INDIA: Purva Yadav and Aisharya Bhattacharjee **Impact of COVID-19on mobility in India: A spatial approach**

Abstract : *Mobility (human) led to the spread of infectious diseases that pose severe risks to global health, and several countries in response to such pandemic threats consider and enforce measures that restrict human mobility as one of their response plans. Such approaches are often considered controversial. India is the second-most populous country in the world with more than 1.3 billion people, hence the potential impact of the COVID-19is catastrophic. The first COVID-19case was reported on January 30th, 2020 and prime minister Narendra Modi has imposed a nationwide lockdown on March, 24th (world's largest) for three weeks, subsequently it was extended till May 3rd. Urban areas with a high magnitude of international and national mobility have emerged as the main node of diffusion. In the case of COVID-19-19, an increase in cases has a direct relationship with mobility at different scales, and hence we tried to capture this trend with the limited available data on mobility. Preliminary results reveal that the lockdown was effective in reducing mobility, and urbanization and accessibility do have a role to play in the spread of the virus. Further, results indicate that states with high urbanization and accessibility (for example, Maharashtra, Gujarat, and Delhi) have registered a steep rise in the number of cases across different phases of the lockdown. Major cities have emerged as hotbeds and a sharp fall in mobility is seen since the imposition of nationwide lockdown.*

The context:

Human mobility has led to the spread of infectious diseases that pose severe risks to global health. Many countries respond to such pandemic threats with measures that deliberately restrict human mobility (Fang et al., 2020; Bajardi et al., 2011; Charu et al., 2017). However, such responses are often controversial because of inherent externalities, including potential economic damage and apprehensions attached to the degree of effectiveness in controlling the transmission of the pandemic. Charu et al. (2017) have noted that disease occurrence and human mobility data are difficult to obtain and we have noted that as well. Also, it is difficult to separate the impact of human mobility from other factors (Hollingsworth et al., 2006).

Several studies have explored the role played by mobility, demography, and environmental factors in disseminating seasonal influenza at regional and global level. For example, the world air transport network acts as a spreader at the global scale, as do short distance work-commutes at national level. Influenza is marked by rapid, hierarchical spread between and within zones of high population density followed by subsequent dissemination to less populous low-humidity environments (Charu, et al., 2017; Russel et.al., 2008; Brockmann et.al., 2013; Viboud, et al., 2006; Brownsten, et al., 2006; Shaman, et al., 2009).

The present paper aims to capture the spatiality of COVID-19 spread and its impact on mobility in India with the backdrop of governmental nationwide lockdown. Due to the paucity of adequate data on human mobility at different spatial scales in the present time, the analysis is limited in approach and the results are preliminary.

Furthermore, acquiring data from private data owners poses major challenges in collecting the data needed for a particular use case. COVID-19 has been in India for only a few months with no structured data on mobility and the available data is collected in real-time. Niti Ayog (2018) has noted the poor quality of mobility data in India. Sridhar and Majumdar (2020) have noted data difficulties due to varying testing, documentation, and reporting practices that vary across time and between countries.

India[32]is the second-most populous country in the world with more than 1.3 billion people, hence the potential impact of the COVID-19[33]is catastrophic. It is observed that the development process has led to the emergence of important intra and inter-regional mobilities in the country: metropolitan regions spread the length and breadth of the country and are the fulcrums of major daily movements that have a profound impact on disease spread. This has led to many stranded workers from the informal sector. The first COVID-19-19[34]case in India was reported on 30 January 2020. The national lockdown– the world's largest – was imposed three weeks on 24 March. It was subsequently extended till 3 May. The lockdown invoked nineteenth century British Raj provisions (Epidemic Diseases Act, 1897)[35].

Recent Union Health Ministry data gives the death toll due to COVID-19 as 1074 with 33,050 total cases of which 23651 were active. The Ministry also noted that the doubling time for cases had risen to 6.2 days, compared with 3 days before the lockdown. Also noted were urban areas as the main node of diffusion and the magnitude of international and national mobility. The number of cases has a direct relationship with mobility at different scales.

- Mapping indicates show how the reduction in the number of individuals commuting and travelling has decreased the propagation of COVID-19(Fang, 2020, Denis et al. 2020). At the national level, there has been a decline in commuting; in Delhi
- NCT, mobility dipped by around 90 percent, as compared to about 40 percent in other states.

