TECHNIUM
SOCIAL SCIENCES JOURNAL

Vol. 10, 2020

A new decade for social changes

www.techniumscience.com

ISSN 2668-7798

9 772668 779000

Covid-19 spread prediction and its correlation with social distancing, available health facilities using GIS mapping data models in Lahore, Pakistan

Rafaqat Warda¹, Weiguo Song^{1*}, Gill Kaif³, Chuanli Huang¹, Shabbir Salman², Ashraf Nasir³

¹State Key Laboratory of Fire Science, University of Science and Technology of China, Jinzhai Road 96, Hefei, Anhui, People's Republic of China, ²Punjab Information Technology Board, Lahore, Punjab Pakistan, ³University of The Punjab, Lahore, Punjab, Pakistan

warda@mail.ustc.edu.cn

Abstract. Virus spreading and its mitigation is an important safety issue that has drawn wide attention of many countries and people. For researchers in this area, it is an interesting work to study virus spreading with safety theories and methods. In this paper, we worked on the spatial extent of SIR model, which considers the known facts of Covid-19 behavior i.e. its spreading extent with time, the total population of area concerned and dedicated health facilities. Also, a special relationship between Covid-19 cases and NLDI data driven by night-time satellite imagery is being discussed. Results predicted a huge gap between predicted and presently available facilities for number of hospitals, beds, and ventilators. Findings suggest that developing countries like our study area Lahore District, Pakistan needs to follow social distancing at immense level, which not only helps in reducing the numbers of infections and fatalities but also the time duration of the whole epidemic. Maps based on NLDI vales, predicted cases, hospitals and ventilators needs could be greatly helpful for policymakers to analyze situation and concentrate on areas which needs immediate attention. Dealing with the pandemic requires a pre-planned command and control structure that could make quick and informed decisions in the whole city. We recommend that the use of proper model prediction at Union Council level can help local government in policymaking related social distancing and healthcare systems. The decision of social distancing should be on time and like what percent of social distancing is needed, which tackle with the already available health care structure

Keywords. Covid-19, SIR model, Health facilities, Satellite imagery, Social distancing, Policymaking, Mapping

1. Introduction

The COVID-19 is an ongoing pandemic that is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)(WHO, 2020a). The outbreak was identified in Wuhan, China, in December 2019. The World Health Organization (WHO) declared the outbreak a Public Health Emergency of International Concern on 30 January 2020, and a pandemic on 11 March 2020 (Livingston et al., 2020). As of 2 May 2020, more than 3.36 million cases of COVID-19 have been reported in 187 countries and territories, resulting in more than 239,000 deaths. More than 1.06 million people have also been recovered (WHO, 2020b). The 2019–20 coronavirus pandemic was confirmed to have reached Pakistan on 26 February 2020, when a student in Karachi tested positive upon returning from Iran. (“Pakistan Detects First Coronavirus Cases, Links to Iran Outbreak | Voice of America - English,” n.d.) As of 1 May 2020, there have been over 16,800 confirmed cases with 4,315 recoveries and 385 deaths in the country. (“COVID-19 Health Advisory Platform by Ministry of National Health Services Regulations and Coordination ,” n.d.)

In China, the outbreak coincided with chunyun, the annual period of mass migration for the Spring Festival holidays that was to begin on 25 January, 2020. (Backer et al., 2020). To contain the outbreak, China implemented unprecedented intervention strategies on 23 January 2020. Whole cities were quarantined, the national holidays were extended, strict measures limiting travel and public gatherings were introduced, public spaces were closed, and rigorous temperature monitoring was implemented nationwide. (Yang et al., 2020) Confirmed cases of COVID-19 in Hubei, Guangdong and Zhejiang provinces on 10 February, 2020 were 31,728, 1,177 and 1,117, respectively, representing 80% of total cases nationwide. (“Outbreak report,” n.d.). The migration index out of Guangdong and Zhejiang provinces were greater than the inflow and were largest between January 7 and January 23, 2020. (“ Real-time update: map of new coronavirus pneumonia epidemic situation

