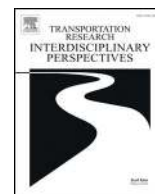




Contents lists available at ScienceDirect

## Transportation Research Interdisciplinary Perspectives

journal homepage: <https://www.journals.elsevier.com/transportation-research-interdisciplinary-perspectives>



# Impact of physical distancing due to novel coronavirus (SARS-CoV-2) on daily travel for work during transition to lockdown



Digvijay S. Pawar<sup>a</sup>, Ankit Kumar Yadav<sup>b</sup>, Ninad Akolekar<sup>c</sup>, Nagendra R. Velaga<sup>b,\*</sup>

<sup>a</sup> Transportation Systems Engineering, Department of Civil Engineering, Indian Institute of Technology (IIT) Hyderabad, Kandi, Sangareddy 502285, India

<sup>b</sup> Transportation Systems Engineering, Department of Civil Engineering, Indian Institute of Technology (IIT) Bombay Powai, Mumbai 400 076, India

<sup>c</sup> Department of Computer Science and Engineering, Indian Institute of Technology (IIT) Hyderabad, Kandi, Sangareddy 502285, India

### ARTICLE INFO

#### Article history:

Received 7 May 2020

Received in revised form 8 August 2020

Accepted 15 August 2020

Available online 19 August 2020

#### Keywords:

COVID-19

Mode choice

Private transport

Public transport

Safety perceptions

Travel behavior

### ABSTRACT

The outbreak of COVID-19 pandemic has resulted in change in both commute and personal travel patterns. Though, in India, lockdown was implemented from 25th March 2020, due to self-awareness and pandemic risk perception, change in commuter behavior was observed from the beginning of March 2020. The period from 15th to 24th March 2020 is considered as the transition phase of COVID-19 outbreak in India (i.e., between no lockdown and lockdown period). This study attempts to use a decision tree approach to investigate the modal preference of 1542 commuters in association with socio-economic and travel characteristics, and safety perceptions with respect to public and private modes during transition to lockdown due to COVID-19 in India. About 41% of commuters stopped traveling during the transition to lockdown phase, 51.3% were using the same mode of transport and 5.3% of commuters shifted from public to private mode. The study findings reported different interactions of factors influencing the decision to use public or private modes of transport for daily commuting during pandemic situations like COVID-19. Interestingly, safety perceptions (associated with personal health) of commuters did not play a significant role in their mode choice behavior during the transition phase. Though people perceived public transportation as unsafe over personal vehicle use, the actual commute patterns did not validate this due to a possible reason that commuters do not have enough alternative modes. Given the uncertainties in the decision making of the commuters regarding their travel behavior due to physical distancing, the insights from this study are important to policymakers and local transport authorities to understand the change in travel patterns.

## 1. Introduction

As on 8th August 2020, 19.5 million people around the world are affected due to the Novel Coronavirus (SARS-CoV-2) pandemic that started in Wuhan city, China, in early December 2019 (Lipsitch et al., 2020; Sohrabi et al., 2020; Jiang et al., 2020; Huang et al., 2020). In addition to its severe effects on human health and life, the virus has potentially impacted the transportation system (Rodríguez-Morales et al., 2020; Bogoch et al., 2020; Sobieralski, 2020). Avoiding physical contacts and reducing interaction between individuals (i.e., physical distancing) became a compulsory norm in most of the countries (Vos, 2020; Wilder-Smith and Freedman, 2020). India has restricted human movement by incorporating lockdown to ensure physical distancing and promote self-isolation. In Indian context, lockdown was defined as the situation where complete travel restrictions were imposed on general public except for the supplies of essential goods and services (such as daily groceries), essential personnel (such as police, medical professionals and media reporters) and for people facing medical emergencies.

In India, the first case of COVID-19 was detected on 30th January 2020 in a university student who returned from Wuhan, China (Ministry of Health and Family Welfare, Government of India, 2020). Consequently, the number of positive cases started increasing in India and the country went into complete lockdown from 25th March for a period of 21 days (Press Information Bureau, Government of India, 2020). To stop the spread of coronavirus, the lockdown period was further extended to 31st May 2020. After that, the relaxations in travel were given in three stages (one month for each stage) starting from 1st June 2020 to 31st August 2020.

Transport sector across the world continues to combat challenges during the global coronavirus pandemic. The travel restrictions began with the ban on international travel of people from COVID-19 affected countries, followed by visa restrictions, border checks/closures and control on entry and exit points across the cities. Quarantine measures were adopted for people with symptoms of infection, and self-isolation and sanitization were enforced to reduce the risk of infection among the population. Many of the European countries approved limited temporary relaxation of driving enforcement and rest times for the drivers of vehicles carrying goods and

\* Corresponding author.

E-mail addresses: [dspawar@ce.iith.ac.in](mailto:dspawar@ce.iith.ac.in), (D.S. Pawar), [ankit.yadav@iitb.ac.in](mailto:ankit.yadav@iitb.ac.in), (A.K. Yadav), [cs16btech11024@iith.ac.in](mailto:cs16btech11024@iith.ac.in), (N. Akolekar), [n.r.velaga@iitb.ac.in](mailto:n.r.velaga@iitb.ac.in), [velaga@civil.iitb.ac.in](mailto:velaga@civil.iitb.ac.in) (N.R. Velaga).

essential services. Moreover, the United States of America passed an act called Coronavirus Aid, Relief and Economic Security (CARES) which allows emergency assistance and health care response for COVID-19 affected individuals, families and businesses. CARES funding of \$25 billion is allocated for public transportation in rural and urban areas, and are available for services provided in response to COVID-19 (US Department of Transportation, 2020). In India, all the passenger trains, metro and flight services were canceled from 25th March 2020 (Press Information Bureau, Government of India, 2020). Transportation for non-essential services are prohibited, and only essential personnel and service providers are allowed to travel. The timeline of positive cases, recovered cases and deaths in India (from 30th Jan to 31st March 2020) due to COVID-19 are shown in Fig. 1.

In the third week of March 2020, the number of COVID cases in India crossed 100 (Shelar, 2020) which led to closing of most of the educational institutes (Ahmed, 2020), religious places restricting the number of devotees (Smitha, 2020), and companies giving option to work from home (Mathur et al., 2020; IANS, 2020). This led to a pandemic fear among the general public in the third week of March 2020. Hence, the third week of March is considered as the transition phase of COVID-19 outbreak in India (i.e., between no lockdown and lockdown period). During the transition period, the pandemic fear started influencing the daily travel behavior of commuters, either directly or psychologically. Public transportation and private vehicles are two major modes of travel generally used by the commuters in India. During this transition period, in order to ensure safety and minimize the spread of COVID-19 while traveling from residence to workplace and vice-versa, the commuters were required to make an appropriate travel mode choice. The choice of mode depends on their socio-economic characteristics (such as age, income and city of residence), travel behavior parameters (such as distance from home to work, travel time and frequency of going to work) and health-related safety perceptions. Therefore, given the uncertainties in the decision making of commuters, it is important to policymakers, administrators of transportation sector and local transport authorities to understand the variations in travel patterns during pandemic situations such as COVID-19. This study is an attempt to understand the commuters' travel behavior during transition to lockdown due to COVID-19 pandemic. The specific objectives of this study are:

1. To investigate the impact of COVID-19 pandemic on mode choice (between public and private modes) during the transition to lockdown period.
2. To identify the association of mode choice behavior with the socio-

economic and travel characteristics, and safety perception of commuters during transition to lockdown in India.

