Influence of mobility, population and effective reproductive number (R) on the transmission of Coronavirus

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Abstract. The present investigation reviews the potential causes of the novel Corona virus (COVID-19) spread based on various parameters studied. At the onset of COVID-19 pandemic there were number of parameters that were believed to be the dominating factor, and the demand of present scenario is to determine the potential variables that enhances the virus transmission. The social distancing is the main weapon to fight against the coronavirus, keeping this in mind the impact of mobility is analyzed. In addition to this the population density and the effect of temperature and humidity is studied on the present pandemic.

Keywords: Corona virus; mobility; population density, effective reproductive number, transmission.

1. Introduction

The major setback in the present scenario faced by the entire world is the spread of novel coronavirus that found its root in the city of Wuhan, China. Till date millions are affected and suffering from it as well as millions deceased. The major challenge faced by the entire world is to control the spread of the corona virus and all the countries are doing their best to cease the spread of this disease, as there is no vaccine for the cure of this novel disease. Scientists and researchers are working to find out the method of reducing the spread by investigating the parameters on which the virus blowout depends [1-5]. Hemmes et al. [1] analyzed the seasonal influence of temperature and humidity on the life of virus. In many organisms their survival in air indicates that these organisms can survive in the dry condition as well. Meanwhile it seems to be beneficial to analyze the effect of temperature and humidity on the survival of the viruses. Similarly, Zhang et al [2] analyzed and found a complex non-linear relationships between the climate parameters and various types of influenza in Shanghai. Schuit et al. [3] reported that the decay rate of virus was depending on the intensity of sunlight, whereas not much difference was observed while analyzing two different relative humidity levels. Marr et al. [4] analyzed the virus behaviour on seasonal parameters. They reported that the Virus survival and transmission depends strongly on absolute humidity (AH) than the relative humidity (RH). A mechanistic explanation for why RH is more prospective than AH to control virus survival and transmission. Number of investigations as well as analysis is going on to determine the influence of temperature and other seasonal parameters on the virus survival and transmission [5-7]. The Effective reproductive Number (R) is determined by the collective data of temperature and humidity by Wang [8]. The Effective Reproductive Number (R) is derived from temperature and humidity, as suggested by Wang et al. [8] and developed a website that generates the data of R Number according to daily temperature and relative humidity of major cities and the data is available at http://covid19-report.com/#/r-value.

Malki et al. [9] used a model of machine learning bring out a relationship between various factors and the spreading rate of COVID-19. The weather variables like temperature and humidity of a region and the data of confirmed cases are analyzed with machine learning algorithms to determine the impact of weather variables on the corona virus transmission. It is revealed that the weather variables are more
applicable in predicting the death rate as compared to the other variables like urbanization, age and population. Munayco et al. [10] evaluated the early COVID-19 spread trend and the impact of social distancing involvements in Lima, Peru. The analysis of reproduction number, $R$ in the early transmission phase in Lima is carried out using daily data. The results of implementing the social distancing in Lima was reported compared to the pre social distancing phase. The results indicates that closing public gathering spots and following the social distancing helped in lowering the pace of coronavirus spread. Saha et al. [11] performed an a study using spatial time-series on the effect of lockdown for coronavirus pandemic on the community mobility for different regions. The data for this study has been collected between 15 February to 30 April, 2020. The analysis bring out a picture of the mobility trends during pre-lockdown and after lockdown period across various places viz. groceries, pharmacies, parks etc. The may help to take decision whether lockdown is a positive move for creating social distancing that may lower the spread Coronavirus.

Sun et al. [12] analyzed the relationship between geographic information viz. latitude, longitude and altitude and confirmed COVID-19 cases to reveal the effect of population density on the virus transmission. The findings of analysis revealed a negative relation between the COVID-19 cases and latitude/altitude as well as under strict lockdown the population density is not an important factor. Espejo et al. [13] targets for a possible association between coronavirus pandemic and environmental factors which will lead to recommendations to control the threats in future. The report indicates the relation between coronavirus transmission and air pollution, but, the pandemic spread having relation with climatic factors could not be established. It was recommend to use smart technology to make a data base and implementing the "one health" approach as well as use of biodegradable medical utilities in future. Shakil et al. [14] carried out the significant analysis of 57 studies based on the correlation between coronavirus outbreak and the environment. About 74% of the analysis presented in the present work are published in Science of the Total Environment. Major four research bands are selected for analysis with COVID-19 are: environmental degradation, air pollution, climate/metrological factors, temperature. Wu et al. [15] investigated the corona cases and deaths on the basis of temperature and relative humidity for 166 countries as of March 27, 2020. The data collected was analyzed and it was reported that the temperature and relative humidity are negatively related to new corona cases and deaths. The results provide preliminary evidence that coronavirus pandemic might partially be lowered with temperature and humidity. Shi et al. [16] analyzed the effect of temperature on the COVID-19 epidemic in China by collecting daily mean temperatures from31 regions. The general prediction by using a susceptible-exposed-infectious-recovered (M-SEIR) model was, that the intensity of coronavirus pandemic decreases slightly with higher temperatures.