,” n.d.). The migration index into Hubei province was greater than the outflow before January 23, signaling the homeward return of the migrant population for Spring Festival celebration. (Wang et al., 2014)After the implementation of control measures on January 23, 2020 the opportunity for the spread was decreased. The availability of a large pool of susceptible individuals allowed for a steady increase in the average number of new daily infections. With such interventions, the epidemic showed its peak on February 17, with 58,016 cases. (“Epidemic Report,” n.d.)The total epidemic size observed was 82,590 cases. Different studies suggested if the introduction of interventions was delayed by five days, the transmission coefficient would have been much greater due to the increase in the average number of contacts with an infected person daily. Case numbers would have increased exponentially, peaking on March 4 2020, at 173,372 cases. By the end of April, the total epidemic size would have been 351,874 cases. China declared a Level 1 emergency response, the highest-level public health response, to the COVID-19 outbreak on January 15 2020, causing the implementation of control measures nationwide. Aside from locking down the Greater Wuhan area, strict reporting of

travel to and from Hubei province was required. Hubei residents were dissuaded from returning to their workplace, and even non-Hubei residents who had travelled via Wuhan were required to self-quarantine for 14 days. The effectiveness and necessity of such undertakings have been questioned, particularly with reports that the Greater Wuhan quarantine may have been instituted too late (Jonathan M. Read, Jessica R.E. Bridgen, Derek A.T. Cummings, Antonia Ho, 2014; Wu et al., 2020). Wu et al. predicted that without control measures, the epidemic size in Wuhan would reach 75,000 infections by January 25, and the epidemic would peak in April. Similarly, Read et al. predicted a peak of 190,000 cases by February 4 without control measures (Jonathan M. Read, Jessica R.E. Bridgen, Derek A.T. Cummings, Antonia Ho, 2014). Guangdong and Zhejiang, the two most affected provinces after Hubei, only account for 6.6% of all PCR-confirmed cases nationally, owing to quicker enforcement of control measures. The slowed epidemic growth in these two provinces compared to Hubei support the effectiveness of quarantine and control measures. SIR model suggested that a five-day delay in implementation of control measures would have increased the epidemic size three-fold. (Yang et al., 2020)

Outside China As of January 30, 2020, a total of 9976 cases had been reported in at least 21 countries, seven including the first confirmed case of 2019-nCoV infection in the United States, reported on January 20, 2020 (Holshue et al., 2020). Countries first and severely affected by Corona was almost the same as countries with a high number of outbound travels. According to Statista Research Department, Dec 30, 2010, on Outbound travel - number of trips by country 2010. The statistic depicts the countries worldwide with the greatest number of outbound travel trips in 2010. Germany was the country with the most outbound travel worldwide with a total of 72.6 million outbound trips, a share of 10 percent of the global outbound travel. (“• Number of outbound travel trips worldwide by country 2010 | Statista,” n.d.) In the list, all ten countries with a sequence are Germany, USA, Great Britain, France, Canada, Netherland, Italy, Russia, China and Japan are all severely affected by COVID-19. It is also observed that countries mostly effected are with good HDI number. The HDI is a summary index using life expectancy at birth, expected years of schooling for children and mean years of schooling for adults, and GINI per capita. (“Human Development Index (HDI) | Human Development Reports,” n.d.) The final HDI is value between 0 and 1 which grouped the countries into four categories depending on the value, very high for HDI of 0.800 and above, high from 0.700 to 0.799, medium from 0.550 to 0.699 and low below 0.550. A study by Min Jiang, Terry DeLacy indicates a significant positive relationship ($r = 0.483$, $p < 0.01$) between tourism intensity and HDI That is, as tourists number increases HDI increases. (Jiang et al., 2011) The component of HDI consist of income, life expectancy, and education have significant impacts on foreign tourist arrivals. Epidemic size without intervention can be determined by HDI values, as it is hard to calculate HDI on a sub-national level; NLDI values have been considered. (Ghosh et al., 2013) Hence, remotely sensed data such as nighttime satellite imagery can be greatly helpful in suggesting pre-epidemic states at a glance.

It is also observed that countries with not higher HDI also get affected such as Iran, Pakistan is among countries which are somehow related to large gatherings such as Umrah and Ziarah in Iran. ("Pilgrimage: Pakistan tops the list of countries with more than 2.1 million people performing Umrah in 2019 | Pakistan – Gulf News," n.d.) As those days were in great importance by Muslim Shia and thousands of Muslims travel on Novroz to Iran. As the number of cases in Pakistan continues to grow, political leaders are encouraging physical (or "social") distancing to slow the rate of transmission.