## 2. Method

### 2.1. Procedure

An online questionnaire survey was designed to capture travel behavior information of commuters before and during the transition period of COVID-19 outbreak. The responses were collected from 18th to 28th March and the participants were specifically asked to fill data corresponding to the transition to lockdown period (i.e., 15th March to 24th March 2020). The questionnaire enquired about the commuters' socio-economic characteristics (such as age, income, and city of residence) along with work-related travel characteristics (such as preferred mode of transport, distance from home to work, travel time and frequency of traveling to work) and health related safety perceptions corresponding to public and private modes. A detailed description of the research organizations involved and motivation of this study was provided to the respondents at the beginning of the questionnaire. Moreover, the participants were informed to provide responses related to COVID-19 impacts on their travel behavior. The online survey link was posted on various social media platforms, public forums and circulated through personal communications. On average, it took about 7 to 10 min to fill the questionnaire. The participation in the study was anonymous, voluntary and confidential. No monetary benefits were provided to the participants.

Fig. 2 shows the research methodology adopted in this study. The first step was to design the questionnaire survey, followed by its distribution and data collection. After the survey, the responses were filtered to remove the erroneous/incomplete data. Thereafter, preliminary analysis was conducted to analyze the mode choice behavior of commuters and their safety perceptions related to public and private modes. Further, the decision tree was developed by adopting a 5-fold cross validation technique to identify the potential interactions of factors influencing the mode choice. Finally, interpretation of the decision tree was discussed and conclusions were outlined.

### 2.2. Participants

In total, 1945 responses were obtained from the survey. Among these responses, 74 were found to be erroneous and 118 were incomplete,

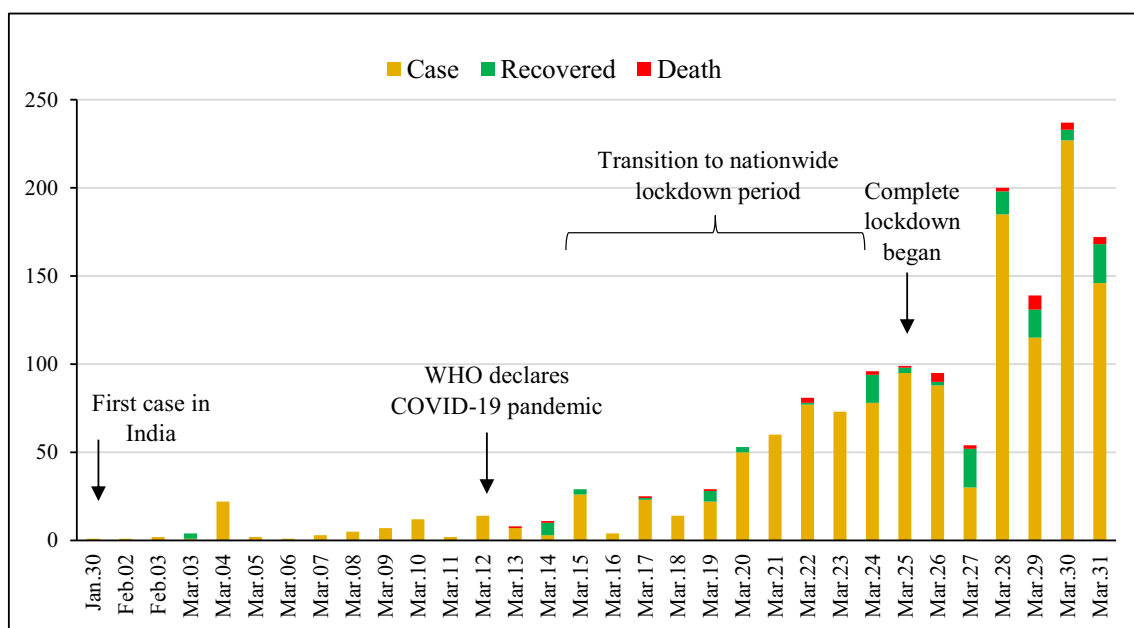


Fig. 1. Timeline of cases, recovered and deaths in India due to COVID-19.

