Impact of COVID-19 pandemic lockdown on the public transportation system and strategic plans to improve PT ridership: a review

Saladi S. V. Subbarao¹ · Raghuram Kadali²

Received: 2 August 2021 / Accepted: 29 October 2021 / Published online: 19 November 2021
© Springer Nature Switzerland AG 2021

Abstract

The pandemic of coronavirus disease 2019 (COVID-19) has caused more than 198.03 million confirmed cases around the world, and nearly 31.65 million cases are reported in India as of 1st August 2021. Though it is reported to have originated from one particular place, the COVID-19 is continuously spreading to various countries due to the movement of people in and around the world. For curbing the spread of the COVID-19 virus, many countries have implemented lockdown and restrictions on public mobility (except the essential goods travel) within various zones. Though this lockdown is going to limit the spread of the virus, at the same time it creates an adverse impact on the livelihood of the people and economy of the country. Despite the surge in infections, the governments of different countries have to ease out the lockdown and allow the mobility of people from one place to another place by public transportation (PT) system due to various reasons. Hence, the present study explores the impact of COVID-19 lockdown on the PT system and the post-lockdown policies implemented by various countries to improve the PT ridership. Further, the study also addresses various challenges to operate the PT system and the emergency relief plans proposed by various countries to make the PT system more sustainable by integrating it with active transport modes such as cycling and walking. The discussed ease-out plans might help the policymakers to design a case-specific plan for the effective and safe operation of the PT system post-lockdown.

Keywords Public transportation system · COVID-19 pandemic · Post-lockdown · Ease-out strategies · Technological innovations · Tracking applications

Introduction

The public transportation (PT) system has a massive role in many cities, in terms of mobility requirements of the passengers and various policies (viz., subsidies, parking-related policies, traffic management policies) that are imposed on travellers in those cities to increase the ridership of PT system. In many cities around the world, the PT systems are serving more efficiently with a very high occupancy ratio, particularly in developing countries [1]. At the same time,

there is evidence from past research studies that the PT system has an influential role in the spread of flu as well as an infectious virus due to the massive number of people confined in less space, low ventilation, common access, and egress points (no separate access points for diseased people) and many common touchpoints which include handles, doors, etc. [2]. A pandemic of infectious diseases such as coronavirus disease 2019 (COVID-19) poses a high risk of transmission of the disease within the community, and there is uncertainty in the control measures to be adopted. As the entire world is struggling to control the rapid transmission of COVID-19, the governments of these countries have announced the lockdown policy as an important step to fight against the pandemic. In this policy, all governments are suggesting avoiding mass gatherings and maintaining hygiene and social distance, which is difficult in the operation of the PT system. Hence, during the lockdown, the governments have also partially shut down their PT systems to eradicate or control the transmission of COVID-19.

✉ Saladi S. V. Subbarao
saladi.subbarao@mahindrauniversity.edu.in
Raghuram Kadali
brkadali@nitw.ac.in

¹ Department of Civil Engineering, Ecole Centrale School of Engineering, Mahindra University, Hyderabad 500043, Telangana, India

² Department of Civil Engineering, NIT Warangal, Warangal 506004, Telangana, India

As per the study conducted by the World Health Organization (WHO), the spread of one of the previously infected virus diseases (viz., Ebola virus disease (EVD)) was observed mainly by the travellers from one country to another country, which indicates transport is a major contribution in the spread of the virus across the globe [3]. Similarly, the COVID-19 spread has been happening mainly due to air travel and many countries have implemented policies for restricted air travel by suspension of visas and air trips. The COVID-19 is one of the most dangerous infectious viruses which transmits easily from one person to another person. The entire world has seen the quick transmission of this virus to their major cities and subsequently to other parts of their country. Many countries have implemented a lockdown policy by restricting people's mobility [4–6]. Many countries have followed different strategies and harmonizing mechanisms to control COVID-19. However, there are many questions to the policymakers in the operation of the public transportation system. In particular, the questions are related to (i) how to resume the public transportation system during the pandemic of COVID-19 by social distancing and maintaining hygiene? (ii) how to organize the people mobility requirements with strategic ways without the spread of COVID-19 within the city as well as regional trips? (iii) how to encourage individuals to use the public transport system if travel is necessary? (iv) how to meet the demand with the reduced capacity of the public transport system due to social distancing?