Early on, epidemiologists observed with growing concern as the number of people around the globe diagnosed with COVID-19 began to increase this year. When the epidemic turned into a pandemic, many anticipated shortages of hospital beds, supplies, devices, and medical personnel as the number of cases grew. ("Mapping and Modeling Combine to Provide COVID-19 Forecasts," n.d.)

Ahead of inquiries from concerned leaders, scientists began creating analytical models that could quantify and predict the surge in COVID-19 cases. From that effort, several powerful models have emerged as useful tools for planning. Penn Medicine's Predictive Healthcare Team adapted the susceptible, infected, and recovered (SIR) mathematical model, Linking SIER model with GIS a locational based Model is created. ("Mapping and Modeling Combine to Provide COVID-19 Forecasts," n.d.) As it is evident somehow areas with high HDI are more at risk so calculating HDI city and town wise can be very helpful in coming times. Also models like SIR linked with locational data can be used to face upcoming challenges well. We divided whole studies into two steps finding union council wise NLDI values for Lahore city. Using the modelling technique, we predicted peak days of Covid-19 spread in Lahore Pakistan and upcoming challenges. Based on this model, city lockdown is effective to block the spread from epidemic area to other cities. In contrast, intensive preparation in the health sector while improving bed capacities area wise can be greatly helpful in controlling epidemic state as well as reducing fatality rate to lowest.

2. Study Area

Lahore is the capital of the Pakistani province of Punjab. It is the country's 2nd largest city after Karachi and 18th largest city in the world. ("Pakistan: Provinces and Major Cities - Population Statistics, Maps, Charts, Weather and Web Information," n.d.) Lahore has a population of 11 million, out of this 9.9 million is urban with almost 5 million residing in the old city and other unplanned congested areas. Average population density is 6.3 persons per square meter. (*The World's Cities in 2018*, n.d.) With this population, Lahore is quite comparable with Wuhan (population > 8.3 million). However, Lahore has almost twice the population density of Wuhan (3.2 persons per square meter).

Lahore's population is 5.1% of Pakistan around three-fourth of that of Karachi. Lahore has the highest disease burden in Pakistan which is almost 18% of total epidemic size in country ("COVID-19 Health Advisory Platform by Ministry of National Health Services Regulations and Coordination," n.d.) Current Disease and mortality is rising sharply. Figure 1. From 2nd

week of march to 1st week of May total 81 deaths were reported in city. Fatality rate of disease in the city is 2.3%.

Figure 1: Rise of Confirmed Cases of Covid-19 in Lahore

3. Methodology

3.1 NLDI value calculation for Lahore City at Union Council level

The nature of urban form and the patterns of urban development are regarded as having a fundamentally important impact on ecosystem function, ecosystem health, and sustainability. Continuing studies of the dynamics of urbanization through time using nighttime lights enables the comprehension of adverse effects of urbanization related to loss of vegetation, increase in temperatures, air and water pollution, loss of species' habitats, growth and spread of urban slums, poverty, and unemployment. (Elvidge et al., 2012) In this study we checked Covid-19 epidemic spread with respect to NLDI values. The source of all the nighttime imagery used in these studies is from the Earth Observation Group (EOG), the National Geophysical Data Center (NGDC) of the National Oceanic and Atmospheric Administration (NOAA). The EOG at NOAA has been archiving and processing Defense Meteorological Satellite Program's Operational Linescan System (DMSP-OLS) nighttime lights data since 1994. The EOG produces two types of nighttime images at approximately 1 km resolution (30 arc-seconds)—the stable light images and the radiance-calibrated images. In all of the following studies, one or both types of nighttime images have been used. The annual, global stable lights are generated by averaging the individual, cloud-free orbits of the Operation Linescan System (OLS) visible band data. In the creation of the stable light's product, fires and other ephemeral lights are removed based on their high brightness and short duration. Annual stable lights images from 1992 to 2012 are available for free download from EOG's website. ("Earth Observation Group - Defense Meteorological Satellite Program, Boulder | ngdc.noaa.gov," n.d.)