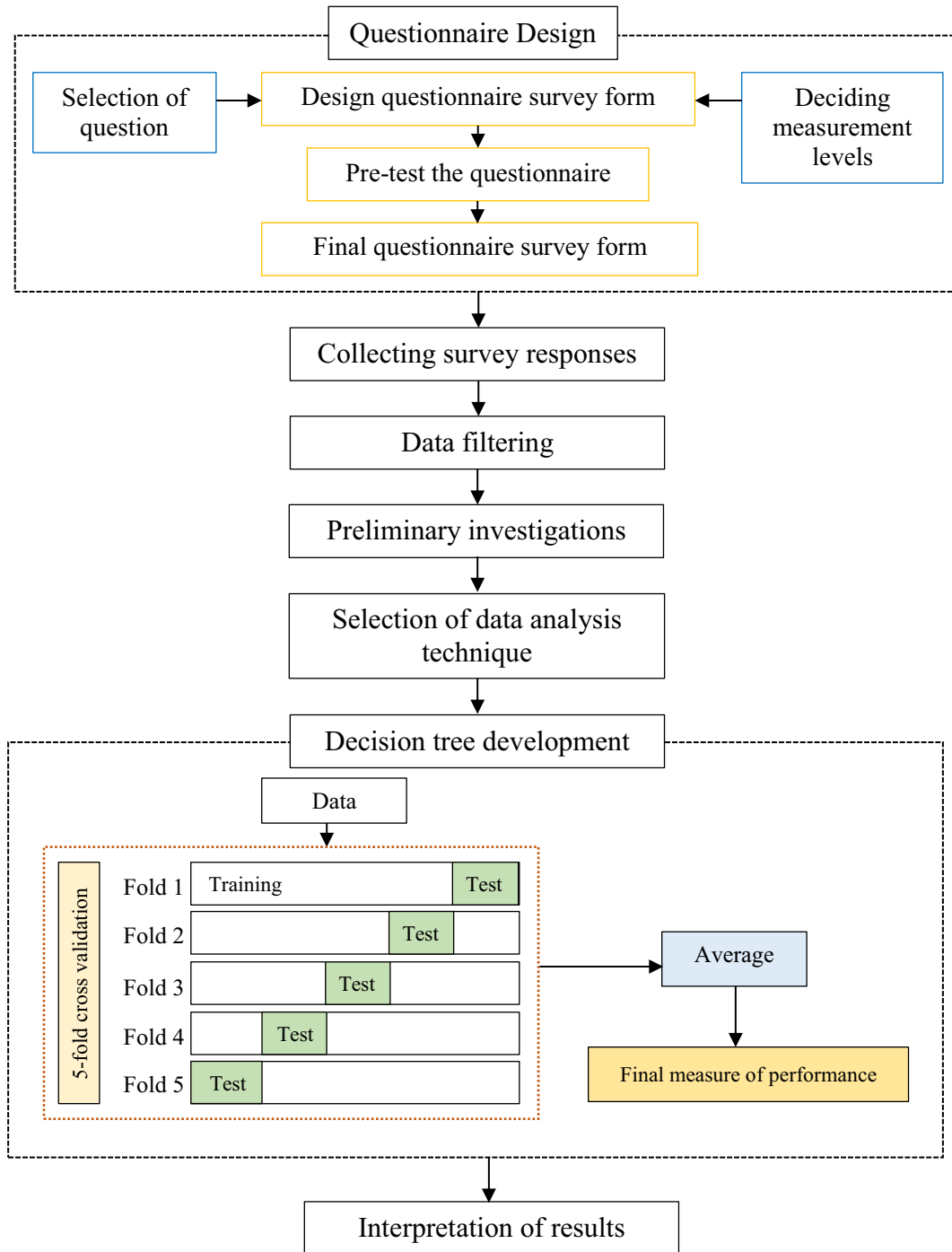


Fig. 2. Research methodology of the study.

which were filtered. As the present study focused on examining the modal preference between public and private modes of transport, the survey data for respondents who used transport modes other than public and private modes to reach the workplace were excluded from the analysis. This consisted of the proportion of people using ridesharing services (119 responses) and auto rickshaws (92 responses). Regarding the ridesharing services, 55.2% of the people responded that they stopped travel during the transition to lockdown period, 31.9% of respondents were still using the ridesharing services, 9.4% switched to private mode, and the remaining shifted to public mode of transport. Whereas, 33.7% of the auto rickshaw users mentioned that they stopped traveling during the transition period, 52.3% continued using auto rickshaws, 10.4% and 3.6% of

the auto rickshaw users switched to private and public transport modes respectively.

The remaining 1542 samples (i.e., using either public or private modes of transport during the transition phase of COVID-19 outbreak) were used for analysis in the present study. The participants were enquired about their mode choice before and during the transition to lockdown period (such as personal cars, two-wheelers, buses, metro rails, trains, bicycle, walk, etc.). These modes of transport were combined into public and private modes. The public mode included buses, trains, metro rails and the private mode consisted of personal cars, motorized two wheelers, bicycle and walk. The descriptive statistics of socio-economic and travel characteristics of respondents are shown in Table 1. From the percentage of income

**Table 1**  
Descriptive statistics of socio-economic and travel characteristics and safety perception of respondents ( $N = 1542$ ).

Factor	Categories	Percentage
Age	<20 years	5.39
	20 to 30 years	49.93
	30 to 40 years	30.13
	40 to 60 years	13.31
	>60 years	1.24
Income (per annum) <sup>#</sup>	Up to 3 lakh rupees	26.65
	3 to 6 lakh rupees	27.31
	6 to 12 lakh rupees	27.09
	12 to 18 lakh rupees	10.21
	>18 lakh rupees	8.74
City of residence*	Tier 1	63.36
	Tier 2	21.09
	Tier 3	15.55
Distance between home and work	<5 km	39.17
	5 to 10 km	19.89
	10 to 20 km	17.33
	20 to 30 km	10.14
Travel time between home and work	>30 km	13.47
	0 to 15 min	37.36
	15 to 30 min	23.97
	30 to 60 min	20.03
	1 to 2 h	12.80
Frequency of travel per week	>2 h	5.84
	Whole week (seven days)	12.39
	Six days	33.82
	Five days	39.02
Health related safety perception with respect to public mode of transport during COVID-19 outbreak	<5 days	14.77
	Not safe	75.51
	Slightly unsafe	16.32
	Moderately safe	6.10
Health related safety perception with respect to private mode of transport during COVID-19 outbreak	Safe	1.66
	Very safe	0.41
	Not safe	3.05
	Slightly unsafe	9.86
	Moderately safe	34.24
	safe	40.79
	Very safe	12.06

\* City of residence is divided into 3 categories based on a ranking system used by the Government of India. Tier-1 denotes the cities with the highest cost of living and population density; Tier-2 cities have medium cost of living and population density, and Tier-3 cities have the lowest cost of living and population density (Ministry of Finance, Government of India, 2014).

<sup>#</sup> 1 lakh = 0.1 million.

category, it is clear that the people from all income levels participated in the study.

### 2.3. Decision tree analysis

The present study analyzed the decision making of commuters related to selecting the public or private modes during the transition period of COVID-19 outbreak. Previous research had shown that the estimation efficiency of decision tree (DT) models is better than the multinomial logit models (MNL) and neural network (NN) models (Rudd and Priestley, 2017). Therefore, a decision tree approach was used to understand the underlying interactions among various explanatory variables (shown in Table 1). Among these variables, distance and travel time might be correlated with each other but may not necessarily be associated with a direct/linear relationship. This can happen due to the level of traffic congestion faced by the commuters. To account for such samples and cases, it is important to consider both the features simultaneously rather than considering

only one of them. During the analysis, we empirically tested all the three possibilities: using only distance, travel-time and both features simultaneously, and found that the model using both distance and travel time along with other features produced the most promising predictive model.

Decision trees are constructed using a top-down approach in a greedy fashion. Specifically, at each node in the decision tree, the training set is split into smaller subsets until the purity of the nodes can no longer be increased. In this work, the Scikit-learn's implementation of Classification and Regression Trees (CART) algorithm were adopted to build a binary decision tree. We also experimented with other popular decision-tree training algorithms such as the Chi-square Automatic Interaction Detector (CHAID) algorithm and the Iterative Dichotomiser 3 (ID3) algorithm. However, analysis results using CART algorithm were found more promising than its counterparts. CART algorithm uses the GINI impurity as the measure of diversity at a particular node (Pedregosa et al., 2011). The GINI impurity at a particular node  $k$  is given by the following expression in Eq. (1) (Breiman et al., 1984; Yao et al., 2019):

$$GINI(k) = 1 - \sum_{j=1}^c p(j|k)^2 \quad (1)$$

where,  $c$  denotes the number of classes and  $p(j|k)$  denotes the fraction of data points at node  $k$  belonging to class  $j$ .