Addressing the above queries and operating the PT system safely during COVID-19 requires special policies and protocols as it involves the mobility of masses. There should be an integrated plan between the central government and the state governments, and it also involves large public transportation (transit) agencies, local public health authorities, and other service providers/stakeholders. Past experiences and research studies have clearly shown that social distancing is one of the prime concerns during the epidemic of infectious diseases in the operation of a public transportation system [5]. Hence, the government, as well as transit agencies, have to focus on the protective measures for the transit crew along with the users. These protective measures have to be taken based on the pandemic condition and public perception of the risk. In this context, the present study attempts to understand the impact of COVID-19 and associated lockdown on the public transportation system and discusses various ease-out plans implemented by the different countries for operating the PT system. The study also tries to identify the challenges in operating the PT system during the COVID-19 outbreak and the relief plans required to operate the PT system more efficiently.

Impact of Pandemic Conditions on Transportation

Transportation plays a major role in the transmission of airborne diseases in an urban environment due to the high population densities and built environment conditions [7]. Though several components play a role in such transmission, PT is the main contributor due to high public utilization of its facilities, highly interactive surfaces, the higher possibility of congestions due to huge crowds, etc. [8]. In the past few years, airborne diseases like H1N1, severe acute respiratory syndrome (SARS), etc., have caused potential damage to the urban community and the transmission of the disease is attributed mainly through transportation across the globe [9, 10]. Past literature shows that flu disease transmission is high during winter [11]. Further, the transmission may depend upon the level of exposure and the duration of exposure based on the different public transport modes. Some research studies have shown that even less duration exposure can cause transmission of the virus [7]. It has a severe impact on the urban community in terms of mobility and health [3]. The public transportation system is highly vulnerable in such pandemic conditions, and it requires new infrastructure in terms of active transport to minimize the transmission. However, research has shown that the psychological factors impact the selection of transport mode and it is most inclined towards car-centric user perception due to the comfort it provides [12]. Hence, although the behaviour of the public changes during the epidemic, the choice of transport mode will be dominated by the convenience of the public. The recent study explored the activity-travel behaviour changes during the COVID-19 pandemic and results concluded that e-learning as well as teleworking directly impacts the changes in activity-travel behaviour [13–15].

Moreover, many studies have been explored on the mode choice due to the risk perception or behavioural changes of human being due to the fear of infected diseases like COVID-19 that may be easy to transfer while they use public transportation [16–18]. However, researchers are argued that these behavioural changes about the mode choice cannot be generalized due to the pandemic and public risk exposures and mass transportation might have negative impacts due to its risk perception [19]. This might result in a decrease in the frequency of travel and avoiding the use of public transportation and a shift to private vehicles such as cars [20, 21]. Also, elderly people have lower-risk perception due to the higher transmission of COVID-19 disease which results in a significant reduction in the use of public transport [22]. Some studies explored the causes of high risk of mass transit due

to density, diversity of contact, and high probability of infected person mobility due to non-tracking system which in turn leads to the public reduction to use of mass transit [23, 24]. Further, researchers have studied that there is a significant reduction in ridership of public transportation due to the perceived risk of COVID-19 by the public [14, 25, 26]. A Sweden-based study showed a 40–60% reduction in ridership of public transportation due to the risk perception of lower active public transport users [27], whereas researchers have shown that the reasons behind the risk being infected are mass mobility with congested cases, the behaviour of co-travellers with COVID protocol, and fear of becoming infected [28]. Various studies are showing that the change in travel behaviour such as working from home or travel patterns and frequency in reduction of travel results in the reduction of public transit share [29]. Furthermore, researchers have studied public transportation mode choice decisions during pandemic and results concluded that the reduction in ridership due to the risk perception as high touchpoints in public transport as compared to the private mode of cars [30]. Another study from New York city showed that there is a significant drop in subway ridership during the first wave of COVID-19 as compared to shared mobility [31], whereas research on bus-based public transport showed the highest drop in ridership during the morning as well as evening peak hours from the higher income commuters [32]. Researchers have also shown that education, income, and workplace type are strong predictors in ridership of public transportation during the pandemic [33].