The HDI is a composite statistic that uses life expectancy, literacy, education, and standards of living to measure human well-being. The strong relationship between NLDI and HDI influences the consideration of NLDI as a supplemental measure of human development. (Ghosh et al., 2013) There is an increasing recognition that the distribution of wealth and income amongst the population in a nation or region correlates strongly with the level of human development of

the population of that nation or region. This, in turn, is correlated to the happiness and well-being of the population of the nation or region. measuring the distribution of wealth and income at national and regional scales is a challenging problem. Thus, an alternative measure of the distribution of wealth was developed using the nighttime lights image and the LandScan population grid. This was called the Night Light Development Index (Elvidge et al., 2012):

Figure 2: Adapted by Elvidge et al.: The Night Light Development Index (NLDI)
Development Index (NLDI)

Min Jiang and Terry DeLacy's study indicates a significant positive relationship ($r = 0.483$, $p < 0.01$) between tourism intensity and HDI. That is, as tourists number increases HDI increases. The component of HDI, consist of income, life expectancy, and education have significant impacts on foreign tourist arrivals. Considering the relation between travel history, HDI and NLDI. We decided to check Lahore inside City NLDI and found areas with high NLDI values and created an overlay map with the base of current positive Corona cases in the city. The correlation found between NLDI numbers, and the total number of Corona cases is 0.41621. Based on the values a graph based on Lahore union council wise NLDI is created. Figure 3.

Figure 3: Lorenz Curve-NLDI for Lahore City Union Council Wise

3.2 Prediction of Covid-19 in Lahore using SIR Model

To predict Lahore effected Population we employee the technique of SIR Model,

The model consists of individuals who are either Susceptible (S), Infected (I), or Recovered (R).

The epidemic proceeds via a growth and decline process. This is the core model of infectious disease spread and has been in use in epidemiology for many years. (“The SIR Model for Spread of Disease - The Differential Equation Model | Mathematical Association of America,” n.d.)

The dynamics are given by the following three equations.

$$S_{t+1} = S_t - \beta S_t I_t$$

$$I_{t+1} = I_t + \beta S_t I_t - \gamma I_t$$

$$R_{t+1} = R_t + \gamma I_t$$

The model's parameters, beta β and gamma γ , determine the severity of the epidemic.

β can be interpreted as the effective contact rate, which is the transmissibility τ multiplied by the average number of people exposed c . The transmissibility is the basic virulence of the pathogen. The number of people exposed c is the parameter that can be changed through social distancing.

γ is the inverse of the mean recovery time in days. For Corona, incubation period is considered as 14 days. (Backer et al., 2020)

An important descriptive parameter is the basic reproduction number R_0 . This represents the average number of people who will be infected by any given infected person. When R_0 is greater than 1, it means that a disease will grow. A higher R_0 implies more rapid transmission and more rapid growth of the epidemic.

For Calculating SIR model at the minimum level we took Lahore at admin level 3 considered as Union councils in-country, union councils shape files are freely available to download at (“Pakistan administrative level 0, 1, 2, and 3 boundary polygons, lines, and central places - Humanitarian Data Exchange,” n.d.)

We calculated population of each union council using Landscan population data. Using statistical technique of GIS population of each cell is derived. As Landscan data is only available in 1x1 km resolution, thus few union councils which size is less than 1x1 km we merged those UC. (“Home | LandScan™,” n.d.) Total number of union councils being used are 141. Population calculated for each union council, is the initial S (Susceptible) input in the SIR model. Daily data of infected patients, is used to estimate the total number of infected individuals in each union council. Map of Union councils with total population and number of cases till 2nd May is shown in Figure 4.

Figure 4: Confirmed Corona Virus Cases in Lahore Pakistan, dated: 2nd May 2020

Figure 5: Locked Down Areas in Lahore

In SIR model time plays a key role as it helps to know R value in each region using Growth rate and doubling days. Growth rate of disease is 10.4% for Lahore city and doubling days for disease spread is almost 6 days currently.

Currently Lahore is under partial locked down, big markets, schools and other educational institutes are closed (Figure 5). Offices related to exchange and banks are working. Currently almost one-fourth of the city is sealed. Total 37 clusters were shut down, out of which 6 were unlocked. Considering the actual situation social distancing percentage is considered 25%. Figure 6 shows the present locked down places in Lahore.