At a particular node, if the GINI index is zero, it implies that there is zero diversity in samples at that node (i.e., all samples at that node belong to only one class). Therefore, an absolute split (0% and 100%) is expected wherever the GINI index is zero. The absolute split at a particular node in the decision tree indicates that all the samples (individuals) reaching that node (i.e. satisfying decision rules from the root node to that particular node) made the same decision of choosing that particular mode of transport.

To prevent overfitting the training data, the decision trees were pruned by setting a maximum limit on the depth of the tree to five. Further, a 5-fold stratified cross-validation method was implemented on the questionnaire dataset to obtain the best possible decision tree. The cross-validation technique used data more efficiently as every observation is used for both training and testing. It was found that the decision tree with depth 5 and geometric mean score (G-mean) as 0.57 outperformed. G-mean score tries to maximize the accuracy on each of the classes while keeping them balanced.

## 3. Results

### 3.1. Preliminary data analysis

The questionnaire enquired the travel behavior of commuters before and during the transition to lockdown period. The respondents' preferred mode of travel between their place of residence and workplace before the transition to lockdown period of COVID-19 outbreak is presented in Fig. 3a. The figure indicates that motorized two wheelers account for the highest share (32.1%) followed by personal cars (23%), buses (16.7%) and walk (12.8%) among the others.

In response to a question about respondents' travel mode choice during the transition to lockdown phase of COVID-19 outbreak, 41.65% said that they stopped traveling during that phase, 51.31% reported that they were using the same mode of transport as before, 5.3% shifted from public to private mode, and remaining 1.74% switched from one public mode to another (Fig. 3b). People who shifted from one public transport mode to another comprised 44.4%, 38.9%, and 16.7% bus, train and metro-rail users respectively.

The health-related safety perceptions of commuters regarding the public mode of transport showed that 75.5% feel unsafe, 16.3% slightly unsafe, 6.1% moderately safe, 1.7% safe and remaining perceived it as very safe. Whereas, safety perception of private modes of transport revealed that 12% of the commuters perceive it as very safe, 41% as safe, 34% as moderately safe, 10% as slightly unsafe and remaining 3% as very unsafe (Fig. 4).

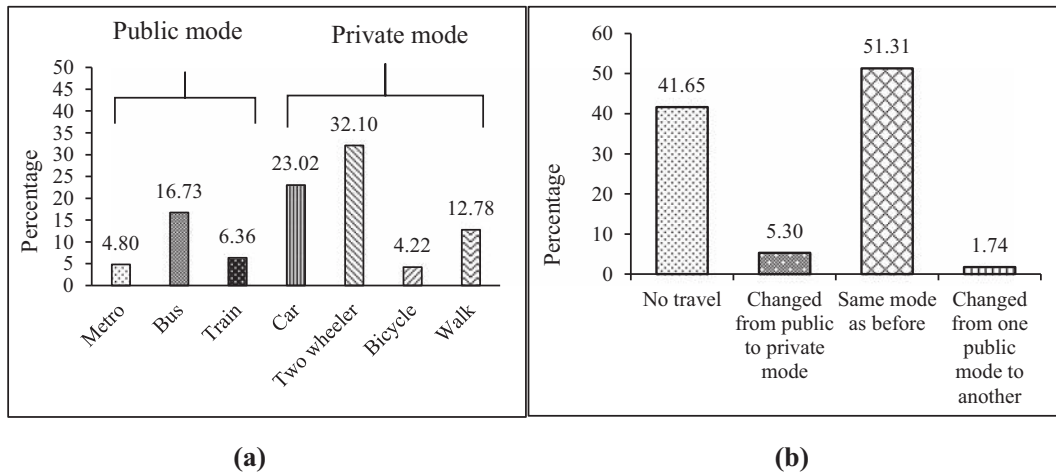


Fig. 3. Modal preference (a) before and (b) during the transition to lockdown phase of COVID-19 outbreak.

3.2. Development of decision tree

The present study used a decision tree approach to investigate the factors influencing the decision to prefer public or private modes of transport during the transition to lockdown period of COVID-19 outbreak. During the development of decision tree, the commuters' decision to choose the preferred mode of transport (public or private) was considered as the dependent variable. Whereas, the independent variables include socio-economic and travel characteristics (Table 1) along with the safety shift. In the questionnaire survey, the health-related safety perceptions of commuters with respect to public and private modes of transport during the transition to lockdown period were enquired (Table 1). From these individual safety perceptions corresponding to public and private modes, the term 'safety shift' was defined as the difference between the health-related safety perception of private and public modes. The difference in the safety perceptions of private and public modes gives the relative safety risk perceived by the commuters between public and private modes. This 'safety shift' is treated as a numerical feature in the model. All the other variables were entered as categorical, except age which was continuous (considered as median of the age categories shown in Table 1).

The developed decision tree is shown in Fig. 5. The nodes with shades of blue color represent the public mode selection and the nodes with shades of orange represent the private mode selection by commuters. In each node of the decision tree, a particular condition is defined based on which the

subsequent possible node is decided. For example, the topmost node defines the condition 'travel time ≤ 30 minutes' (Fig. 5). If the condition is true, it will move to the immediate left node, otherwise it will move to the immediate right node.

3.2.1. Factors influencing private transport mode choice

The combinations of various factors influencing the selection of private mode of transport during the transition to lockdown period due to COVID-19 outbreak are presented in Table 2. The first three interaction terms focused on the individuals whose travel time is less than or equal to 15 min. It further categorized them into two groups with income less than or equal to 12 lakh rupees (1.2 million) per annum (Interaction terms 1 and 2) and income >12 lakh rupees per annum (Interaction term 3 and 4). Among these commuters, the first interaction term suggests that people with income less than or equal to 12 lakh rupees, who have to travel for <5 days a week, are expected to use private mode of transport even if their perceived safety shift is less (i.e. less perceived safety of private mode over public mode). The second interaction term indicates that private mode of transport is preferred by people with age >32.5 years whose income is less than or equal to 12 lakh rupees and higher perceived safety shift (i.e., higher perceived safety of private mode over public mode). Under the same category of commute time <15 min, and annual income higher than 12 lakhs, it was observed that the use of private transport is preferred by younger people with age less than or equal to 27.5 years (as