[32]35 States/Union Territories, 640 Districts and 53 Urban Agglomerations (Census of India, 2011)
[33]According to WHO (2020) report COVID-19-19 is a zoonotic virus and transmits via droplets and fomites during close unprotected contact between an infector and infectee. Given Wuhan's transport hub status and population movement during the Chinese New Year infected individuals quickly spread throughout the country, and were particularly concentrated in cities with the highest volume of traffic with Wuhan. Some of these generated limited human-to-human transmission chains at their destination.
[34]Ro (reproductive number) for COVID-19-19, that is the number of secondary infections generated from one infected individual- is understood to be between 2 and 2.5 for COVID-19-19 virus (higher than for influenza)(https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200306-sitrep-46-COVID-19-19.pdf?sfvrsn=96b04adf_4). If Ro is greater than 1 then number of infected is likely to increase and vice-versa if it is less than 1. For India, Rai et al. (2020), have found Ro to be 2.56. (https://www.researchgate.net/publication/340655147_COVID-19-19_in_India_Predictions_Reproduction_Number_and_Public_Health_Preparedness/citations)
[35]Indian Express, April 30th, 2020- Accessed at IndianExpress.com

- Cities have experienced a major exodus of migrants resulting in a dramatic fall in their population while rural areas gain. Data suggest that in the pre lockdown period, cities were at the center of significant population shifts during the day from neighboring areas, but this mobility was restricted during the lockdown hence disrupting daily movements toward city centers from neighbouring rural areas (Denis et al. 2020).

Database and Methodology

Our data includes State/UT-wise urbanization levels from the 2011 Census of India and the Road Network Access Index[36] divided into three classes (high, medium, and low). These are cross-referenced to form a bivariate matrix. Cartographic techniques are used to map the derived matrix and COVID-19cases. A multivariate regression model (Table 1) is used to further support our results[37]. To test the validity of the claims, hypothesis tests have been using t-statistics or the significance level for the variables for five time periods.

Data pertaining to the impact of the pandemic on mobility trends at different locations have been retrieved from Google's Community Mobility Database. Also TomTom has come up with a detailed database on daily traffic levels in major cities of the world. In our analysis, in order to assess the impact of the pandemic on road traffic levels across the city, the weekly average value has been deduced from the daily data and a comparison with regards to the weekly trend in COVID-19cases has been made for four major cities (also hotspots) of India, namely, Mumbai, Delhi, Pune, and Bengaluru. From Apple we also have data on weekly changes in the relative volume of directions requests made by users as compared to a base line volume by transportation type. The data has been used in the present study for the two largest megacities in India, to reflect upon the impact of the closing down of public transport systems on individual mobility behavior. Therefore we made an attempt to capture the broad trends at different spatial scales.

So what is the impact of COVID-19on mobility in India? Let's see

Among other South Asian countries, India has the highest number of confirmed COVID-19cases, with a steep rise from 7 April (Figure 1). Based on the Google data, location wise mobility patterns at the macro scale for the pre and post lockdown reveal a significant decline in the mobility patterns across destinations revealing that the lockdown was clearly effective in reducing mobility (Figure 2). For example, the sudden spurt in COVID-19cases is visible from 21 March, however, the rate of decline varies in the mobility pattern (See Figure 2) for places such as malls/restaurants (85%), pharmacies/groceries (43%), parks (60%), transit stations and public transport hubs (65%), workplaces (65%). Only mobility to residential areas (Figure 2f) registered an increase (31%). The trend is indicative of the impact of social distancing and accessibility to essential items or necessary movement of on

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[36]Developed by LSI Financial Services Private Limited in "India Road Sector Outlook 2017-18" by a composite scoring of Road Network Indicators, Road Density, and Registered Motor Vehicles.

[37]In the model we have used state wise number of COVID-19-19 cases in India as the criterion variable and
the urbanization level (%) of the state and its road network access score as the two predictor variables.

the citizens in different phases of lockdown. The trend is only indicative in nature as it based on a sample of Google users, hence concrete generalizations cannot be drawn at this stage.