4. Analysis and Results

4.1 Relation between NLDI numbers and predicted SIR values with 25% Social Distancing

This shows an early air travel ban can help in dealing with pandemic cases, and satellite imagery like Nighttime satellite imagery can be greatly beneficial in early decision making. For example, an early locked down of the areas with high NLDI can change the results. Figure 6 shows that all union councils with higher than 0.91 are those which has highest number of confirm cases till 2nd May 2020. Figure 7, shows relation between predicted hospitalized cases and NLDI values on expected peak date with 25 percent social distancing.

Figure 6: Comparison between NLDI Value and Confirmed Cases in Lahore

Figure 7: Relation between NLDI Values and Predicted Cases on expected peak date in Lahore using SIR Model with 25% Social Distancing

4.2 Peak Graphs with Different Social Distancing

The SIR model for the spread of COVID-19 in Lahore with no social distancing approach is presented in figure 8, under the assumptions mentioned in Model Parameters, indicate that the number of infections will peak nearly on 27 June 2020 and 200,000 individuals could be potentially infected in Lahore city. Figure9. With no interventions and social distancing after

the peak date number of infections will rapidly decrease and in end of September pandemic will end.

In Figure 9, 10 It was observed with 25 percent social distancing and 100 percent social distancing graph of people needed to hospitalized reduce respectively. Total need of beds with zero to 100 percent social distancing will change from 2893 to 1414.

Need of ICU cases will change from 3707 to 166 with zero to 100 percent social distancing also need of ventilators will change from 1200 to 50 in round figure.

Figure8: Suspected, Infected and Recovered Projections in Lahore with 0%Social Distancing

Figure 9: Daily Hospital Census Projection with 25% Social Distancing

Figure 9: Daily Hospital Census Projection with 100% Social Distancing

4.3 Spatial Representation of Predicted Result by SIR Model

As discussed, social distancing plays a vital role in restricting covid-19 pandemic, maps were built to see impact of social distancing at UC level in whole city. Figure 11 shows the difference between effected union councils with 25 percent and 100 percent social distancing. With hundred percent social distancing we can save a large area to be affected by Covid-19. Maximum number of hospitalized in case of 25% social distancing are between 1001 and 2194. If 100 percent of social distancing is deployed maximum need of beds will be left only between 101 and 200.

Figure 10: Difference in Hospitalized persons with different social distancing.

4.4 Comparison between predicted need and available health facilities

Sr. No	Name of Hospital	City	Division	Total No of beds of hospital	No. of Single bedded Isolation Rooms	No. of beds in Isolation wards	No. of Beds in HDUs	No. of Ventilators Dedicated for Corona	Suspected Patients	Confirmed patients	Deaths	Discharged from Confirmed Patients
16	Government Kid Khawaja Saheed Teaching Hospital, Lahore	Lahore	Lahore	149	1	10	4	6	0	0	0	0
17	Punjab Institute of Cardiology, Lahore	Lahore	Lahore	547	0	5	0	0	0	0	0	0
18	Punjab Institute of Mental Health, Lahore	Lahore	Lahore	1510	0	0	0	0	0	0	0	0
19	Lady Willington Hospital, Lahore	Lahore	Lahore	235	3	4	4	1	0	0	0	0
20	Sir Ganga Ram Hospital, Lahore	Lahore	Lahore	908	6	10	8	6	4	0	0	0
21	Punjab Dental Hospital, Lahore	Lahore	Lahore	30	0	0	0	0	0	0	0	0
22	Services Hospital, Lahore	Lahore	Lahore	1450	14	12	7	7	13	3	0	0
23	Mayo Hospital, Lahore	Lahore	Lahore	2484	20	100	15	15	16	35	0	3
24	Govt. Sial Miha Teaching Hospital, Lahore	Lahore	Lahore	100	0	3	0	0	0	0	0	0
25	PKJL, Lahore	Lahore	Lahore	211	70	26	9	25	0	16	0	0
26	Govt. M. Nawaz Sharif Teaching Hospital, Yakk Gatta, Lahore	Lahore	Lahore	195	0	5	5	6	0	0	0	0
27	Lady Aitchison Hospital Lahore	Lahore	Lahore	200	5	4	3	2	0	0	0	0
28	Children's Hospital & The Institute of Child Health, Lahore	Lahore	Lahore	1100	16	20	6	6	1	0	0	0
29	Government Teaching Hospital Shahdara Lahore	Lahore	Lahore	300	0	4	9	4	0	0	0	0
30	Govt. Moazang Teaching Hospital Lahore	Lahore	Lahore	45	0	5	0	1	0	0	0	0
31	Lahore General Hospital, Lahore	Lahore	Lahore	1000	8	10	10	6	23	0	0	0
32	Govt. Mian Munsif DHQ Teaching Hospital Lahore	Lahore	Lahore	140	4	16	4	0	0	0	0	0
33	Jinnah Hospital, Lahore	Lahore	Lahore	1500	13	35	18	5	6	0	0	0
LAHORE DIVISION (TOTAL)				12113	160	269	102	90	63	54	0	3

