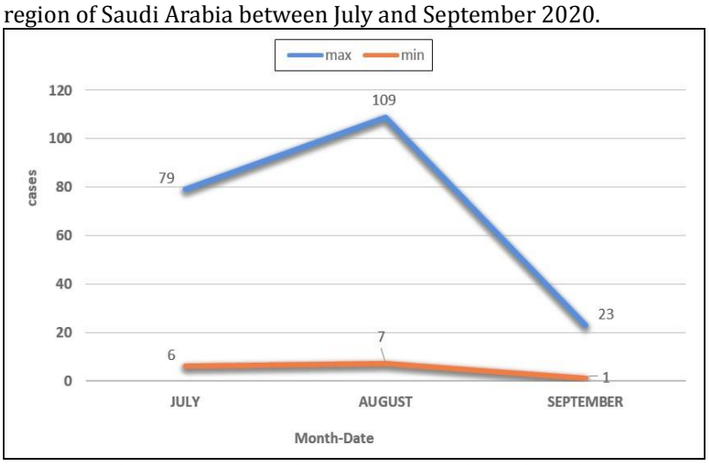

Figure 2: The maximum and minimum number of confirmed cases for JAZAN in the southern region of Saudi Arabia between July and September 2020.

Network analysis: Figure 3 shows the degree distribution of the infection curve visibility graph for JAZAN patients. We analyze this visibility graph's sparsity (spy) plot, representing the adjacency matrix with not equal to zero elements represented by dots (Tsiotas, 2019). Figure 4 showed the sparsity (spy) plot of Gvisibility graph for JAZAN patients.

Result of prediction: The multi-step model can predict results for a single sample. We can forecast the next two or more future time steps by giving the input. MSE and RMSE displayed in Table 1 depict that forecasting the next three values is more accurate by 1D-CNN. Figure 5 shows the Persistence Test baseline is nearly close to the original one. Assessing resilience to pandemics with reliable metrics of basic competencies that enable and support adequate preparedness and public health response to future epidemics or novel varieties that are more proactive are beneficia.

We find that the Kingdom of Saudi Arabia has been a pioneer among all countries in the experiences of the Applying precautionary measures. Due to the worldwide coronavirus outbreak, Saudi Arabia declared on Friday, March 20, that it will halt all domestic flights, buses, taxis, and railroads. One week later, on March 26, the government declared a statewide curfew and a total lockdown of Medina, Mecca, and Riyadh as part of expanded necessary precautions (Moneim, 2020). Religious officials asked all Muslims in Saudi Arabia to offer prayers at home for the first time in the Kingdom's history, and the five daily prayers were outlawed in all 300,000 mosques across the nation. Given that Saudi Arabian legislation is founded on Islamic law and that the majority of Saudis pray in large groups five times per day in mosques, this is an impressive step. Soon after, a variety of services utilizing digital health were launched, such as the "My Health" app, which allows people to get prescriptions filled and seek medical attention without visiting a hospital. It's crucial to remember that all of these actions were taken while there were still less than 300 confirmed cases in Saudi Arabia, a nation with over 34 million people (Leading countries//statista.com/statistics/242606,2020).

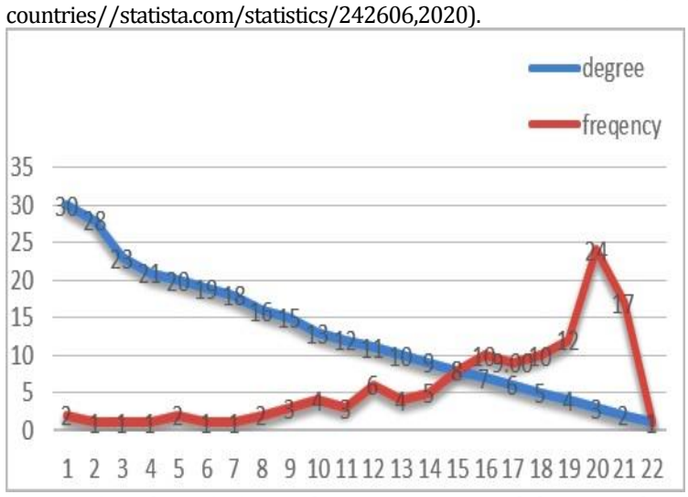

Figure 3: The JAZAN infection curve visibility graph G's degreedistribution.