Public Perception about COVID-19 outbreak

It is important to understand the public perception to motivate and educate them about the pandemic conditions and for engaging the travellers to adopt careful and safe behaviour while using public transportation. In such a process, if the government gives health-related precautionary messages, then the PT users will take positively for their benefit [34]. Infected PT users have a high probability of infecting others if they use public transport or interact with the public [35]. Studies have proven that anxiety about knowing the outbreak conditions will change public behaviour quickly [36], and it would impact negatively on the public transport system. Rubin et al. confirmed this fact during the epidemic of the swine flu outbreak [34]. Hou et al. have assessed the public risk, emotion and behavioural response during the outbreak of COVID-19, and they concluded that announcements and rumours would severely impact the public perception and may create a panic situation [37]. The earlier pandemics which include “Severe Acute Respiratory Syndrome in 2003 and Middle East Respiratory Syndrome in 2012” have given

clear ideas about the public perception towards such pandemic conditions and the situation returned to normal in course of time [38]. Due to the extreme severity of COVID-19, the public has shown higher panic behaviour, while it is also very difficult to assess the risk due to their normal behaviour (ignoring precautions) and other specific behaviour necessary in pandemic situations. Hence, motivating the public to adopt specific behaviour related to hygiene and social distancing has proved to be useful and also the implementation of new strategies about hygiene during the outbreak of diseases helps the PT system to recover quickly. Many studies showed that the pandemic has significantly impacted transportation, a substantial increase in teleworking due to pandemic [19]; in this same line in Australia 47% of people are shifted to teleworking [14]; there is a significant reduction in out-of-home activities and recreational activities due to pandemic [39]; researchers found that risk perception significantly affected the decrease in outdoor activities of leisure and recreational trips [13, 40]. Researchers have explored that the perceived risk, subjective norms, and role of ICT during the pandemic, and results identified that there is an increase in the use of ICT during the pandemics [41, 42]. It was observed that the following risk factors have been observed by the common people for using public transportation.

Ease-out Plans for the operation of Public Transportation by Various Countries

The operation of the public transportation system is an essential activity for both urban and rural areas to mobilize people and goods, and it is one of the major contributors to the economic development of those areas. In this regard, many countries have functionally operated public transportation systems with austere instructions for both passengers and transport workers during the lockdown as well as during the post-lockdown period. These guidelines include disinfection and sanitation, workforce monitoring and altering, access controls at station points during boarding and alighting, continuity plans, and communication [43]. The disinfection and sanitation of the high touch points by the passengers are one of the prime measures in the control of COVID-19 during the operation of the public transportation system. Many countries have suggested the passengers as well as the transport crew to follow the hygiene practices before boarding into the public transportation system. Access control through thermal screening is one of the measures which helps to identify the affected persons to prevent their entry into the PT system. It is also important to protect the public transport staff, who are exposed to a large community, and various countries are taking necessary measures like shielding drivers, digitalizing the ticketing process, providing

safety kits to staff, etc. Another important aspect is communication to the PT users about the measures taken in the form of hygiene and social distance norms, which makes the user confidently board the public transit system. This section discusses the various ease-out measures for the public transportation system adopted by various countries during and post-lockdown due to COVID-19.

China

As per the various sources of information, the first case of COVID-19 was observed in Wuhan city, China, in December 2019¹. As of 1st August 2021, over 0.1 million² confirmed cases were observed in the country with a fatality rate of nearly 5%. During the pandemic of COVID-19, the ridership of the public transportation system dropped drastically in many Chinese cities. However, the outbreak of COVID-19 gradually reduced by mid-April of 2020 and the lockdown has been lifted in Wuhan city, which was reportedly an epicentre of the pandemic. Chinese cities have implemented their measures to curb the spread of COVID-19 on public transport, mainly based on the number of cases exposed in each city. Beijing, Shanghai, and Guangzhou, which were less severely affected, continued an altered operating schedule of metros and buses, even during the early weeks of the outbreak. By early March 2020, a total of 8 cities completely suspended public transit operations, around 13 cities suspended operations on some lines, or at some stations, around 30 cities adjusted their operating hours and only 2 cities did not make any operational adjustments. The preventive measures adopted by all cities are centre around the following activities: preventing the access and isolation of infected persons, disinfection and ventilation, and controlling people in the station, on the platform, and throughout the train. Not all measures are adopted by all cities and the measures change over time as restrictions lessened or were further imposed.