Figure 11: Statistics of Punjab Government Dedicated Hospital for Corona in Lahore

According to prediction based on 25 percent social distancing, peak date expected is between 1st to 7th July and expected hospitalized, ICU and people on ventilator cases are 19351, 2479, 989 respectively.

While in Lahore, the government hospitals have around 250 ventilators only, out of it government dedicated ventilators for corona patients are only 90. Total number of beds for hospitalization in hospitals suggested for Corona patients in Lahore Pakistan are 12113. ("Coronavirus: Pakistan much deficient in machines designed to provide mechanical ventilation," n.d.)

Figure 12 shows the list of all dedicated hospitals for Covid-19 in Lahore shared by Punjab Health Department. Report based on division wise corona patient's stats and beds availability in tertiary care hospital of Punjab prepared on 26.03.2020 by Punjab health department.

Map was built to observe difference in predicted and current covid-19 facilities in city. Figure 13 and 14 shows the predicted need of ventilators and beds in city with 25 percent social distancing and present capacity of ventilator and beds. It was observed maximum needed ventilators in Cantt union council was found between 49 to 112, while total dedicated ventilators maximum in whole city is only between 16 to 25, which also not fall in the concerned union council. Huge gap between needed and present health facilities in city can be observed just by seeing map at a glance. Maps also show the uneven selection of hospitals dedicated to covid-19, there location and distance from needed place is totally ignored. It shows that use of locational data for decision making is immensely needed in city.

Figure 12: Need of Ventilators During Peak Days - 25% Social Distancing

Figure 14: Need of Beds During Peak Days - 25% Social Distancing

5. Discussion

Results Discussed above are predicted cases of Covid-19 based on SIR modeling using data of total hospitalized persons Lahore city. There was great need to check the validity of data. While compiling and writing the study 2nd to 8th May 2020 Covid-19 cases increases. We checked the validity of our predicted numbers. Interestingly while comparing values of predicted cases with actual number it was observed that data was nearer to prediction of social distancing at zero percent.

Basic reason could be government increased the testing capacity from first week of May hence growth rate of disease is more visible now It also shows that government partially locked down is not advisable, and social distancing requirement is not being followed in city.

Figure 13: Predicted Cases with No Social Distancing Versus Actual Cases social distancing policy of area Recommendations

Coronavirus exist in almost every corner of the world, but it is spreading differently everywhere depending upon the precautionary measures adopted. Government of Pakistan has announced to lift and ease lockdown throughout the country on pressure of small and medium businesses and keeping in view for upcoming religious event of Eid-ul-Fitr. The government announces to reopen all shops, small markets and allied industries of construction sector. Markets are expected to be flooded with people to shop for the event of Eid-ul-Fitr. However, People are softly advised to follow social distancing and guidelines but if public failed to follow guidelines, it may lead to extreme spike in infectious cases resulting great hike in death ratio. Strict lockdown is advised to cope with the pandemic and projected extraordinary number of infected cases which may lead to the collapse of health system as well as economy. Figure 16, 17 maps show the need on ventilator and beds on peak date with hundred percent social distancing, that how number of needed ventilator and beds reduces with maximum social distancing it also advised 100% locked down is only best solution while knowing current health facility status of city. 100% social distancing can be implemented with food, grocery, medical and emergency related services to continue. Export oriented industrial units allowed can also work with health safety restrictions including mandatory periodical testing of their labor. Promotion of on-line vending is advisable as much as possible. Predicted graphs above give a very good idea that how social distancing at immense level not only reduces the impact of epidemic state but also time periods.