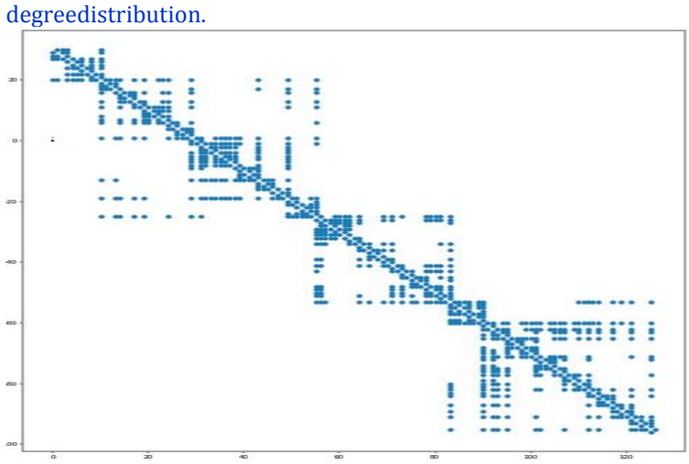

Figure 4: The sparsity (spy) plot of Graph JAZAN COVID-19 infection.

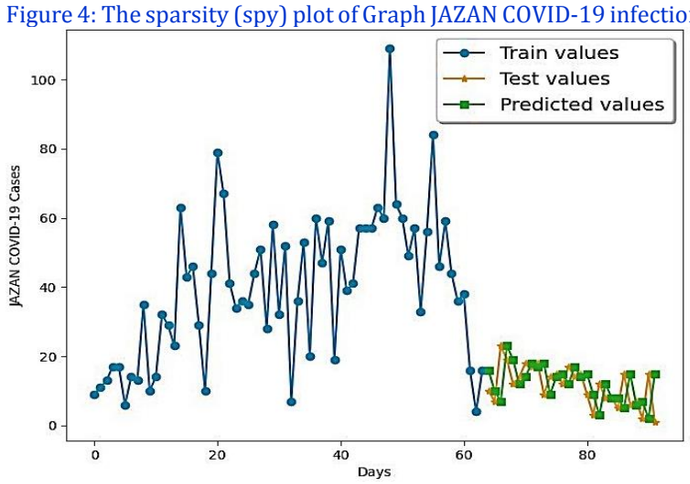

Figure 5: The Persistence Test prediction for JAZAN Cases from July 1st to September 30th 2020. The predicted value is the green color curve.

Series	n-Steps out	1D-CNN MSE	1D-CNN RMSE	ED-LSTM MSE	ED-LSTM RMSE
JAZAN Cases from JJuly 1st to September 30th 2020	2	1.96	1.40	2.6	1.63
	3	0.24757	0.49756	8	3
	4	2.9	1.7	2.9	1.7

Table 1: The prediction error using 1D-CNN and ED-LSTM with more than 1 output step.
Statistical metrics mean square error (MSE) and root mean square error (RMSE).

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In the final week of March, when there were 500 incidents, Saudi Arabia implemented a curfew and severely penalized those who broke the rule (West and Bergstrom, 2021). By the end of March, the Saudi government offered free healthcare to all of its citizens and residents. The bulk of the country was placed under a 24-hour curfew, many major city neighborhoods and districts were ordered to be locked down and isolated, and a vast community testing program was initiated by Saudi Arabia in April as part of its strictest measures to date. Since distance education has become a reality, we must stand at it to identify its positives to enhance and develop it. Parents and students alike attested that distance education is the way of the future and offers numerous benefits, chief among them being the ability to communicate with teachers and students as well as access lessons at any time. Additionally, it encourages parents to educate their children electronically. Saves work and time. Since the educational process solely looks forward to the academic content, it stimulates the student to obtain the greatest quantity of abilities and educational achievement. It encourages the person to fully trust himself by allowing him to select the sources of knowledge he finds inspiring. Jo *et al.* (2023) presented Reality Visualizations of Online Fitness Videos Support Flow for At-Home Exercises in response to the growing availability of smart devices and the Internet. The old approaches to online physical education (OPE) and exercise have been supplanted by fitness software and smart gadgets. Chen *et al.* (2021) reported that online fitness has become more well-liked by the public with the use of live broadcasting.

In relation to the anti-COVID-19 strategies implemented during that period, we assess the COVID-19 infection curve over many structural pathways in the JAZAN region that is we analyze the data in a variety of ways. Figure 6 shows data are aggregated according to 4 intervals of time; in the first interval data increased until the number of cases of COVID-19 peaks on August 18th, 2020, and then continues to drop until it reaches zero by the end of September 2020, the fourth interval. This result lends support to relevant hypotheses, such as those of the authors of (Schlickeiser and Schlickeiser, 2020), who describe a Gaussian, bell-shaped evolution to account for the temporal spread of epidemic events.

