Analyzing the Impact of Lockdown on COVID-19 Pandemic in Saudi Arabia

Jayadev Gyani[1], Mohd Anul Haq[2], Ahsan Ahmed[3,*]

[1,2]Department of Computer Science, College of Computer and Information Sciences, Majmaah University, Al-Majmaah-11952, Saudi Arabia
[3]Department of Information Technology, College of Computer and Information Sciences, Majmaah University, Al-Majmaah-11952, Saudi Arabia

*Corresponding Author: Ahsan Ahmed, a.ahmed@mu.edu.sa

Summary
The spread of Omicron, a mutated version of COVID-19 across several countries is leading to the discussion of lockdown once again for curbing the spread of the new virus. In this context, this research is showing the impact of lockdown for the successful control of the COVID-19 pandemic in Saudi Arabia. The outbreak of the COVID-19 pandemic around the globe has affected Saudi Arabia with around 2,37,803 confirmed cases within the initial 4 months of transmission. Saudi Arabia has announced a 21-day lockdown from March 23, 2020, to reduce the transmission of the COVID-19 pandemic. Machine Learning-based, Multinomial logistic regression was applied to understand the relationship between daily COVID-19 confirmed cases and lockdown in the 17 most-affected cities of KSA. We used secondary published data from the Ministry of Health, KSA daily dataset of COVID-19 confirmed case counts. These 17 cities were categorized into 4 classes based on lockdown dates. A total of three scenarios such as night lockdown, full lockdown, and no lockdown have been analyzed with the total number of confirmed cases with 4 classes. 15 out of 17 cities have shown a strong correlation with a confidence interval of 95%. These findings provide evidence that the COVID-19 pandemic may be partially suppressed with lockdown measures.

Keywords:
Omicron; Correlation; Covid-19; Machine Learning; Multinomial Logistic Model; Lockdown

1. Introduction

As per the statistics of the Ministry of Health portal, there are confirmed Cases: of 549,955 up to the first week of December 2021. The first case of Omicron was reported in Saudi Arabia in the first week of December 2021. Coronavirus disease (COVID-19) is a pandemic that was first found in Wuhan City of Hubei Province, China, in December 2019(World Health Organization, 2020). The World Health Organization (WHO) has declared COVID-19 as pandemic after it spread across the globe, and there are about 13,113,181confirmed cases (ncases)with 7,268,022(55.42%) recovered cases worldwide and 573,288(7.88%) total deaths as of July 14, 2020, worldwide (World Health Organization, 2020). Saudi Arabia reported an index case of the COVID-19 pandemic in the first week of March 2020. In Saudi Arabia the ncases were 237,803with 177,560(74.66%) number of recovered cases and 2283(1.28%) number of deaths till July 14, 2020 (Ministry of Health, 2020). Ministry of Health, Saudi Arabia maintains a daily covid cases portal [3]. Fig. 1 shows the number of daily cases and number of recovered persons from COVID-19.

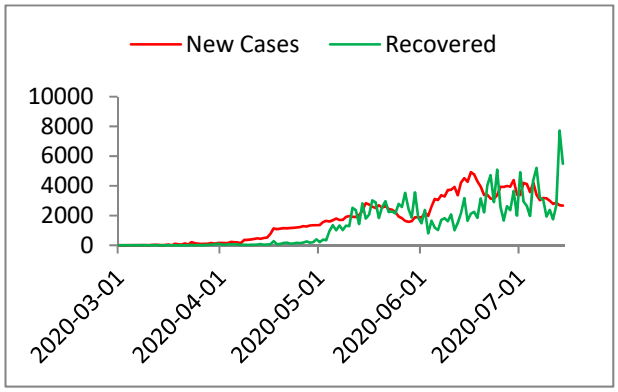

Figure 1: Total number of ncases per day in Saudi Arabia from March 02, 2020 to July 04, 2020

In absence of a vaccine, lockdown is one of the best solutions to prevent the spread of COVID-19. To slow down the transmission of the pandemic, around 172 countries implemented different types and levels of lockdown (UNESCO 2020). In Saudi, the index case of COVID-19 was observed on March 02, 2020, and the lockdown has been started on March 23, 2020. This nationwide lockdown was important to limit the movement, except for essentials including food and healthcare. The lockdowns were lifted off after 04 July 2020.