Figure 14: Need of Beds During Peak Days with 100% Social Distancing

Figure 15: Need of Ventilators During Peak Days with 100% Social Distancing

6. Conclusion

Location based SIR model can be very helpful not only in predicting the COVID-19 epidemic peaks and sizes, but also to check health facilities need area wise. Furthermore, remotely sensed data like nighttime satellite imagery can help building maps which can be used by decision and policy makers to find areas which needs immediate attention also in taking steps to stop epidemic state converting it to pandemic state. Based on study, it was found that immense need of social distancing is needed in big cities of developing countries where health facilities are not present at large scale. Spatial maps can help finding gaps in health facilities. It also helps determining what are the gaps in health sector by health sector to cover in current situation. As well as what areas in Lahore city needs new hospitals, and what number of beds, ICUs and ventilators are immediately required in each hospital.

Acknowledgements

This research was supported by National Key R&D Program of China (2018YFC0807000); the Fundamental Research Funds for the Central Universities (Grant No.WK2320000040). Special Thanks to Deputy Commissioner - District Administration Lahore for sharing daily details of Covid-19 cases, as well as all health related data and State Key Lab of Fire Sciences for giving us resources to carry the study.

References

- [1] Backer, J.A., Klinkenberg, D., Wallinga, J., 2020. Incubation period of 2019 novel coronavirus (2019- nCoV) infections among travellers from Wuhan, China, 20 28 January 2020. Eurosurveillance. <https://doi.org/10.2807/1560-7917.ES.2020.25.5.2000062>
- [2] Coronavirus: Pakistan much deficient in machines designed to provide mechanical ventilation [WWW Document], n.d. URL <https://www.thenews.com.pk/print/630435-coronavirus-pakistan-much-deficient-in-machines-designed-to-provide-mechanical-ventilation>. (accessed 5.9.20).
- [3] COVID-19 Health Advisory Platform by Ministry of National Health Services Regulations and Coordination [WWW Document], n.d. URL <http://covid.gov.pk/> (accessed 5.9.20).
- [4] Earth Observation Group - Defense Meteorological Satellite Program, Boulder | ngdc.noaa.gov [WWW Document], n.d. URL <https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html> (accessed 5.9.20).
- [5] Elvidge, C.D., Baugh, K.E., Anderson, S.J., Sutton, P.C., Ghosh, T., 2012. The Night Light Development Index (NLDI): A spatially explicit measure of human development from satellite data. *Soc. Geogr.* 7, 23–35. <https://doi.org/10.5194/sg-7-23-2012>
- [6] Ghosh, T., Anderson, S.J., Elvidge, C.D., Sutton, P.C., 2013. Using nighttime satellite imagery as a proxy measure of human well-being. *Sustain.* 5, 4988–5019. <https://doi.org/10.3390/su5124988>
- [7] Holshue, M.L., DeBolt, C., Lindquist, S., Lofy, K.H., Wiesman, J., Bruce, H., Spitters, C., Ericson, K., Wilkerson, S., Tural, A., Diaz, G., Cohn, A., Fox, L., Patel, A., Gerber, S.I., Kim, L., Tong, S., Lu, X., Lindstrom, S., Pallansch, M.A., Weldon, W.C., Biggs, H.M., Uyeki, T.M., Pillai, S.K., 2020. First Case of 2019 Novel Coronavirus in the United States. *N. Engl. J. Med.* 382, 929–936. <https://doi.org/10.1056/NEJMoa2001191>
- [8] Home | LandScan™ [WWW Document], n.d. URL <https://landscan.ornl.gov/> (accessed 5.9.20).
- [9] Human Development Index (HDI) | Human Development Reports [WWW Document], n.d. URL <http://hdr.undp.org/en/content/human-development-index-hdi> (accessed 5.9.20).
- [10] Jiang, M., DeLacy, T., Mkiramweni, N.P., Harrison, D., 2011. Some evidence for tourism alleviating poverty. *Ann. Tour. Res.* 38, 1181–1184. <https://doi.org/10.1016/j.annals.2011.03.008>
- [11] Jonathan M. Read, Jessica R.E. Bridgen, Derek A.T. Cummings, Antonia Ho, C.P.J., 2014. Novel coronavirus 2019-nCoV: early estimation of epidemiological parameters and epidemic predictions. *Antimicrob. Agents Chemother.* 58, 7250–7. <https://doi.org/10.1101/2020.01.23.20018549>
- [12] Livingston, E., Bucher, K., Rekito, A., 2020. Coronavirus Disease 2019 and Influenza 2019-2020. *JAMA - J. Am. Med. Assoc.* 323, 1122. <https://doi.org/10.1001/jama.2020.2633>