The Institute for Transportation and Development Policy (ITDP) has conducted a travel survey in Guangzhou city, and it is identified that only 34% of people are using PT system and 40% of commuters have shifted to private cars, taxis, ride-hail service post-COVID-19, and many others are using walk and bike as a transport mode [44]. In China, many public transport agencies have taken proactive measures to make the system safe and efficient in operation. The PT system has created new health standards for the operation of the system which includes the usage of Personal Protective

Equipment (PPE) such as masks and goggles by staff and also training of the staff for minimizing the risk to them and the passengers. Further, new guidelines have been set up for the social distancing in buses, disinfection of buses (at least twice a day), and avoiding the operation of the services through high-risk zones. Also, cities like Beijing and Shenzhen have implemented smart payment methods for avoiding personal touchpoints. Moreover, the data-driven tracking and scheduling system which operates based on the requirement of the users is also implemented. Furthermore, the Beijing “Public Transport Group” has identified the new routes as per passenger demand by considering their changes in travel patterns and operated public buses along the identified routes post-COVID-19 [45]. In addition to this, the temperature check at the entry point for both the passengers and transport staff is made mandatory. Also, there are different communication channels (viz., Tik Tok, Wechat) that have been used to pass the information to the passengers about seating arrangements in the PT for maintaining social distance [43].

United States of America (USA)

The USA is the most affected country by the COVID-19 as of 1st August 2021 (see footnote 1). Since the first case was reported on 23rd January 2020, nearly 34.98 million (see footnote 2) confirmed COVID-19 cases are reported with a fatality rate of 1.75%. In the USA, nearly one-third of the total 2.8 million transit commuters are workers who are dependent on public transit systems [46]. Hence, it is necessary to operate the PT system to meet the demand even during pandemic conditions, but with specific measures like sanitization and social distancing [47]. Though the USA also faces a decline in their PT ridership due to COVID-19, the American Public Transportation Association (APTA) has been given strict guidelines to transport agencies for the protection of their transit workers for the safe operation of the PT system during COVID-19. Also, the USA announced an emergency fund of \$23.8 billion for the operation of the PT system across the country [48]. It has also been suggested to the transport agencies to follow the report, “A Guide for Public Transportation Pandemic Planning and Response” which is prepared by the “National Cooperative Highway Research Program (NCHRP)”. The NCHRP report mentions hand hygiene as well as environmental hygienic conditions during the flu pandemics, which is also considered applicable for the COVID-19 pandemic. The report also mentions the social distancing to be maintained at access points to PT stations for both passengers and transport staff. Further, it has also reported the PPE (Personal Protective Equipment) requirements of transport staff and the necessary ventilation system required while operating the PT system during pandemic conditions [49]. Some transit agencies have

¹ The data related to first reported case has taken from https://en.wikipedia.org/wiki/COVID-19_pandemic_in_Country

² <https://coronavirus.jhu.edu/map.html> (The data of number of cases, recovery rate and fatality rate has been taken from the Johns Hopkins University site for all the countries); .

implemented policies like reducing the number of entry points to public transit and suspending long trip-based services [47].

India

In India, the first infected case was reported on 30th January 2020 (see footnote 1) and the Government announced the complete lockdown on 24th March. Now the country is experiencing a record number of infected cases every day, and as of 1st August 2020, the total number of infected cases is reported to be about 31.65 million (see footnote 2) with a fatality rate of 1.34%. To prevent the spread of COVID-19, the government has demarcated various areas/states into red, orange, and green zones based on the number of infections [50, 51]. Interstate public transport has been permitted in green zones with limited seat capacity as of 27th May 2020. The government of India has proposed different guidelines for the operation of public transportation which is prepared by the Council of Scientific and Industrial Research, Central Road Research Institute (CRRI). The major points include staggered working hours to control the crowd in public transport, marking for social distancing at bus stops as well as footpaths, increased stoppage time for alighting as well as boarding (viz., bus and metro), reduction in the capacity of bus and metro (viz., limit the number of passengers), dedicated lines for buses, contactless ticketing system, allowing boarding from the rear door and alighting from the front door [52]. Further, the guidelines also addressed the transit worker's protection such as usage of face masks (viz., N95 respirator masks), sanitizing inside the vehicle, and protecting the vehicle driver by restricting access from front doors. Also, the guidelines addressed the issues related to the disinfection of high touch points and station locations; however, there are no clear guidelines about the frequency as well as transit unit disinfection [53].