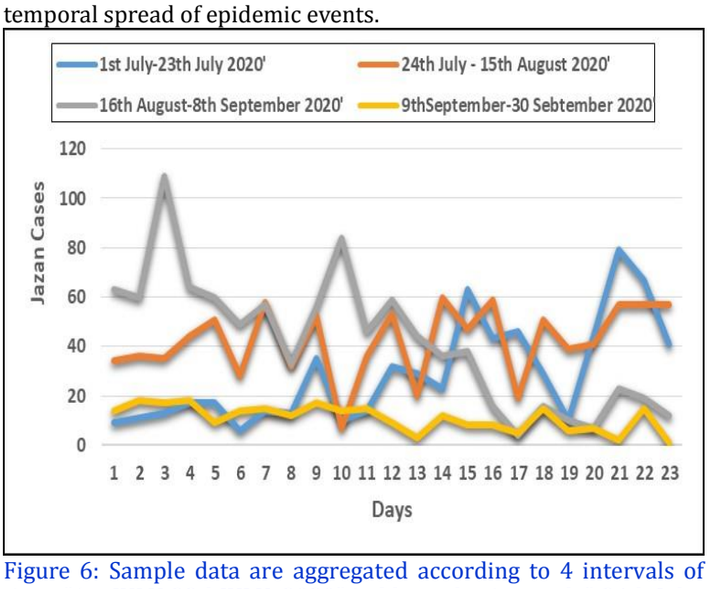

Figure 6: Sample data are aggregated according to 4 intervals of time; "1st JULY-23thJULY, 2020" in blue color interval, " 24th July-15th August, 2020" in orange color interval, "16thAugust-8th September,2020" gray color interval and "9th September - 30th September, 2020" yellow color interval.

This indicates that the policies implemented are what cause the anti-COVID-19 policies' apparent impact, as shown by the infection curve in this research. The visibility graph is a time series analysis method that developed by Lacasa *et al.* (2008) developed. Due to the nonzero elements' significant concentration along the major diagonal of the matrix, the visibility network is spatially limited, indicating that connections are predominantly generated between close nodes. The result demonstrates that the possibilities of hitting maximum (infection) values (and so creating new points in the visible network) in the future are considerably low, in contrast to medium and low-degree nodes, whose future behavior is less clear. Policy implementation has reduced predicted assessment error.We used two algorithms: encoder-decoder LSTM and 1D-CNN.LSTM aims to solve long-term reliance issues by building long-term memory (Hochreiter and Schmidhuber, 1997). The encoder model reads and interprets input sequences. The encoder produces a fixed-length vector representing the model's sequence interpretation. The encoder output feeds the decoder.Start by repeating the encoder's fixed-length output for each time step in the output sequence (Kumar *et al.*, 2023). A basic CNN is made up of three layers: a convolutional layer, a pooling layer, and a fully linked layer. The fully connected layer, a traditional neural network output layer is used to present the findings. The convolutional layer is responsible for extracting the patterns and features, the pooling layer is used to minimize the dimensions. A neural network with more than three layers, including the inputs and outputs, is referred to as a "deep learning algorithm". Splitting the sequence into input/output patterns, or samples,so that the model can learn from them and helps us develop an n-step prediction. The input and output components may have different numbers of time steps.For instance, consider the univariate time series: (1, 2, 3, 4, 5, 6, 7, 8, 9). We can use the last three time steps; (5, 6, 7) to predict the next two (8,9).

For prediction evaluation, we employ two methods: The persistence algorithm suchnaive forecast (Palupi, 2022) uses the previous time step (t-1) value as a baseline to estimate the future time step (t+1). For "training," 70% of observations will be kept and 30% assessed. As shown in Figure 5the predicted green curves are close to the real orange curves. MSE takes into account the average quadratic discrepancies between real and anticipated values. We evaluated multi-step input and output performance utilizing ED-LSTM and 1D-CNN. We get an average result by running the model several times. Table 1 showed 1D-CNN's forecasts for the following three values are very close to real.

CONCLUSIONS Several technologies were essential to keeping the nation running, during the pandemic. In this study, we highlighted that the Kingdom of Saudi Arabia is a model for best practices in the fight against COVID-19 because of the technologically driven success of certain of its countermeasures. As an example of the results of these approaches, we proposed a case evolution study from the southern province of Jazan. Data on the daily Jazan COVID-19 infection curve collected from July 1 to September 30, 2020, were processed using multiple Python 3.7 software modules. This made it possible to create a complex network analysis of time series to find structural changes in the infection curve. Additionally, this sequential compression of the COVID-19 infection curve portions suggests that the pandemic in Saudi Arabia is about to peak and enter the second (declining) half of the bell-shaped distribution from the standpoint of Gaussian modeling. With this measurable shift in the COVID-19 infection curve, Saudi Arabia can now be considered a success story in the fight against pandemic.

CONFLICT OF INTEREST: All the authors mentioned in this paper declared that they have no conflict of interest.

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