- [13] Mapping and Modeling Combine to Provide COVID-19 Forecasts [WWW Document], n.d. URL <https://www.esri.com/about/newsroom/blog/models-maps-explore-covid-19-surges-capacity/> (accessed 5.9.20).
- [14] Pakistan: Provinces and Major Cities - Population Statistics, Maps, Charts, Weather and Web Information [WWW Document], n.d. URL <http://www.citypopulation.de/Pakistan-100T.html> (accessed 5.9.20).
- [15] Number of outbound travel trips worldwide by country 2010 | Statista [WWW Document], n.d. URL <https://www.statista.com/statistics/271371/outbound-travel-trips-by-country/> (accessed 5.9.20).
- [16] Outbreak report [WWW Document], n.d. URL http://www.nhc.gov.cn/xcs/yqtb/list_gzbd.shtml (accessed 5.9.20).
- [17] Pakistan administrative level 0, 1, 2, and 3 boundary polygons, lines, and central places - Humanitarian Data Exchange [WWW Document], n.d. URL <https://data.humdata.org/dataset/pakistan-administrative-level-0-1-2-and-3-boundary-polygons-lines-and-central-places> (accessed 5.9.20).
- [18] Pakistan Detects First Coronavirus Cases, Links to Iran Outbreak | Voice of America - English [WWW Document], n.d. URL <https://www.voanews.com/science-health/coronavirus-outbreak/pakistan-detects-first-coronavirus-cases-links-iran-outbreak> (accessed 5.9.20).
- [19] Pilgrimage: Pakistan tops the list of countries with more than 2.1 million people performing Umrah in 2019 | Pakistan – Gulf News [WWW Document], n.d. URL <https://gulfnews.com/world/asia/pakistan/pilgrimage-pakistan-tops-the-list-of-countries-with-more-than-21-million-people-performing-umrah-in-2019-1.68715106> (accessed 5.9.20).
- [20] Real-time update: new coronavirus pneumonia epidemic map [WWW Document], n.d. URL https://voice.baidu.com/act/newpneumonia/newpneumonia/?from=osari_aladin_top1 (accessed 5.9.20).
- [21] The SIR Model for Spread of Disease - The Differential Equation Model | Mathematical Association of America [WWW Document], n.d. URL <https://www.maa.org/press/periodicals/loci/joma/the-sir-model-for-spread-of-disease-the-differential-equation-model> (accessed 5.9.20).
- [22] The World's Cities in 2018, n.d.
- [23] Wang, X., Liu, C., Mao, W., Hu, Z., Gu, L., 2014. Tracing The Largest Seasonal Migration on Earth.
- [24] WHO, 2020a. Novel Coronavirus (2019-nCoV) Situation Report - 1. WHO Bull. 1–7.
- [25] WHO, 2020b. Coronavirus disease. World Heal. Organ. 2019, 2633. <https://doi.org/10.1001/jama.2020.2633>
- [26] Wu, J.T., Leung, K., Leung, G.M., 2020. Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan,

China: a modelling study. *Lancet* 395, 689–697. [https://doi.org/10.1016/S0140-6736\(20\)30260-9](https://doi.org/10.1016/S0140-6736(20)30260-9)

- [27] Yang, Z., Zeng, Z., Wang, K., Wong, S.S., Liang, W., Zanin, M., Liu, P., Cao, X., Gao, Z., Mai, Z., Liang, J., Liu, X., Li, S., Li, Y., Ye, F., Guan, W., Yang, Y., Li, F., Luo, S., Xie, Y., Liu, B., Wang, Z., Zhang, S., Wang, Y., Zhong, N., He, J., 2020. Modified SEIR and AI prediction of the epidemics trend of COVID-19 in China under public health interventions. *J. Thorac. Dis.* 12, 165–174. <https://doi.org/10.21037/jtd.2020.02.64>