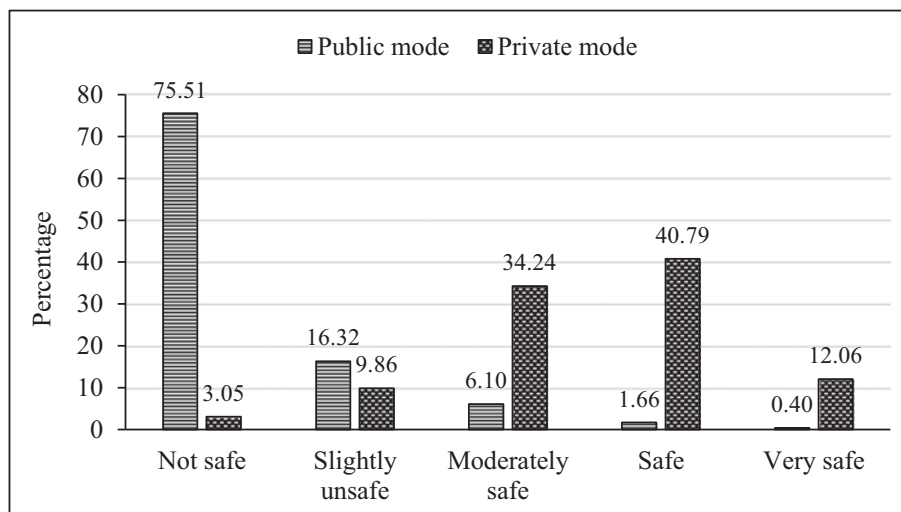


Fig. 4. Safety perception of commuters with respect to public and private mode during the transition to lockdown phase of COVID-19 outbreak.

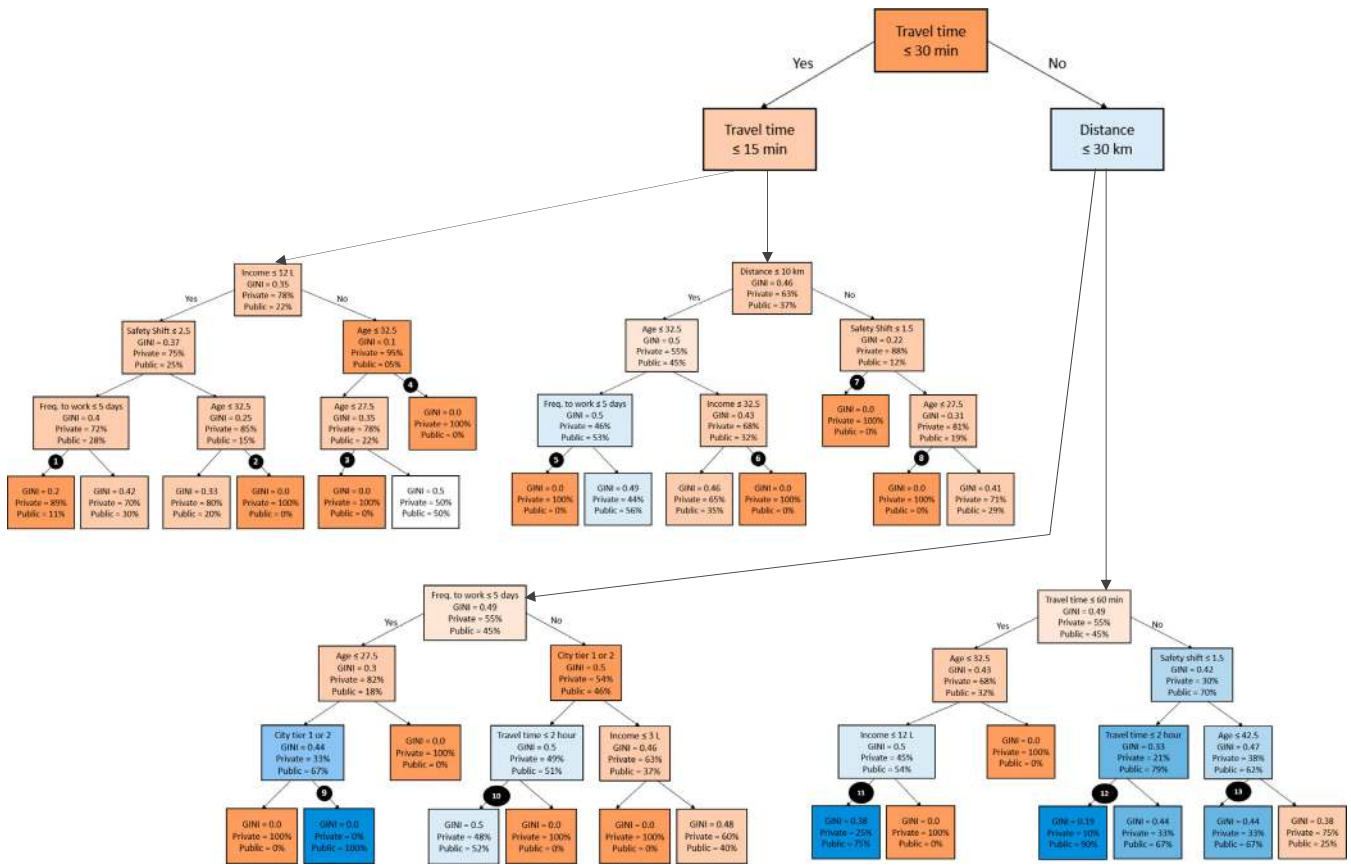


Fig. 5. Decision tree for public vs private mode choice.

Table 2

Interactions of explanatory variables for preferring private transport during COVID-19 transition to lockdown period.

Interaction terms	Description
Interaction term 1	Commuters with travel time less than or equal to 15 min, income less than or equal to 12 lakh rupees per annum, safety shift less than or equal to 2.5, and frequency of travel < 5 days per week
Interaction term 2	Commuters with age >32.5 years, travel time less than or equal to 15 min, income less than or equal to 12 lakh rupees per annum, and safety shift higher than 2.5,
Interaction term 3	Young commuters with age less than or equal to 27.5 years, income higher than 12 lakh rupees per annum, and travel time less than or equal to 15 min
Interaction term 4	Commuters with age >32.5 years, income higher than 12 lakh rupees per annum, and travel time less than or equal to 15 min
Interaction term 5	Commuters with age less than or equal to 32.5 years, travel time between 15 and 30 min, travel distance less than or equal to 10 km, and frequency of travel < 5 days per week
Interaction term 6	Commuters with age >32.5 years, income >18 lakh rupees per annum, travel time between 15 and 30 min, distance less than or equal to 10 km
Interaction term 7	Commuters with travel time between 15 and 30 min, travel distance higher than 10 km and perceived safety shift less than or equal to 1.5
Interaction term 8	Young commuters with age less than or equal to 27.5 years, travel time between 15 and 30 min, travel distance higher than 10 km and perceived safety shift >1.5

indicated by the third interaction term), and by individuals aged above 32.5 years as indicated by the fourth interaction term (Fig. 5).

The next four interaction terms designate the category of commuters with travel time between 15 and 30 min who tend to use private mode of

transport. Further, they are categorized on the basis of distance travelled during commuting (Fig. 5). In this, the first category is of young people (less than or equal to 32.5 years) who have to travel for < 10 km and < 5 days a week (Interaction term 5). The second category is of people

Table 3

Interactions of explanatory variables for preferring public transport during COVID-19 transition to lockdown period.