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Some studies assess the effect of lockdown with COVID-19 spread in different parts of the world. Tobias assessed the effect of lockdown using quasi-Poisson regression based on ncases, deaths, and number of admissions in an intensive care unit (ICU) in Italy and Spain[1]. A conceptual model based on the SIR method was applied to assess the effectiveness of lockdowns for the reduction in contacts [2]. Ambikapathy and Krishnamurthy used differential equation-based modeling to assess the impact of lockdown on COVID-19 spread in India[4]. Nalini et al., applied the ARIMA time series model to assess the effect of lockdown on ncases in Italy[5]. Mamud et al. discussed the measures taken by Saudi Arabia for the prevention of COVID-19 pandemic such as taking precauationary measures, quarantining the people arriving the country, closing international boarders, tracing and treating the patients[6]. Wilke et al., analyzed the impact of COVID-19-related implementations on global physical activity levels[7]. Roques et al. estimated the effect of the lockdown in France on the contact rate and the effective reproduction number Re of the COVID-19 using mechanistic-statistical formalism[8]. Al-Awadhi and Ahmed used logistic regression models to identify factors that lead to student attrition and gain insight into possible measures to reduce the attrition rate[9]. UNESCO COVID-19 response and resources are made available to all nations by UNESCO[10].

Li K et al. analyzed the impact of stimulus payments to low-income people on their spending during the pandemic [11]. Yun et al. proposed a COVID-19 mortality prediction model to reduce the load on the healthcare infrastructure [12]. Ayoub et al. proposed a system to classify and categorize the COVID-19 outbreak in Pakistan by analyzing the data collected every day from different regions of Pakistan. They compared the performance of various machine learning classifiers such as Decision Tree, Naive Bayes), Support Vector Machine, and Logistic Regression on the COVID-19 dataset collected in Pakistan.[13].

In the initial stages of spreading of this virus, there were around less than a thousand confirmed cases in China. From that period, the number of people who were reported to have died increased drastically day by day [14]. The WHO declared that the most common symptoms of this virus are tiredness, fever, and dry cough [15]. Most people with mild symptoms can recover without rigorous treatment or prescriptions. People who are affected with severe symptoms needed in-patient treatment [16].

In the United Kingdom, the National Health Service (NHS) reported cases with more severe symptoms, including high fever and persistent cough. The NHS recommended these people to self-quarantine for 14 days [17]. The infection spreads from one person to another person through the droplets emitted from the infected patients, when an infected person coughs or sneezes [18]. People may become infected by touching contaminated surfaces and then touching the face [19].

Attaallah et al. proposed a model to predict the level of COVID-19 spread in Saudi Arabia and suggested the administration to take precautionary measures [20]. Algaissi et al. reviewed the response of Saudi Arabia to COVID-19 with the experience learned from the Middle East respiratory syndrome coronavirus (MERS-CoV) epidemic control in Saudi Arabia during 2012 [21].

2. Dataset

The data of COVID-19 confirmed cases (ncases) of 17 cities was collected from the official website of the Ministry of Health - Kingdom of Saudi Arabia (https://COVID19.moh.gov.sa/). Fig. 1 presents the status of the number of confirmed and recovered cases (as of July 04, 2020) in Saudi Arabia. The location map of 17 cities under investigation showed in Fig. 2. Among all cities maximum number of cases are reported in Riyadh followed by Jeddah, Al- Makkah, Al-Madinah, Dammam, Al Houfuf, Khobar, Ta'if, Al Jubayl, Al Qatif, Dhahran, Buraydah, Diriyah, Khamis Mushait, Al Mubarraz, Tabuk, Ha'il. These 17 cities cover nearly 83.46% of the total ncases in Saudi Arabia.