Oztig and Askin [17] studied the relation between human mobility and the coronavirus spread in 144 countries. The result reveals a positive correlation between higher airline passenger traffic in a country with a large patient’s count of COVID-19. Similarly the countries with higher population density, and elderly population have a higher corona cases as compared to other countries. Zhu et al. [18] investigated the role of air quality on the link with human mobility and the infection caused by this novel coronavirus. The daily data pertaining to air quality, coronavirus cases, and human mobility was collected for 120 cities from China. The results revealed that a noteworthy connection between human mobility and daily coronavirus cases. The final conclusion suggests that reduced human mobility could lower the pandemic transmission. Carteni et al. [19] with an aim to determine the effect of human mobility on the transmission of Coronavirus in Italy. The results revealed that the human mobility is a major variables that determines the coronavirus cases with others variables and environmental variables. This result produced, if confirmed by other investigations, will lay down the base for more effective control of coronavirus.
The present investigation is taken up with an aim to predict the potential parameters that plays a significant role in the transmission of the novel coronavirus. The major variables that influence the pandemic spread are temperature, humidity, air quality, human mobility etc. An effort to determine the major dominating parameters are determined that are helpful in lowering down the coronavirus transmission.

2. Prediction of mobility on the coronavirus transmission
The present coronavirus pandemic is spreading at a larger pace and the rate is increasing as the lockdown restrictions are slowly being released. The complete lockdown phase and the post lockdown phase reveals that the mobility and social distancing is the major factor that should be taken care of. The data of the flights of selected countries is of 2018 and it is used to predict the country that is having higher human mobility across the countries. This data is helpful in predicting the transmission of coronavirus in the first phase, where the virus is carried by human across the countries. Fig. 1 shows the flight data of different countries and the coronavirus cases per million. The figure reveals that majorly the countries with higher mobility across the countries are affected. There can be exceptions in some of the countries as the mobility in the present scenario needs to be analyzed, as well as the medical facilities and other variable also plays a major role in the transmission.

![Figure 1. Comparison of corona cases/million for flight travel.](image)

3. Prediction of population density on the coronavirus transmission
Figure 2 displays the population density of different countries and the corona cases per million to bring out an inference about the transmission. The figure reveals the transmission in a country phase 2 and 3 (WHO designed), where the mass transmission of virus will take place. It is seen that the countries with high population have a higher transmission and thus large number of cases. But it should be kept in mind that phase 2 and 3 transmission takes place when the virus is brought in the country through a traveller. Thus Fig. 1 and 2 should be seen together and carefully to analyze the transmission of virus. A country
with higher population might not have a higher corona cases as the mobility of people is very low, whereas with very low population and higher mobility the cases increases.

![Graph showing comparison of corona cases/million for population density.](image)

**Figure 2.** Comparison of corona cases/million for population density.

4. **Prediction of Effective reproductive number**

The data collected for number of countries for Corona patients and the transmission of virus for a period ranging from 15 February to 4 August, 2020 is analyzed. The analysis is carried out by taking into account the annual Effective reproductive Number ($R_e$) for a country and then the forecast for the transmission of virus is made comparing the cases in other countries. The Effective reproductive Number ($R_e$) for various countries is shown in Fig. 3. It is seen that the $R_e$ number is higher in winters whereas as the summer approaches it reduces. Fig. 4 shows the variation of the corona cases for Italy for a period of 22 January to 4 August, 2020, where the $R_e$ number was high at the beginning of year and then it reduces. This indicates that the spread of the coronavirus in this region will also see a downfall in the upcoming months. The prediction of coronavirus spread depending on $R_e$ number gains authenticity as we can see in Fig. 4 that the value of the $R_e$ number is almost constant on a higher side, which is promoting the spread of virus. Throughout the year the $R_e$ number is constant and this alarms towards a severe upcoming condition as well as the present also.

Fig. 5 presents the data of United States of America for coronavirus cases and the $R_e$ number. It is seen that the value of the $R_e$ number is almost constant and low throughout the year, which is always below value of 2. Being a cold country and the summer are almost there, but the temperature does not goes up to a higher value, thus the limitation the spread of coronavirus will be low. In the upcoming months the $R_e$ number will decrease, and it can be predicted that the spread of the coronavirus will be controlled.
Figure 3. The Effective reproductive Number (R) for different countries.

Figure 4. Data of corona cases and $R$ Number for Italy.
Fig. 5. Data of corona cases and $R$ Number for USA.

Fig. 6 presents the data of India for coronavirus cases and the $R$ number. It is seen that the value of the $R$ number is on the lower side throughout the year, which is always below value of 1.8. Being a hot country and the summer are almost there, provides an advantage to limit the spread of coronavirus. In the upcoming months the $R$ number will decrease, and it can be predicted that the spread of the coronavirus will be controlled.

Fig. 6. Data of corona cases and $R$ number for India.
By comparing the $R$ number of other countries with that of India it is observed the values $R$ number are lower for India as compared to other country. The origin of coronavirus was China and then it spread all over the world, still the country with lower $R$ number is way behind the others in the coronavirus patients as seen in the graphs provided. This comparison is carried out to justify the effect of temperature and humidity on the coronavirus spread. As $R$ number is the integrated number obtained from temperature and humidity, thus it can be concluded that the spread of coronavirus is depending on $R$ number in addition to several other parameters.

5. Conclusions
It can be concluded from the analysis that there are number of potential parameters that should be addressed with serious concern to lower down the pandemic transmission. The human mobility is one of the major factor which cannot be ceased, but should be carried out with utmost care and precautions. Similarly the countries with higher population density have to take commanding measures to make the social distancing equivalent to law. It is observed from the study that the transmission rate is significantly high in the locations where the Effective reproductive number ($R$) is high and it can be predicted that in the upcoming seasons, the transmission of virus may lose its potential to spread.

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