The Ministry of Health document plan for large outbreaks of COVID-19noted several variables that affect the success of large outbreak cluster containment operations through geographic quarantine. These include geographical characteristics of the area like accessibility and population density and their movement. Hence we made a preliminary attempt to broadly capture their relative role/ impact on COVID-19or vice-versa[38].Several reports have suggested that major concentrations of COVID-19cases cluster at the urban center of countries across the globe.[39] We hypothesized that states with higher urbanization levels and better accessibility (it will encourage mobility of different kinds) are likely to form India's COVID-19 hotspots[40]. Preliminary results indicate an interesting trend. Before lockdown, Initially both indicators were statistically insignificant in explaining variation in COVID-19 cases, with a low adjusted R-squared (Table 1). However, just before the lockdown started which was basically a result of the rising number of cases, the accessibility parameter found to be highly significant, partly because sudden lockdown triggered a mass movement of urban poor via road to their villages/towns. It remained statistically significant across phases, while urbanization has turned out to be significant especially in the first week of COVID-19hotspots[41]. Preliminary results indicate an interesting trend. Before lockdown, Initially both indicators were statistically insignificant in explaining variation in COVID-19 cases, with a low adjusted R-squared (Table 1). However, just before the lockdown started which was basically a result of the rising number of cases, the accessibility parameter found to be highly significant, partly because sudden lockdown triggered a mass movement of urban poor via road to their villages/towns. It remained statistically significant across phases, while urbanization has turned out to be significant especially in the first week of lockdown phase 1. This could also be partly linked to the fact that the closing down of public transport led to the exodus of urban labor force primarily engaged in the unorganized sector on foot and in the process, this movement from highly urbanized states have had an influence in the transmission and associated rise in the number of cases in adjacent districts. The adjusted R-squared value during the lockdown period varied (Table 1) from 0.38 to 0.54 to 0.41. It is worth to note that accessibility and urbanization are not the only variables to

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[38]For details please visit https://www.mohfw.gov.in/pdf/3ContainmentPlanforLargeOutbreaksofCOVID-1919Final.pdf

[39]This might be due to their higher degree of accessibility and connectivity at the global level.

[40]"In 2009, during the H1N1 Influenza pandemic, it was observed that well connected big cities with substantive population movement were reporting a large number of cases, whereas rural areas and smaller towns with low population densities and relatively poor road/ rail/ airway connectivity were reporting only a few cases. The current geographic distribution of COVID-19-19 mimics the distribution of H1N1 Pandemic Influenza. This suggests that while the spread of COVID-19-19 in our population could be high, it's unlikely that it will be uniformly affecting all parts of the country. This calls for a differential approach to different regions of the country while mounting a strong containment effort in hot spots."(Ministry of Health and Family Welfare, Government of India)

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affect COVID-19 spread, considering other factors (for example, demographic attributes and health infrastructure) can further help in better understating the geographic spread of the virus and will also strengthen the model.

Map 1 reveals that states with high urbanization levels and high road networks access scores like Maharashtra, Gujarat, and Delhi have registered a steep rise in the number of cases. For instance, 27.3% of the red districts are concentrated in Delhi, 8.3% in Kerala, and 6.1% in Gujarat[42]. This is mainly owing to the rising trends of the pandemic in major urban agglomerations (Figure 3) which are located in these states. In fact, as a whole, urban agglomerations have evinced the steepest rise in cases. This is clearly evident from the top red districts (as of 1 May 2020). With 130 districts in the red zone, 284 in orange zone, and 319 green zone districts, Maharashtra, Delhi, and Gujarat are among the high COVID-19-19[43]. Most of these districts have heavy commuter flows to workplaces via public modes of transport like train and buses[44], that might result in local transmission or which may also be cited as a plausible reason for the sharp increase in the form of direct local/community transmission.

Nevertheless, the onset of the pandemic and strict measures of lockdown, some of the red districts which are major contributors to the Indian economy, for Mumbai and Delhi which occupy the top two ranks in terms of PPP GDP ($310 billion and $294 billion respectively) have almost come to a standstill as mobility in terms of daily commuting has significantly declined. A similar situation is seen in other metropolitan areas like Bangalore, Pune, Hyderabad, Kolkata, and Ahmedabad. For instance, Figure 4 shows traffic levels for Delhi, Mumbai, Pune, and Bangalore. We see that similar to macro and meso level patterns, post-March 21st traffic has drastically dipped with a significant rise in the active COVID-19 cases (Figure 5). The spread of the virus has varied significantly across cities with Mumbai at the top, and Bangalore experiencing a slower pace of rising in cases. Moreover, some unusual mobility patterns with respect to the mode of travel have been noted with the lockdown of public transport usage. For example, weekly changes in the relative volume of directions requests made by users as compared to a baseline volume by transportation type (Figure 6) for two largest megacities of India i.e. Delhi (Figure 6a) and Mumbai (Figure 6b) have evinced that post lockdown the volume of direction requests by walking is relatively higher, which might be a result of mass movement of laborers that took place from Delhi to adjacent states in Uttar Pradesh, Rajasthan and also to Bihar.