The CRRI has given guidelines about public transit demand reduction strategies (viz., encourage intermediate public transit, compartmentalized auto-rickshaws, and capacity enrichment strategies such as changes in the timetable, alternative routes, optimum use of fleet with social distancing, targeted offers for the public, etc. [53]. Moreover, apart from the central government guidelines, the state transportation agencies have planned various strategies like staggered timings for working hours, contactless payments, thermal screening of passengers, reduced capacity in buses (viz., 15–20 number in the bus), and following a multi-modal trip approach, viz., from origin to destination [54].

Brazil and Russia

Though the first case reported in Brazil (i.e. 26th February 2020 (see footnote 1) is later than many other countries,

as on 1st August 2021, it is the third most affected country in the world behind the USA and India with confirmed infections of more than 19.9 million (see footnote 2) with a fatality rate of 2.79%. The first infected case due to COVID-19 has been reported in Russia on 31st January 2020 (see footnote 1), and the Government restricted the movement of people by announcing lockdown on 2nd March [55]. Later, Russia reported a surge in the number of infections, and as of 1st August 2021, the total number of infections is 6.2 million (see footnote 2) with a fatality rate of 2.52%. Despite the record number of infections in the country, the Government eased the lockdown from 13th May 2020 and insisted the people wear gloves and masks in supermarkets as well as in taxis and public transportation along with social distancing measures.

United Kingdom (UK)

The UK government has issued necessary guidelines to prevent the spread of COVID-19 immediately after reporting its first infected case on 31st January 2020 (see footnote 1) as they observed the surge in infections, the government announced the lockdown on 23rd March 2020. As of 1st August 2021, the country has nearly 5.88 million (see footnote 2) infected cases with a fatality rate of 2.2%, which is quite higher than in many countries.

The Transport for London (TfL) has taken different preventive measures which include suspension of late-night scheduled trains, disinfection of transit system (viz., tube system and buses) and transit stations at a regular interval, and sanitizing frequent touchpoints. Further, other common preventive measures are like thermal screening at entry points of PT stations for both passengers and transport staff, and social distancing during the entire journey [43]. Other specific measures have been taken in London buses which includes insisting the passenger to board the bus by the middle door (viz., before COVID-19 passenger usually boarded from the front door to punch their travel pass) to maintain social distance between passengers and drivers for transit staff safety [56]. However, the Scottish government (viz., Transport Scotland) has pointed out that the measures of social distancing have a significant negative impact on the capacity of the bus and the ridership has dropped to one-quarter of its capacity, which is challenging for transit agencies to meet the public demand. Further, the transit officials have recommended the employees of various companies to work from home to avoid the usage of PT during peak hours and also to avoid unnecessary trips [57]. London Government proposed some measures to the local municipalities like increasing the capacity of cycle lanes by closing the traffic lanes, widening the footpaths, real-time information for the occupancy levels to monitor the social distancing, dedicated bus routes, improved waiting facilities at the transit

terminals, etc., to prevent the transmission of COVID-19 [58]. As the PT system is not operating with its full capacity due to social distancing and the surplus demand for the PT system leads to an increase in the usage of private modes which impacts air quality [59]. The recent research study results also suggested that the active travel modes (viz., cycling and walking) are most satisfying as compared to the motorized modes and PT and also concluded that boosting the infrastructure of such active travel modes increases the commuter travel satisfaction during the epidemic/pandemic conditions [60].

Specific measures to prevent the spread of COVID-19 during PT operation in other countries

Many countries have shut down their PT services due to the risk factors for using PT during pandemic conditions. Travelling by public transportation at busy locations and being exposed to persons with cold symptoms will always increase the probability of becoming infected with circulating respiratory diseases. As per one report, if co-travellers are not wearing masks, one asymptomatic infected passenger spread the virus to at least 22 passengers in a bus capacity of 67 [61]. Further, the increased risk of COVID-19 infection in public transit stations is due to many factors like people have a limited amount of room to work with. Because of the increased danger of getting a potentially deadly virus after the COVID-19 epidemic, travel on crowded buses or trains has become more uncomfortable. Further, there is a possibility that there is not enough access control in place to detect unwell passengers or employees. Numerous surfaces, such as benches, railings, doorways, and ticket machines, can readily spread germs [62].