Lockdowns were imposed on different dates for different cities based on the intensity of spreading of Covid-19 cases. The 17 cities were categorized into 4 classes based on lockdown dates. A total of three lockdown status scenarios such as night lockdown (nl), full lockdown (fl), and no lockdown (nol) have been analyzed with the ncases into 4 lockdown status classes. Fig. 2 shows the cities observed under this study.

The 17 cities are grouped according to the imposition of lockdown dates and lockdown status as shown in Table 1.

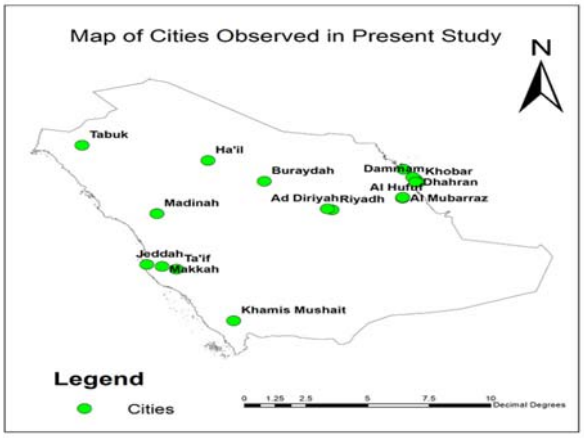

Figure 2: Map of Cities observed in Present Study

Table 1: Lockdown Status in Saudi Arabia in 4 different classes

Lockdown Patterns	Cities	Dates	Lockdown Status
Class-I	Riyadh,Dammam,Tabuk,Dhahran,Hofuf,Jeddah, Taif,Khobar and, Qatif(9 cities)	21/03/2020 to 22/03/2020, 22/06/2020 to 04/07/2020	nol
		23/03/2020 to 05/04/2020, 24/04/20220 to 22/05/2020, 28/05/2020 to 21/06/2020	nl
		06/04/2020 to 23/04/2020, 23/05/2020 to 27/05/2020	fl
Class-II	Jubail,AlMubbarraz,KhamisMushaiat, Buraidah, Abha and Hail (6 cities)	21/03/2020 to 22/03/2020, 22/06/2020 to 04/07/2020	nol
		23/03/2020 to 22/05/2020, 28/05/2020 to 21/06/2020	nl
		23/05/2020 to 27/05/2020	fl
Class-III	Al Makkah	21/03/2020 to 22/03/2020, 22/06/2020 to 04/07/2020	nol
		23/03/2020 to 01/04/2020, 24-04-2020 to 25-04-2020, 15-05-2020 to 22/05/2020, 28/05/2020 to 21/06/2020	nl
		02/04/2020 to 23/04/2020, 26/04/2020 to 14/05/2020, 23/05/2020 to 27/05/2020	fl
Class-IV	Al Madinah	21/03/2020 to 22/03/2020, 22/06/2020 to 04/07/2020	nol
		23/03/2020 to 01/04/2020, 24/04/2020 to 22/05/2020, 28/05/2020 to 21/06/2020	nl
		02/04/2020 to 23/04/2020, 23/05/2020 to 27/05/2020	fl

3. Methodology

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As a preprocessing step, 3 days moving average was applied to smooth the dataset of ncases. Machine learning-based multinomial regression was applied to find the correlation between lockdown status and the spread of COVID-19 disease using the equations (1) and (2). Multinomial regression is similar to logistic regression but is applicable when the response variable is a nominal categorical variable with more than 2 levels. Multinom function from the nnet package of R Language was used on total of 4 classes for 3 lockdown statuses (Table 1). We choose the level of our outcome that is to be used as the baseline and will be used in relevel function. The noc is taken as a reference for the estimation of z-values and p-values. The multinom package has no option for p-value calculation for the regression coefficients, therefore p-values are calculated using z-tests.

$$\ln\left(\frac{P(LockDownStatus=fl)}{P(LockDownStatus=nol)}\right) = C_{10} + C_{11}\, ncases \quad (1)$$

$$\ln\left(\frac{P(LockDownStatus=nl)}{P(LockDownStatus=nol)}\right) = C_{20} + C_{21}\, ncases \quad (2)$$