Concluding remarks

Recently media has reported that all metro zones including Delhi, Mumbai, Chennai, Kolkata, Hyderabad, Bengaluru and Ahmedabad will be declared as red zones post 2nd phase of lockdown. Given the adverse impact of nationwide lockdown on the economy, government

[42] https://epaper.livemint.com/Home/ArticleView

[43] https://www.thehindu.com/news/national/COVID-19-19-health-ministry-lists-red-orange-and-green-zone-districts-for-week-after-may-3/article31478592.ece

[44] Census 2011, B-28 The table on mode of travel to place of work

is planning to open certain sectors with strict safeguards[45]. Furthermore, all metro zones including Delhi, Mumbai, Chennai, Kolkata, Hyderabad, Bengaluru and Ahmedabad will be declared as red zones[46]. However, as the neoliberal paradigm goes, urban areas are locations that have a high level of accumulation and concentration of economic activities so mobility is a key economic driver. The virus spreads via physical proximity and as a consequence, we have witnessed a historic lockdown that has brought our cities to a standstill tied with high costs.

WHO has applauded India for her attempt to control/slow the pandemic spread. We believe it is too soon to judge as we are still experiencing the pandemic and related policy implications. For a populous country like India, policymakers truly face a daunting task. Is lockdown a sustainable solution to control the spread in the long run? It may have given the government a window of opportunity to ramp up its health infrastructure and embark on a structured approach. Opposition and several studies did question the lockdown particularly its damaging economic and social effects. its harsh impact on the poor, and the daunting number of migrants stranded in our cities. With the recent ending of the second phase of lockdown, the government has announced some easing of restrictions post-May 3rd. However, it is disconcerting to see that the top 20 high burden (COVID-19-19) districts comprised of state capitals and several industrial zones of India.

Thus, COVID-19 trends and associated containment policies have thrown India's entire neoliberal agenda of urbanism into a massive conundrum. How and to what extent will easing mobility address the concerns raised during the first and second lockdown phase?

How will urban and regional economies respond to the newly announced staggered lockdown approach? What spatiality will emerge from the mobility flows?

Will India flatten its curve? Will our cities return to being 'engines of economic growth' rather than being 'engines of COVID-19 growth'? Only time will tell. #

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[45]The Ministry of Health based the list on factors such as number of cases, doubling rate, extent of testing and surveillance feedback. In order to devise effective exit plan post 2nd phase, health ministry identified three major zone districts- red, orange and green.

[46]https://www.businesstoday.in/latest/trends/coronavirus-lockdown-3-govt-identifies-delhi-mumbai-all-metros-as-red-zones-post-may-3/story/402547.html

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Section D: Global Issues: INDIA: # Impact of COVID-19 on mobility in India