Though the magnitude of the number of infected cases is less in the following countries, their governments put their best effort to improve the safety of passengers. The Hong Kong city eased out the public transportation by sanitizing the vehicles with robots at every terminal area, mandatory temperature checking, masks, and social distancing for every passenger and transport crew, as well as mandatory protective cloth for the transport crew. The Hong Kong government has also taken important measures to educate commuters about hygienic practices and social distancing by using various social media platforms [43]. The government has also initiated subsidizing fares to encourage the public to use the public transport system during the outbreak of COVID-19 [63]. In contrast to Hong Kong, Belgium eased out the PT in a phased manner and advised the people to avoid public transport during peak hours and encourages to utilize modes such as a car and bike. Moreover, the Belgium government improved the NMT (Non-Motorized Transport) infrastructure and asked travellers to use NMT modes for short-distance trips. Further, the trips related to tourism

and inter-zonal trips have been permitted in later phases of easing of lockdown [64]. Furthermore, to protect transport workers, a deep cleaning technique has been adopted for the public transit system after completion of every transport trip and shuffling the transport staff along with “barrier gesture” (viz., protection at transit driver seat), describing the measures to people to reduce the risk of infection [65]. South Korea also eased out public transportation due to a reduction in infections and an alarming rate of reduction in PT utilization. The government advises following the protective measures strictly like wearing face masks and social distancing, though it increases the waiting time of the travellers [66]. Park conducted a study on public perception in PT usage and identified that PT users are very much conscious about hygiene and social distancing during the initial days; however, it was observed to reduce later on [67].

The Singapore government insisted the PT users follow protective measures such as using hand sanitizers, disinfectants, and masks during travel, and it has also enforced cleaning of transit stations every two hours [43]. Further, they have operated the PT with reduced frequency and transport staff has been recommended to take Vitamin C tablets for boosting their immunity. Further, the Singapore government also imposed a hefty fine on those people who violate the social distance and other COVID-19 measures at public places including the PT system [68]. The Canadian Urban Transit Association (CUTA) has come up with different ease-out plans for the operation of public transit such as preparedness (viz., staff information, availability of cleaning equipment), personal protection (viz., disinfection system for both staff and passengers, cleaning of the transit system in regular hours), reduction of contact (viz., customer service with social distancing, new measures for ticket inspection) and reducing services (viz., weekend operations, alternative route identification) [69]. South Africa has released a gazette for the operation of the PT system which specifies the hygiene and disinfection measures to be followed in public transportation. Further, the government insisted that private companies and operating units provide their transport to their employees to minimize the load on the PT system [70]. France's government has introduced a stimulus package of \$20 million towards the development of other active travel modes like walking and cycling for making these modes more attractive to the users [71], and the same was publicized aggressively through social media and print articles.

Further, some countries (Japan, Taiwan, Australia, etc.) have not implemented complete lockdown during the pandemic of COVID-19, but these countries have instructed the transport agencies and commuters to follow stringent protective measures while operating and using the PT system. Yang studied the impact of COVID-19 on the usage of the PT system in Taiwan and observed a significant drop (viz., 52%) in the PT utilization [72]. Most importantly, Taiwan

controlled this outbreak of COVID-19 successfully by considering the travel history of an infected person for a period of the previous 14 days and it has been integrated with their health insurance data, which helps them identify the other contact cases [73].

Though various countries followed different ease-out plans for operating the public transportation system and improving the PT utilization, still it is evident that commuters from many countries are reluctant in using the PT system and they are either shifting to or temporarily using other modes. Hence, some countries have attempted to use technology innovations to reduce the risk of commuters as well as transport crew. The next section discussed the role of technology in controlling the COVID-19 spread.

Role of technology in controlling the pandemic of COVID-19

Several mobile applications have been launched by various countries to track infected persons and providing information about them to the non-infected people in those areas. China has launched a “close contact detector” mobile application in which the users need to provide information like name, identification number, contact number, etc., which is useful to identify the users by scanning the “Quick Response (QR)” code with their mobile applications, while they are making a trip [74]. With the application, the health codes are generated to the users as green, yellow, and red in which green indicates no restrictions, yellow indicates the need for reporting immediately, and red indicates two-week quarantine [75]. Also, China integrated the Big Data application with the Internet of Things (IoT) and Artificial Intelligence (AI, SenseTime, and Hanwang Technology) which are used for face mask recognition and thermal screening of the public at the entrance of the public transit stations as well as other crowd gathering locations [76]. Moreover, Closed-Circuit Television (CCTV) cameras are also installed inside the public transit vehicles to track public social distancing during the travel [77, 78]. Many public transit agencies installed CCTV cameras to ensure social distance as well as face masks inside the transit and to identify the violators [78].