H_0: Null hypothesis: There is no effect of lockdowns on the ncases detected in Saudi Arabia.
H_1: Alternative Hypothesis: There is a significant effect of lockdowns on the ncases detected in Saudi Arabia.
Z-statistic can be calculated using the formula:

$$Z\ \text{Test} = (\bar{x} - \mu)/(\sigma / \sqrt{n}) \quad (3)$$

Where $\bar{x}$ = mean of Sample; μ = mean of Population; σ = standard deviation of the population; n = number of observations

The null hypothesis is false when the probability value is less than 0.05. The probability threshold value is called α below which the null hypothesis is rejected. αis also called the significance level. If the data produce values that exceed this threshold, then the null hypothesis can be rejected; otherwise, we fail to reject the null hypothesis. We consider α=0.05 and use a two-tailed z-test to reject the null hypothesis.

When the null hypothesis is rejected, the effect is said to be statistically significant.

4. Results and Discussion Acknowledgments

The correlation results for all 4 classes are given in Table 2. Class I and Class II showed a strong correlation whereas Class-III and Class-IV showed a weak correlation. Class-III and class-IV have many outliers even after applying a 3-days moving average therefore the relationships were weak.

4.1 Class-I

In Class-1 for 9 cities (Riyadh, Dammam, Tabuk, Dhahran, Hofuf, Jeddah, Taif, Khobar, Qatif)

C_{11} an increase of one unit in the variable ncases is associated with the decrease in the log odds of being in fl vs nol in the amount of 0.00204.

C_{21} an increase of one unit in the variable ncases is associated with the decrease in the log odds of being in nl vs nol in the amount of 0.00079.

As the z-value is below -1.96 and the p-value is <0.05 there is a strong correlation between ncases and fl with reference to nol. So the null hypothesis is rejected.

As the z-value is below -1.96 and the p-value is <0.05 there is a strong correlation between ncases and nl with reference to nol. So the null hypothesis is rejected. Fig. 3 shows the spreading of Covid-19 in 9 cities.

4.2 Class-II

In Class-II for 6 cities (Jubail, AlMubbarraz, Khamis Mushaiat, Buraidah, Abha, Hail)

C_{11} an increase of one unit in the variable ncases is associated with the decrease in the log odds of being in fl vs. nol in the amount of 0.01198

C_{21} an increase of one unit in the variable ncases is associated with the decrease in the log odds of being in nl vs. nol in the amount of -0.01351

As the z-value is below -1.96 and the p-value is <0.05 there is a strong correlation between ncases and fl with reference to nol. So null hypothesis is rejected.

As the z-value is below -1.96 and the p-value is <0.05 there is a strong correlation between ncases and nl with reference to nol. So null hypothesis is rejected. Fig. 4 shows the spreading of Covid-19 in 6 Cities.

4.3 Class-III

In Class-III for Makkah City

C_{11} an increase of one unit in the variable ncases is associated with the decrease in the log odds of being in fl vs. nol in the amount of 0.0011071673

C_{21} an increase of one unit in the variable ncases is associated with the decrease in the log odds of being in nl vs. nol in the amount of 0.0005840428

As the z-value is in the range -1.96 to +1.96 and the p-value is >0.05 there is no evidence of correlation shown between ncases and fl with reference to nol. So null hypothesis is true.

As the z-value is in the range -1.96 to +1.96 and the p-value is >0.05 there is no evidence of correlation shown between ncases and nl with reference to nol. So null hypothesis is true.

The reason is when no lockdown was imposed the number of cases came down as the Government of Saudi Arabia took stringent steps during full lockdown and night lockdown days to reduce the spread of infected cases. Fig. 5 shows the spreading of Covid-19 in Makkah City.