Figure 1

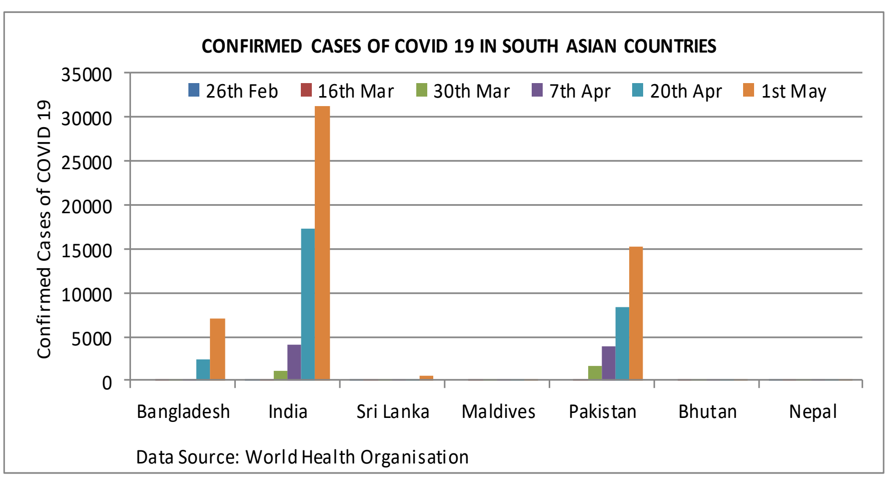


Figure 2: Impact of COVID-19on mobility trends at different locations in India

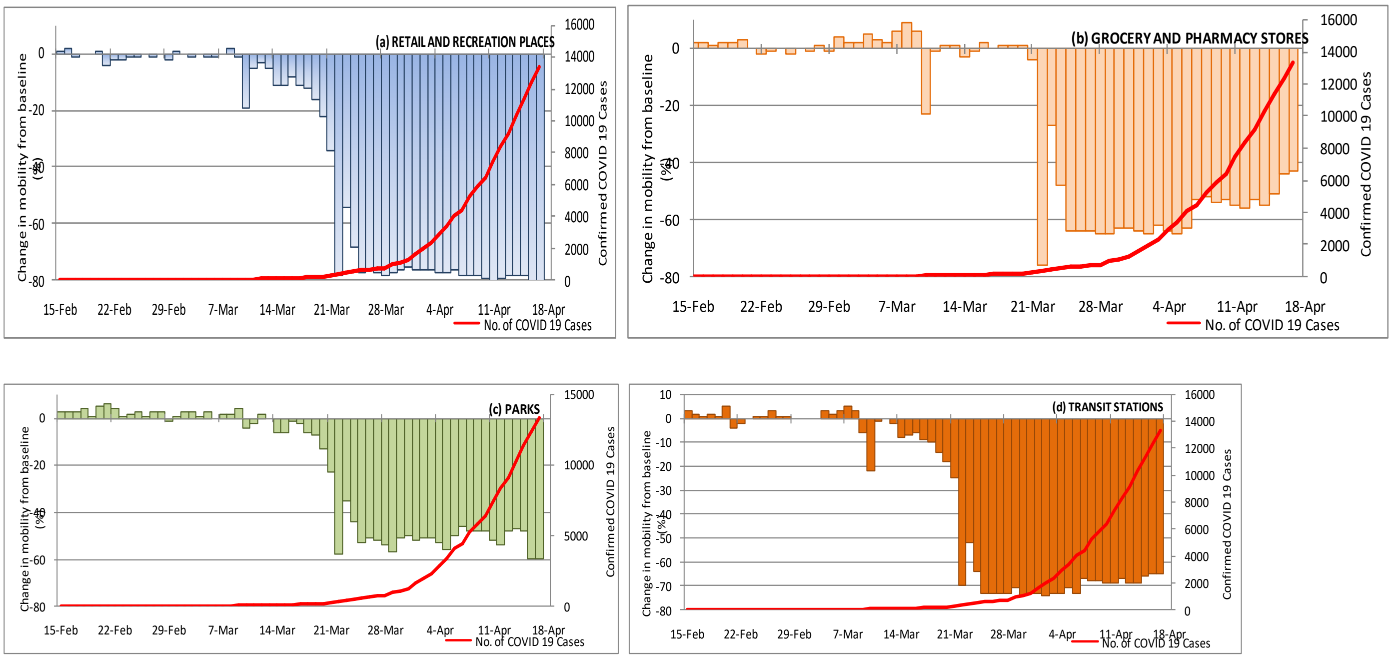
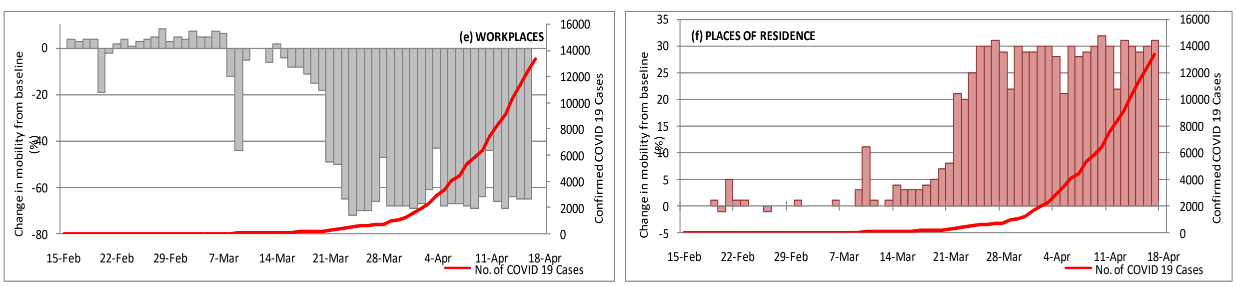