Singapore government had launched the “TraceTogether” mobile application which tracks the people with mobile Bluetooth signals, and the data are stored for 21 days for tracing the contacts with the diagnosed person [79]. Australia has launched a “COVIDSafe” mobile application to trace the transmission cases with confirmed cases of COVID-19 and it traces the individuals by their mobile numbers within 1.5 m range from the infected persons [78]. Further, Italy has launched the “Fast Tender” mobile application by considering public data privacy and it considers the monitoring as well as medical support to the public [78].

South Korea has initiated the tracking of infected people's data through “Korea's Centres for Disease Control and Prevention (KCDC)” by the application of a smart management system (SMS) which gives the idea about the movement of the affected public [80]. Some of the European countries have taken different strategies for the tracking system instead of mobile applications due to user privacy issues. Germany has adopted “Pan-European Privacy-Preserving Proximity Tracing (PEPP-PT)” with the help of US technology support from Apple and Google [80]. The Indian government has launched the “Aarogya Setu” application which means “Health Bridge” to track the infected persons based on their previous travel history [81, 82]. In some cities such as Hyderabad (India), traffic police have used artificial intelligence (AI)-based face mask identification systems for the public through traffic cameras and the violators have been imposed with hefty fines [83]. Some countries such as the USA are using mobile network data for the tracking of infected people with the help of state and local governments, and these data have been shared with the “Centres for Disease Control and Prevention (CDC)” for preventive measures to curb the spread of the disease [84]. In a broader aspect, these technological interventions must track the infected population and isolate or alert the healthy population in public areas and public transportation.

Challenges for operating PT system during COVID-19 outbreak

As per the opinion of transport professionals, the effect of the COVID-19 pandemic in transit services is less when compared to shopping malls, multiplex theatres, schools, etc. The transmission of the pandemic depends on various factors like in-transit time, the destination of the trip, the crowd inside the vehicle, and the co-passengers health condition. Hence, avoiding the crowd inside the bus is one of the prime concerns in the operation of the public transport system [85]. It is necessary to understand the public risk-taking behaviour in COVID-19 conditions for maximizing the PT operations. Nevertheless, it is a hurdle to the transport agencies and government to protect the public by meeting their demand and also the transport crew from the pandemic of COVID-19 and at the same time meeting the economic challenges. During these difficult situations, it is the government's responsibility to encourage people to use PT and at the same time meeting the demand with social distancing measures.

Further, operating the public transit system with its full capacity, after implementing lockdown for a long duration is not an easy task. It requires creating confidence about the safety in the user's mind and meeting daily demand with less frequency by adopting the plans like altering work schedules, etc. [46]. Another challenging task for the transit

agencies and governments is providing protective equipment to the working staff of transit agencies. The government, states, and local transportation agencies need to review the situation regularly and adjust the operational measures based on the transmission levels. Also, the transit agency has to focus on new routes based on the change of travel patterns according to the peak passenger demand. In India, some state government agencies have implemented a new fare collection system such as a QR code-based system and mobility card-based system which enables contactless multi-modal trips to the users. In some countries, the disinfection process is implemented by using new technologies like retrofit systems (in Taiwan) and robotic systems (in Hong Kong) which may be safer than human intervention [43]. These are some of the technological improvements made to make the PT system safer, which is the need of the hour for countries like India after lockdown. In India, due to additional specific factors such as highly diverse culture and festivals around the year, specific monsoon season during June–October in large parts of the country, specific time zones followed by many for marriages, etc., the challenges associated with maintaining social distancing and control on pandemic are more challenging.

A recent research news article suggested that there is a need for coordinated demand management for the operation of the public transportation system [86]. The coordinated demand management includes (a) impact assessment (viz., demand control and management measures which include suspension of supply and managing the demand, (b) public transport booking and appointee system (viz., users have to book the appointment to access the transit station), (c) shift to active modes (viz., encourage the commuters to shift to active transport modes such as walking and cycling) [86]. Further, Transformative Urban Mobility Initiative (TUMI) has suggested the “Avoid-Shift-Improve” approach during the pandemic of COVID-19 which suggests avoiding public transit to reduce the demand, shift to the active transport modes like cycle and walking, and improve the public transport service by avoiding PT during peak hours [86]. Georgia has suggested that the revival of the country's economy is possible only with the operation of the integrated public transportation system. Many transport professionals and health experts agree that the pandemic is going to continue for some more time and the only option left to the transit agencies is to operate the PT with precautionary measures rather than shutting down the operations. It is advised to educate the public through social media to prepare for such pandemic conditions with the necessary measures while using the public transport system [87].