Interaction terms	Description
Interaction term 9	Young commuters with age less than or equal to 27.5 years living in Tier-3 cities, with travel time >30 min, travel distance less than or equal to 30 km and frequency of travel < 5 days a week
Interaction term 10	Commuters staying in Tier-1 and Tier-2 cities, with travel time between 30 min to 2 h, travel distance less than or equal to 30 km, and frequency of travel 5 or more days a week
Interaction term 11	Commuters with age less than or equal to 32.5 years, income less than or equal to 12 lakh rupees per annum, travel time between 30 min to 1 h, and travel distance >30 km
Interaction term 12	Commuters with travel time between 1 and 2 h, travel distance >30 km, and perceived safety shift less than or equal to 1.5
Interaction term 13	Commuters with age less than or equal to 42.5 years, travel time >1 h, travel distance >30 km, and perceived safety shift >1.5

with age >32.5 years earning high income (>18 lakhs per annum) and need to travel for <10 km (Interaction term 6). The third category is of commuters who have to travel for longer distances (>10 km) and they prefer private mode even after having reduced perceived safety shift (Interaction term 7). The last category reports that the commuters of age less than or equal to 27.5 years with higher perceived safety shift, and have to travel for >10 km for work, prefer private mode of transport over the public mode (Interaction term 8).

### 3.2.2. Factors influencing public transport mode choice

Various interactions were observed from the decision tree designating the categorization of commuters preferring public mode of transport during the transition period of COVID-19 pandemic. These interactions are illustrated in Table 3. The ninth interaction term suggests that young commuters with age less than or equal to 27.5 years living in Tier-3 cities, with travel time >30 min, travel distance less than or equal to 30 km and frequency of travel <5 days a week preferred public transport. In the tenth interaction, within the same distance category, commuters staying in Tier-1 and Tier-2 cities, with travel time between 30 min to 2 h, and frequency of travel more than or equal to 5 days a week, are more likely to use public transport (Fig. 5).

The eleventh interaction term suggests that individuals with age less than or equal to 32.5 years, annual income less than or equal to 12 lakh rupees (1.2 million), travel time between 30 min to 1 h, and need to travel for >30 km to their workplace, consider public mode as favorable. The next two interactions involve the perceived safety shift of commuters. In the twelfth interaction, the use of public transport was preferred by the commuters with travel time between 1 and 2 h, travel distance >30 km, and reduced perceived safety shift (i.e., less perceived safety of private mode over public mode). The last interaction indicated that the commuters with age less than or equal to 42.5 years, who need to travel for >30 km, taking travel time >1 h, would prefer public mode even if their perceived safety shift is higher (i.e., higher perceived safety of private mode over public mode).

The relative importance of various interaction variables used in the decision tree analysis is shown in Fig. 6. The importance (value) of a particular feature is computed as the (normalized) total reduction of the criterion, in our case the GINI impurity, particular to that feature. This is also known as the GINI importance. To capture the total reduction, the weighted impurity decrease at a given node is first defined using the following Eq. (2) (Pedregosa et al., 2011).

$$NI_j = \frac{N_j}{N} \left( C_j - \frac{N_{RIGHT(j)}}{N_j} C_{RIGHT(j)} - \frac{N_{LEFT(j)}}{N_j} C_{LEFT(j)} \right) \quad (2)$$

where,  $N$  is the total number of samples,  $N_j$  is the number of samples at the current node  $j$ ,  $C_j$  denotes the value of GINI impurity at node  $J$ , and  $Left(j)$  &  $right(j)$  denote the left and right child nodes of node  $j$  respectively.

The feature importance of a feature  $k$ , would then be given by Eq. (3) as shown below (Pedregosa et al., 2011).

$$FI_k = \frac{\sum_{j: \text{node } j \text{ splits on feature } k} NI_j}{\sum_{j \in \text{all nodes}} NI_j} \quad (3)$$

The higher the value of feature importance, the more important is the corresponding feature.

It can be observed that people give the highest importance to travel time followed by the distance covered between the residence and workplace. The next deciding factors are age and income of commuters, followed by the frequency of going to work, safety shift and the city of residence.

## 4. Discussion

The present study investigated the factors influencing commuters' decision to select a favorable mode of transport during transition to lockdown due to COVID-19 outbreak. The effects of complex combinations of their socio-economic and travel characteristics were analyzed. An interesting observation from the study is that, although public transportation was rated as the most unsafe among other modes, the mode choice decision did not significantly rely on the safety perception of the commuters during the transition to lockdown phase (i.e., 15th March to 24th March). It was observed that 18.3% of the commuters continued using public transportation during this period. Irrespective of the public health effects and safety risks of COVID-19, passengers did not give much importance to safety aspects while taking the mode choice decision for daily commute during the transition to lockdown period. This behavior probably would be due to (a) Lack of alternative modes of transport from home to work and vice-versa (Shinde et al., 2019; Bhattacharya, 2018), and (b) Less awareness of ill effects of coronavirus among Indian commuters during the initial phase of COVID19 (John, 2020).

In Budapest (Hungary), public transport ridership was reported to reduce by 90% in March 2020 after the movement restrictions were implied (Bucsky, 2020). In the Netherlands, about 80% of the people significantly reduced their outdoor activities, and number of trips decreased by 55% after the implementation of lockdown compared to pre-lockdown period (Haas et al., 2020). Moreover, COVID-19 impacts on transportation sector

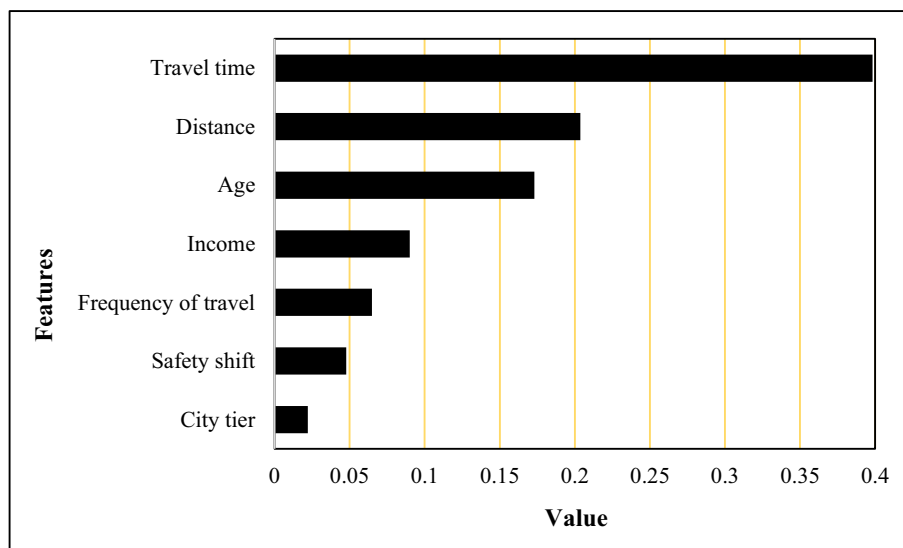


Fig. 6. Feature importance of decision tree variables.