Figure 3: Impact of COVID-19on Mobility Trends at Workplaces and at Home



Source: Google

Figure 4

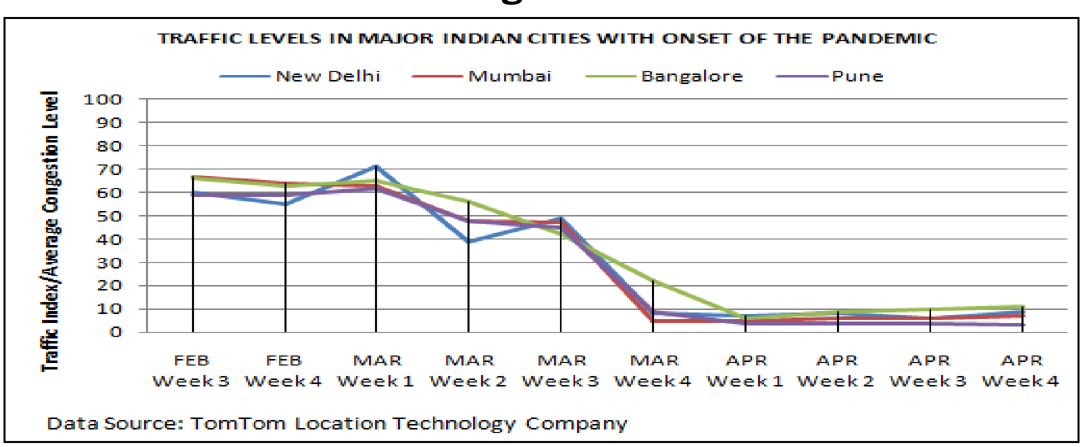


Figure 5

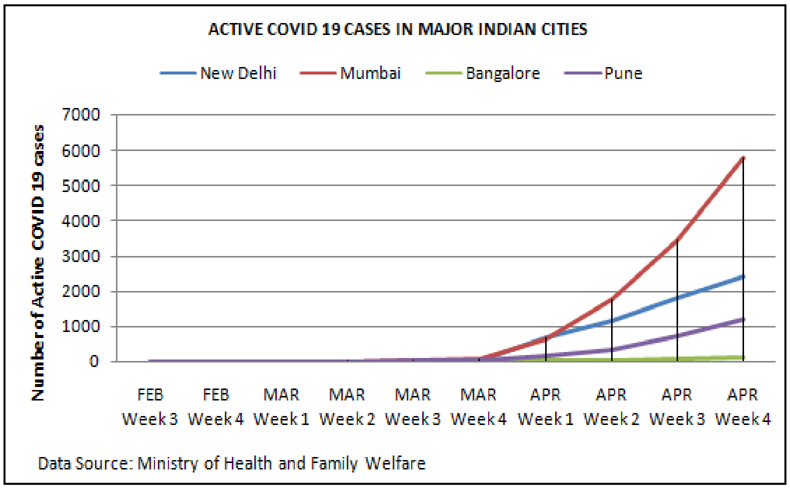


Figure 6(a): Weekly changes in relative volume of directions requests made by users as compared to a baseline volume by transportation type (a) Delhi