4.4 Class-IV

In Class-IV for Madinah City

C_{11} an increase of one-unit in the variable ncases is associated with the decrease in the log odds of being in fl vs. nol in the amount of 0.005777350

C_{21} an increase of one unit in the variable ncases is associated with the increase in the log odds of being in nl vs. nol in the amount of 0.001985112

As the z-value is in the range -1.96 to +1.96 and the p-value is >0.05 there is no evidence of correlation shown between ncases and fl with reference to nol. So null hypothesis is true.

As the z-value is in the range -1.96 to +1.96 and the p-value is >0.05 there is no evidence of correlation shown between ncases and nl with reference to nol. So null hypothesis is true.

The reason is when no lockdown was imposed the number of cases came down as the Government of Saudi Arabia took stringent steps during full lockdown and night lockdown days to reduce the spread of infected cases. Fig. 6 shows the spreading of Covid-19 in Madinah City.

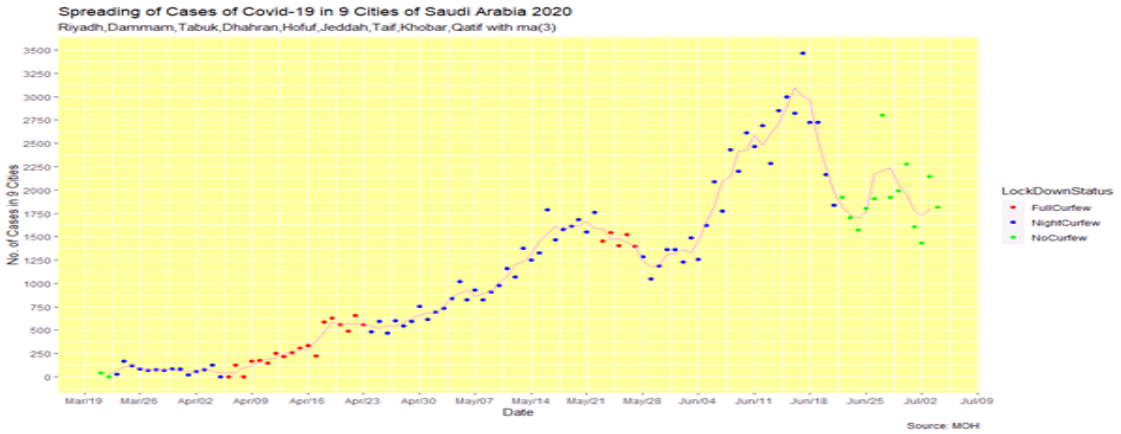

Figure 3: Spreading of Covid-19 in 9 cities