in Nigeria resulted in increased travel costs, as reported by about 95% of the people (Mogaji, 2020). A recent study in Seoul, South Korea observed variations in the subway ridership due to the risk perceptions of COVID-19 (Park, 2020). Compared to January 2020, the daily count of passengers reduced by 40% in the first week of March. However, after that, the daily passenger count has increased slowly due to decreasing risk perceptions and provision of physical distancing (Park, 2020). In the USA, transit agencies are incurring financial loss owing to the drastic reduction in transit users across the country (Badger, 2020). Due to COVID-19 pandemic in Washington, reduction in travel frequencies was significantly lower among the lower income population and less-educated individuals (Brough et al., 2020). Further, in the UK, COVID-19 outbreak resulted in road travel reduction by 73% (Carrington, 2020). Due to the significant reduction in passenger ridership in public transport, various cities across the world (e.g. Berlin, Bogota, Philadelphia, etc.) are temporarily converting their car lanes into sidewalks and bike lanes, thereby allocating more space to pedestrians and cyclists (Laker, 2020).

In Indian context, the issue of COVID-19 outbreak is critical as it instills fear among the population due to its rapid spread, lack of vaccine or treatment, increased number of fatalities, and the gaps in knowledge and understanding of its behavior (John, 2020). As India is the second most populous country in the world after China, there is a high chance of viral transmission due to mass public movements, which is quite common while using public transportation. Before the initiation of lockdown, there were no official COVID-19 related safety precautions enforced by public transportation companies. However, people may have taken safety precautions (such as use of masks, sanitizers, etc.) after realizing the health-related safety threats of COVID-19 at an individual level during their travel. In this regard, strict monitoring of infected individuals and efficient enforcement of preventive measures such as physical distancing need to be followed effectively. The lockdown approach adopted by the Government of India is crucial in minimizing the spread of COVID-19 at initial stages. If there would be no lockdown, people would still be using public transportation for their commute, which would have led to increased transmission of COVID-19 among the Indian population. A recent study in Wuhan, China analyzed the effectiveness of control strategies such as social and physical distancing, and have reported positive benefits such as reduction in the number of infections, and providing more time to the healthcare sector for developing the vaccine for COVID-19 (Prem et al., 2020). Another study in mainland China examined the effect of travel restrictions on the spread of COVID-19 and found that travel quarantine delayed the spread of disease from Wuhan to other areas of mainland China (Chinazzi et al., 2020). In South Korea, the transport ministry created a national level integrated surveillance system to monitor contact tracing on a large-scale. This strategy has been found effective in slowing down the spread of COVID-19 virus (Lee and Lee, 2020). Based on these studies, it can be concluded that lockdown strategies are beneficial in minimizing the spread of COVID-19 pandemic.

## 5. Conclusions and limitations

The present study aimed to understand the impact of COVID-19 pandemic on modal preference of commuters and association of their mode choice behavior with socio-economic and travel characteristics, and health-related safety perceptions during the transition to lockdown period in India. The key conclusions obtained from the study are as follows:

- 41.65% of the people stopped traveling during transition to lockdown period, and 51.31% were using the same mode of transport as before.
- Only 5.3% of the people shifted from public to private mode of transport during transition period.
- Travel time was observed as the most important feature considered by people to decide their work-related travel mode choice.
- Health-related safety perceptions towards mode choice did not significantly influence the mode choice decisions of commuters.

This study is the first attempt to understand the impact of COVID-19 on transport-related decisions in a developing country like India. The

researchers recommend spreading more awareness about the ill-effects and spread of COVID-19, especially in the lower strata of society. This study is quite useful in understanding the decision-making behavior of commuters while selecting their preferred mode of transport during a pandemic like COVID-19, which is a threat to public health as well as economy of the world. The rapidly changing diaspora of the pandemic is making human life more challenging. More research is required to investigate the public concern over mode choice during disastrous situations like COVID-19.

The study faced certain limitations. The survey data was collected using an online questionnaire. Therefore, commuters who are not compatible with technology may have been left out during the data collection process. Additionally, online questionnaires are susceptible to have non-responder bias which may have affected the study results. The study enquired about limited user characteristics for rapid collection of data; future research may include a large set of explanatory variables in the questionnaires (such as working policies of companies, impact of government policies, etc.) for detailed analysis of travel choice behavior of commuters during hazardous situations like COVID-19. The present study did not examine the variations in usage of ridesharing services during the transition to lockdown period compared to pre-lockdown period. Moreover, the present study did not address the influence of social media on transport-related decisions of commuters, which can be an interesting scope for future research in this area. This study focused only on work-related travel behavior of individuals. Future studies shall investigate the travel behavior corresponding to non-work-based trips. Further, a critical comparison of travel behavior of individuals regarding work-based and non-work-based trips can be an interesting motivation for future research.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declaration of competing interest

None.

## References

- Ahmed, S., 2020. VNIT, IIT, IIM ask over 4,000 students to vacate hostels due to Coronavirus. Times of India, 16 March 2020, <https://timesofindia.indiatimes.com/home/education/news/vnit-iit-iim-ask-over-4000-students-to-vacate-hostels-due-to-coronavirus/articleshow/74652989.cms> (Accessed July 11, 2020).
- Badger, E., 2020. Transit has been battered by coronavirus. What's ahead may be worse. The New York Times, 9 April 2020, <https://www.nytimes.com/2020/04/09/upshot/transitbattered-by-coronavirus.html?searchResultPosition=2> (Accessed May 5, 2020).
- Bhattacharya, T., 2018. Use of public transport by older women in semi-urban West Bengal, India. *Indian Journal of Gerontology* 32 (4), 348–363.
- Bogoch, I.I., Watts, A., Thomas-Bachli, A., Huber, C., Kraemer, M.U., Khan, K., 2020. Potential for global spread of a novel coronavirus from China. *Journal Travel Medicine* 27 (2), taaa011.
- Breiman, J., Friedman, R., Olshen, A., Stone, C., 1984. *Classification and Regression Trees*. Chapman & Hall, New York, NY, USA.
- Brough, R., Freedman, M., Phillips, D.C., 2020. Understanding Socioeconomic Disparities in Travel Behavior DURING the COVID-19 Pandemic. University of California, Irvin Department of Economics Working Paper Series, June 2020.
- Bucsky, P., 2020. Modal share changes due to COVID-19: the case of Budapest. *Transportation Research Interdisciplinary Perspectives* 100141.
- Carrington, D., 2020. UK road travel falls to 1955 levels as Covid-19 lockdown takes hold. The Guardian, 3 April 2020, <https://www.theguardian.com/uk-news/2020/apr/03/uk-roadtravel-falls-to-1955-levels-as-covid-19-lockdown-takes-hold-coronavirus-traffic> (Accessed May 5, 2020).
- Chinazzi, M., Davis, J.T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., Viboud, C., 2020. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. *Science* 368 (6489), 395–400.
- Haas, M.D., Faber, R., Hamersma, M., 2020. How COVID-19 and the Dutch 'intelligent lockdown' change activities, work and travel behaviour: evidence from longitudinal data in the Netherlands. *Transportation Research Interdisciplinary Perspectives* 6, 100150.
- Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Cheng, Z., 2020. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 395 (10223), 497–506.
- IANS, 2020. Coronavirus: Is Your Organization Ready for Work From Home in India? The Hindu. 13 March 2020. <https://www.thehindu.com/sci-tech/technology/coronavirus->