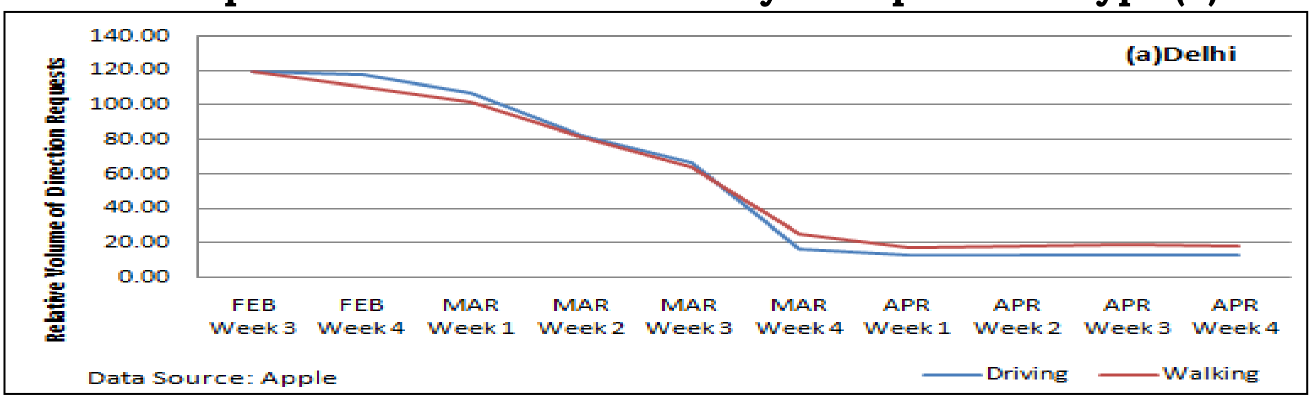
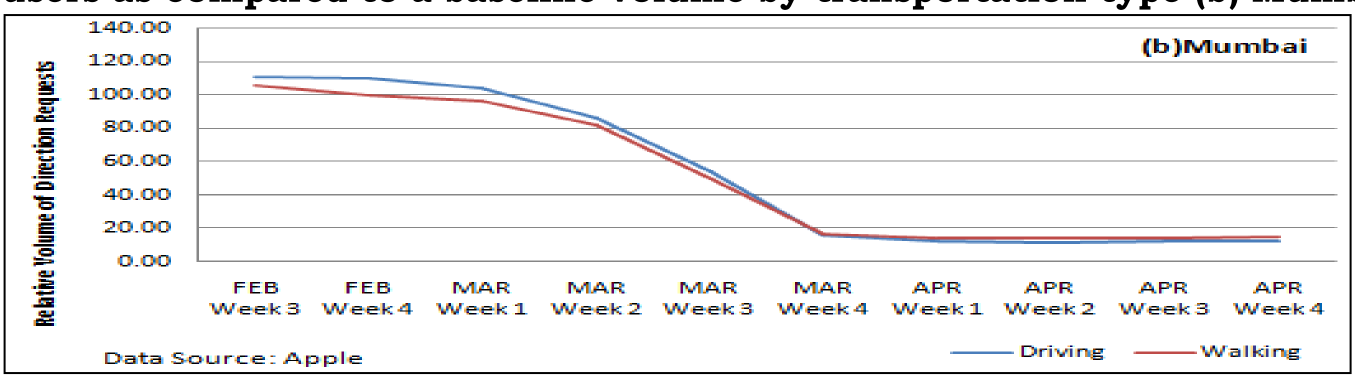
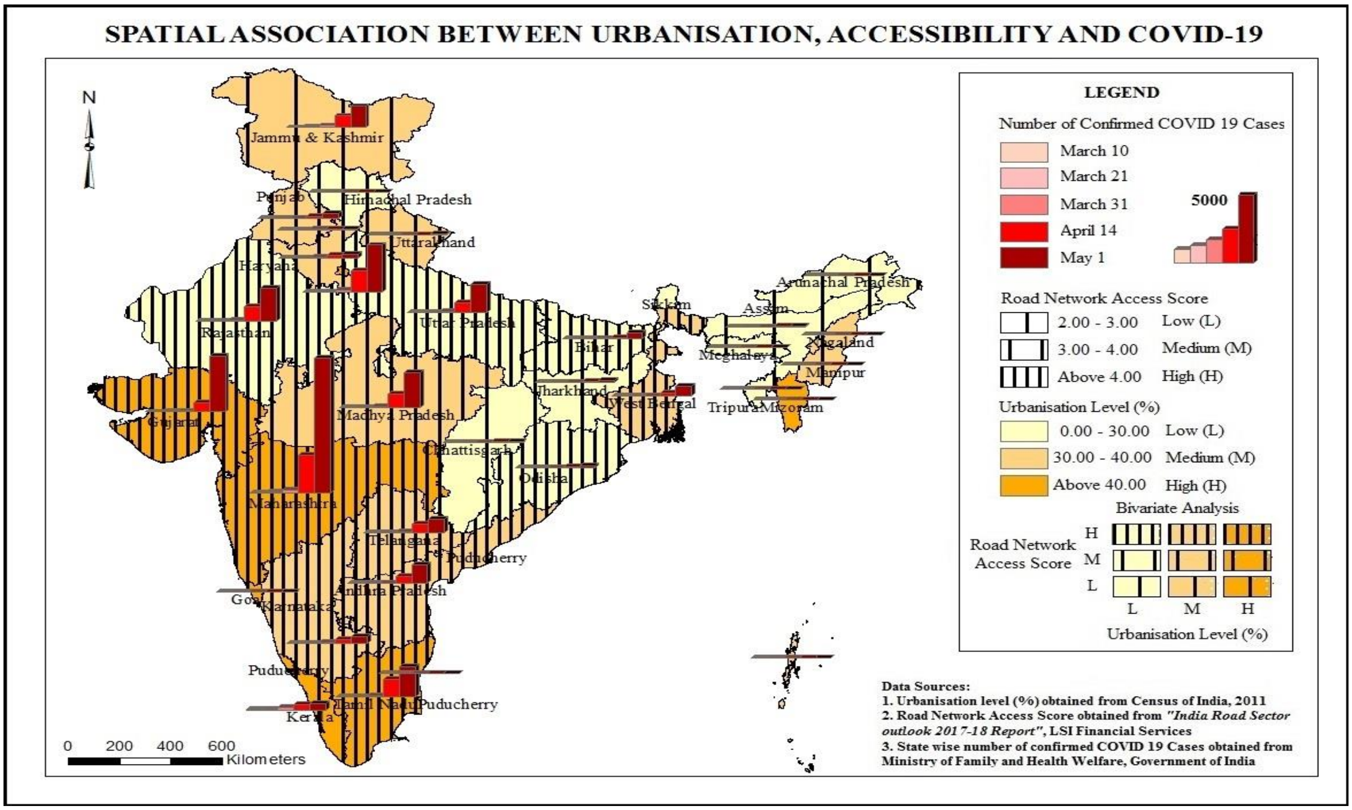