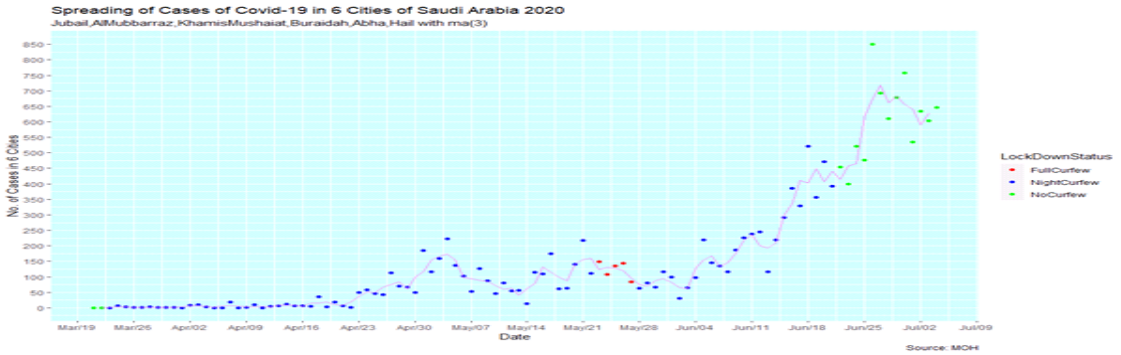

Figure 4: Spreading of Covid-19 in 6 cities

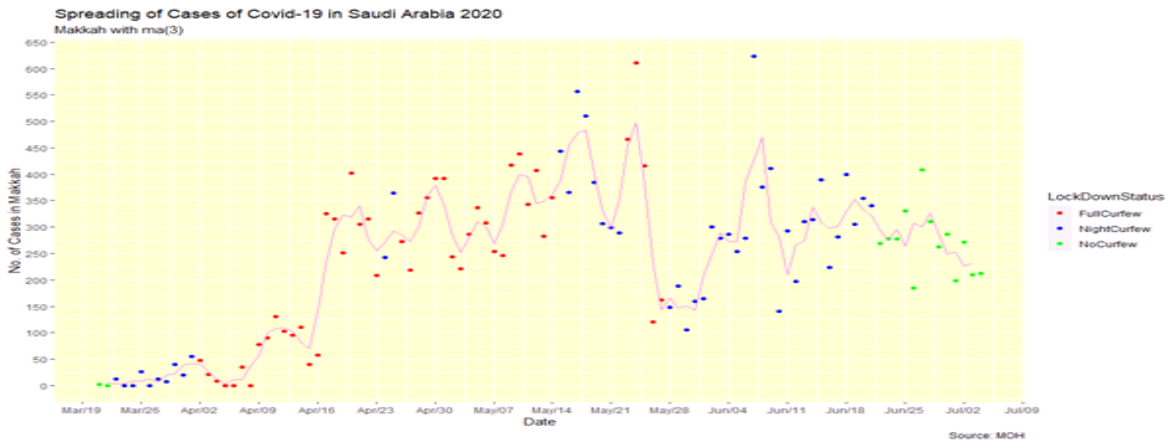

Figure 5: Spreading of Covid-19 in Makkah City

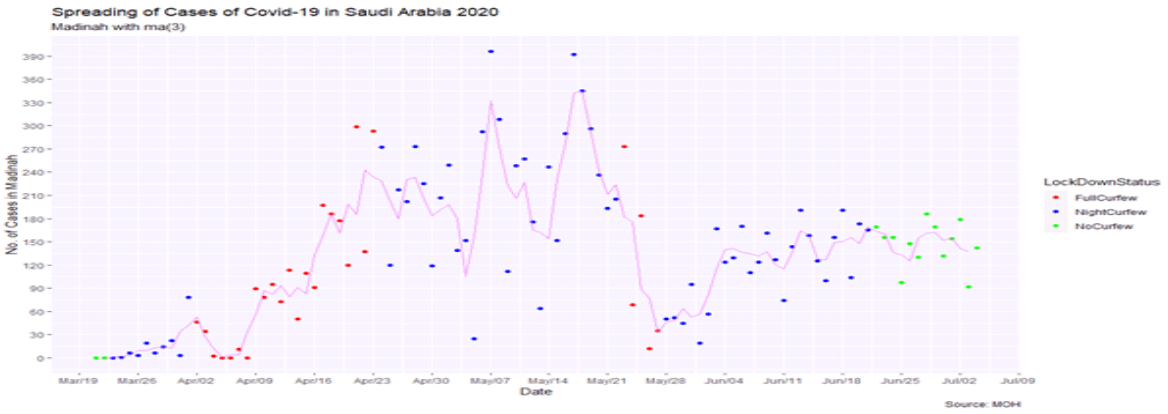

Figure 6: Spreading of Covid-19 in Madinah City

Table 2: Correlation Results for Different Cities Grouped on Lockdown Status in Saudi Arabia

Class No.	Multinomial Reference	z-Value	p-Value	Standard Errors	Results
CLASS-I	fl/nol 9 Cities	-3.828745	0.0001287983	0.0005337769	Strong Correlation CI>95%
	nl/ nol 9 Cities	-2.066731	0.0387595406	0.0003864419	Strong Correlation CI>95%
CLASS-II	fl/ nol 6 Cities	-2.673585	7.504525e-03	0.004479272	Strong Correlation CI>95%
	nl/ nol 6 Cities	-4.179856	2.916933e-05	0.003231271	Strong Correlation CI>95%
CLASS-III	fl/ nol Makkah	-0.4656594	0.6414593	0.002377633	No significant correlation
	nl/ nol Makkah	-0.2444806	0.8068586	0.002388912	No significant correlation
CLASS-IV	fl/ nol Madinah	-1.3214980	0.1863354	0.004371819	No significant correlation
	nl/ nol Madinah	0.5174922	0.6048126	0.003836022	No significant correlation