- is-your-organisation-ready-for-work-from-home-in-india/article31057675.ece. (Accessed 11 July 2020). .
- John, T.J., 2020. How prepared is India to control the COVID-19 pandemic? *Economic and Political Weekly* 55 (11).
- Jiang, F., Deng, L., Zhang, L., Cai, Y., Cheung, C.W., Xia, Z., 2020. Review of the clinical characteristics of coronavirus disease 2019 (COVID-19). *Journal of General Internal Medicine* 35, 1545–1549.
- Laker, L., 2020. World cities turn their streets over to walkers and cyclists. *The Guardian*, 11 April 2020, [https://www.theguardian.com/world/2020/apr/11/world-cities-turn-their-streets-over-to-walkers-and-cyclists?CMP=share\\_btn\\_tw](https://www.theguardian.com/world/2020/apr/11/world-cities-turn-their-streets-over-to-walkers-and-cyclists?CMP=share_btn_tw) (Accessed May 5, 2020).
- Lee, D., Lee, J., 2020. Testing on the move: South Korea's rapid response to the COVID-19 pandemic. *Transportation Research Interdisciplinary Perspectives* 5, 100111.
- Lipsitch, M., Swerdlow, D.L., Finelli, L., 2020. Defining the epidemiology of Covid-19 — studies needed. *N. Engl. J. Med.* 382 (13), 1194–1196.
- Mathur, N., Kundu R., Nidheesh, M.K., 2020. Coronavirus: Allow employees to work from home, states tell firms. *Live mint*, 17 March 2020, <https://www.livemint.com/companies/news/coronavirus-allow-employees-to-work-from-home-states-tell-firms-11584468960852.html> (Accessed July 11, 2020).
- Ministry of Finance, Government of India, 2014. Recommendations of the Sixth Central Pay Commission - Decision of Government Relating to Grant of Dearness Allowance to Central Government servants.
- Ministry of Health and Family Welfare, Government of India, 2020. <https://www.mohfw.gov.in>. (Accessed 5 May 2020). .
- Mogaji, E., 2020. Impact of COVID-19 on transportation in Lagos, Nigeria. *Transportation Research Interdisciplinary Perspectives* 6, 100154.
- Park, J., 2020. Changes in subway ridership in response to COVID-19 in Seoul, South Korea: implications for social distancing. *Cureus* 12 (4), 1–11.
- Pedregosa, F., Varoquaux, G., Gramfort, A., Michel, V., Thirion, B., Grisel, O., Vanderplas, J., 2011. Scikit-learn: machine learning in python. *The Journal of Machine Learning Research* 12, 2825–2830.
- Prem, K., Liu, Y., Russell, T.W., Kucharski, A.J., Eggo, R.M., Davies, N., Abbott, S., 2020. The effect of control strategies to reduce social mixing on outcomes of the COVID-19 epidemic in Wuhan, China: a modelling study. *Lancet Public Health* [https://doi.org/10.1016/S2468-2667\(20\)30073-6](https://doi.org/10.1016/S2468-2667(20)30073-6).
- Press Information Bureau, Government of India, 2020. [www.pib.gov.in/newsite/PrintRelease.aspx?relid=200655](http://www.pib.gov.in/newsite/PrintRelease.aspx?relid=200655). (Accessed 15 April 2020). .
- Rodríguez-Morales, A.J., MacGregor, K., Kanagarajah, S., Patel, D., Schlagenhauf, P., 2020. Going global-travel and the 2019 novel coronavirus. *Travel Med. Infect. Dis.* 33, 101578.
- Rudd, J.M., Priestley, J.L., 2017. In: Kennesaw State University (Ed.), *A Comparison of Decision Tree With Logistic Regression Model for Prediction of Worst Non-financial Payment Status in Commercial Credit*, pp. 1–5.
- Shelar, J., 2020. Coronavirus: number of confirmed cases in India crosses 100. *The Hindu*, 15 March 2020, <https://www.thehindu.com/news/national/other-states/coronavirus-five-more-test-positive-near-pune-maharashtra-count-rises-to-31/article31070898.ece> (Accessed July 11, 2020).
- Shinde, A.M., Dikshit, A.K., Singh, R.K., 2019. Comparison of life cycle environmental performance of public road transport modes in metropolitan regions. *Clean Techn. Environ. Policy* 21, 605–624.
- Smitha, N., 2020. Devotees banned at Guruvayur temple in Kerala from March 21. *Deccan Chronicle*, 20 March 2020, <https://www.deccanchronicle.com/nation/current-affairs/200320/devotees-banned-at-guruvayur-temple-in-kerala-from-march-21.html> (Accessed July 11, 2020).
- Sobieralski, J.B., 2020. COVID-19 and airline employment: insights from historical uncertainty shocks to the industry. *Transportation Research Interdisciplinary Perspectives* 5, 100123.
- Sohrabi, C., Alsafi, Z., O' Neill, N., Khan, M., Kerwan, A., Al-Jabir, A., Agha, R., 2020. World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19). *Int. J. Surg.* 76, 71–76.
- US Department of Transportation (US-DOT), 2020. <https://www.transportation.gov/coronavirus>. (Accessed 4 May 2020). .
- Vos, J.D., 2020. The effect of COVID-19 and subsequent social distancing on travel behavior. *Transportation Research Interdisciplinary Perspectives* 5, 100121. <https://doi.org/10.1016/j.trip.2020.100121>.
- Wilder-Smith, A., Freedman, D.O., 2020. Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. *Journal of Travel Medicine* 27 (2), taaa020.
- Yao, Y., Zhao, X., Du, H., Zhang, Y., Zhang, G., Rong, J., 2019. Classification of fatigued and drunk driving based on decision tree methods: a simulator study. *Int. J. Environ. Res. Public Health* 16 (11), 1935.