Figure 6(a): Weekly changes in relative volume of directions requests madeby users as compared to a baseline volume by transportation type (b) Mumbai




SPATIAL ASSOCIATION BETWEEN URBANISATION, ACCESSIBILITY AND COVID-19
N
Jammu & Kashmir
Punjab
Himachal Pradesh
Uttarakhand
Haryana
Rajasthan
Uttar Pradesh
Bihar
Sikkim
Assam
Arunachal Pradesh
Meghalaya
Nagaland
Manipur
Tripura
Mizoram
Jharkhand
West Bengal
Gujarat
Madhya Pradesh
Chhattisgarh
Odisha
Maharashtra
Telangana
Puducherry
Goa
Karnataka
Andhra Pradesh
Tamil Nadu
Kerala
0 200 400 600
Kilometers
LEGEND
Number of Confirmed COVID 19 Cases
March 10
March 21
March 31
April 14
May 1
5000
Road Network Access Score
2.00 - 3.00 Low (L)
3.00 - 4.00 Medium (M)
Above 4.00 High (H)
Urbanisation Level (%)
0.00 - 30.00 Low (L)
30.00 - 40.00 Medium (M)
Above 40.00 High (H)
Bivariate Analysis
Road Network Access Score
H
M
L
L M H
Urbanisation Level (%)
Data Sources:
1. Urbanisation level (%) obtained from Census of India, 2011
2. Road Network Access Score obtained from "India Road Sector outlook 2017-18 Report", LSI Financial Services
3. State wise number of confirmed COVID 19 Cases obtained from Ministry of Family and Health Welfare, Government of India

Multivariate Regression Results					Phases
R squared = 0.44		F = 12.85	Adjusted R squared = 0.41		Terminating period of lockdown phase 2
Y	**Confirmed Cases, May 1**	Coefficient	t	P>|t|	
X1	Urbanization Level (%)	14.68	1.24	0.22	
X2	Road Network Access Score	1062.8	4.93	0	
constant		-3324.04	-3.64	0.01	
R squared = 0.56		F = 21.03	Adjusted R squared = 0.54		Termination of lockdown phase 1 and beginning of lockdown Phase 2
Y	**Confirmed Cases, April 14**	Coefficient	t	P>|t|	
X1	Urbanization Level (%)	6.15	1.89	0.06	
X2	Road Network Access Score	370.46	6.23	0	
constant		-1177.15	-4.67	0	
R squared = 0.42		F = 11.68	Adjusted R squared = 0.38		First week of lockdown Phase 1
Y	**Confirmed Cases, March 31**	Coefficient	t	P>|t|	
X1	Urbanization Level (%)	0.5	2.47	0.04	
X2	Road Network Access Score	28.99	4.63	0	
constant		-84.29	-3.17	0.003	
R squared = 0.29		F = 6.62	Adjusted R squared = 0.24		Pre lockdown period
Y	**Confirmed Cases, March 21**	Coefficient	t	P>|t|	
X1	Urbanization Level (%)	0.0491	0.68	0.5	
X2	Road Network Access Score	4.734	3.59	0.001	
constant		-12.85	-2.3	0.028	
R squared = 0.0297		F = 0.49	Adjusted R squared = 0.03		
Y	**Confirmed Cases, March 10**	Coefficient	t	P>|t|	
X1	Urbanization Level (%)	0.0048	0.17	0.865	
X2	Road Network Access Score	0.5046	0.98	0.336	
constant		-0.6888	-0.31	0.755	

Source: Based on Authors' calculation