5 Limitations

In the present investigation, two types of data i.e. nominal (lockdown status) and continuous (ncases) were analyzed using multinomial logistic regression. In the present scenario, we can't apply linear regression directly between nominal and continuous variables therefore logit transformation of the dependent variable is required. In the case of Makkah and Madinah, we have more outliers even after applying 3 days moving average therefore we got a weak relationship between ncases and lockdown status. The fitting of the dependent variable was performed by adding or deleting alternative outcome categories that do not affect the results among the remaining outcomes. In the case of multinomial logistic regression, it is not as straightforward to apply statistical analysis for model diagnostics, unlike

logistic regression. A large sample size is required in multinomial regression as it uses a maximum likelihood estimation method.

6 Conclusion

The current study analyses the impact of lockdown measures with COVID-19 cases transmission in 17 cities of Saudi Arabia using multinomial logistic regression. These 17 cities were categorized into 4 classes based on lockdown dates. A total of three scenarios such as night lockdown, full lockdown, and no lockdown have been analyzed with the total number of confirmed cases with 4 classes. 15 out of 17 cities have shown a strong correlation with a confidence interval of 95%. The two cities Makkah and Madinah followed a different COVID-19 spread pattern as there was full lockdown for several days, so no lockdown days were minimum for analysis. The future scope of this research is to include more parameters such as city-wise transmission rate, geospatial road traffic data for a better understanding of measures. The impact of lockdown was visible across the world to control the spread of Covid-19. In the first week of December 2021, the Covid-19 cases in Saudi Arabia are moving around 30. If the spread of Omicron becomes uncontrollable, lockdown is the only choice left for the administration.

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JAYADEV GYANI has been working in the Department of Computer Science at CCIS, Majmaah University, Kingdom of Saudi Arabia since 2015. He received his PhD in Computer Science from the University of Hyderabad, India in 2009 and Master's degree in Computer Science and Engineering from Osmania University, INDIA in 1994. He worked as Lecturer, Asst. Professor, Professor, and Head of the CS Department, and had a teaching experience of 25 years. His research interests include software engineering, big data analytics, distributed computing, machine learning algorithms, and their applications. He has several publications in international journals and conferences to his credit. He presented papers in conferences held in Germany, Malaysia, and Nepal. He is a member of ACM and senior member of IEEE.

MOHD ANUL HAQ earned a Ph.D. from Indian Institute of Technology Roorkee, India, in 2013. He received a Master's degree in Computer Applications from UP Technical University (currently Dr. A.P.J. Abdul Kalam Technical University Uttar Pradesh) and Bachelor's Degree from HNB Garhwal University, Srinagar, Uttarakhand. The central component of his research is in artificial intelligence and machine learning. The target applications of his research are deep learning-based image classification, modeling, and forecasting. He completed several research projects sponsored by different national/international agencies. He serves as guest editor and reviewer in reputed journals including Nature, Elsevier, Springer, Techscience press, and many more. He was invited from Microsoft HQ, Redmond, to showcase his AI research projects for the AI for Earth summit in 2019.

AHSAN AHMED earned his Master's degree in Computer Science from Jamia Hamdard University, New Delhi, India, in 2008. From 2008 to 2010, he was a research intern at CSIR's laboratory. Since November 2010, he has been working as a lecturer in the Department of Information Technology, College of Computer and Information Sciences, Majmaah University, Al-Majmaah, Kingdom of Saudi Arabia. He had 11 years of experience in teaching. His research interests include machine learning, web technologies, cloud computing, reputation systems and e-learning. He has presented four papers in international conferences and published nine research papers in reputed journals indexed by Scopus and SCI under his research and other technical areas.