The major cities of various countries in Europe and America have planned to create infrastructure for active transport modes like separate cycle tracks and walking tracks as an alternative/supplementary service to the PT system to

improve urban air quality. In this line, Colombia also added temporary new cycle routes of 500 km length in the city to meet the public demand as an alternative to the public transit system during the COVID-19 pandemic [88]. Further, many countries have observed a substantial increase in the usage of bicycles post-COVID-19 lockdown, and they have observed an increase in their trip length with bicycles as a transport mode [89]. Hence, an active mode of transport would help in supporting the PT system, by ensuring limited traffic towards the PT system.

Emergency relief plans for Public Transport System

The public transportation system anywhere in the world (viz., sub-urban train, metro, bus) is an essential service for the urban commuters, and it is necessary to continue those services with some measures to uplift the economy even in the difficult situation like the COVID-19 pandemic. Hence, it is necessary to provide protective measures in the PT system like disinfection of stations, sanitization of frequent touchpoints, maintaining hygienic and social distancing by the staff and passengers at the transit locations and vehicles. These measures require an additional budget which further creates hurdles for the local authorities as well as state and central government during this difficult time when revenue is reduced [90]. In this context, the Canadian Urban Transit Association (CUTA) has submitted various proposals to the federal government (Canada) for emergency relief funds to meet the initial demands of the public transit system [61]. The Federal Transit Administration (FTA) in the USA has announced a total package of \$25 billion for the emergency fund for both urban and rural transit operations, and this fund has been released through “Coronavirus Aid, Relief, and Economic Security (CARES)”. The majority of this fund has been allocated for the operation of urban transit with the epidemic/pandemic measures [91, 92]. Transit agencies in the USA have proposed to raise the fare of the system for meeting the operational expenses while running with the low capacity by maintaining social distance [93]. The rural transit system of Charlevoix County Transit (CCT) in northern Michigan (USA) waived transit fares for the riders [94]. Transport planners and policymakers have to address the demand-responsive service in cities in the present situation for meeting the commuter demand with less frequency by maintaining social distance. Perhaps, the government has to think about integrating the active travel modes with the PT system by providing a dedicated network in urban areas. It is important to spend a part of the emergency fund on creating or improving the non-motorized transport infrastructure which keeps the urban environment more sustainable.

Further, the policymakers have to come up with long-term plans for strengthening the PT system with the expected relief fund and the development plans not only for improving the transit system but also to create employment for the new generation. The previous studies reported that economic stimulus packages for public transit have contributed greatly to employment creation in the USA and South Korea [95]. Developing countries like India are majorly dependent on PT for meeting their daily travel needs. Hence, it is a challenging situation for the transit agencies to meet the demand with PT by maintaining social distance measures. In this context, planning experts have opined that it is necessary to promote active travel through various social media platforms. Also, it has been proven that air quality has improved around the world due to fewer motorized vehicles during COVID-19 lockdown and it is necessary to maintain the same quality by promoting an active mode of travel by integrating non-motorized modes with the PT system.

The transportation experts have suggested different stimulus plans for public transportation post-COVID-19 for strengthening public transit. They have proposed five different plans as a part of the package to create employment and boosting the economy of the country. The plans include revenue provision to the transit operation (viz., to maintain minimum disinfection process to control the fear of public about public transit), building high-quality buses and strengthening of transport network (viz., make more reliable bus operation with the greater available network by control on personalized vehicles, planning for expansion or building new Bus Rapid Transit (BRT) system), encouraging modernization by electrifying the bus fleets, investing more on active transport networks and efforts towards coordinated urban planning for the public transit operation [95, 96].

Suggested methodology for post-lockdown easing for PT system

The present study proposes a methodology for a post-lockdown strategy to ease out the PT system as shown in Fig. 1. The strategy is focussed on five aspects: (a) creating a public database for screening, (b) strategy for public transport operating system, (c) control measures for the public at transit stations and vehicles, (d) public transport disinfection system, and (e) strengthening of the public transport system and addressing ridership issues.

For the first aspect, there is a need to create a public database of Covid-19-positive and quarantined people as well as cured people. These data need to be linked with the PT system by the unique identification number of the citizens through a tracking system for the generation of quick response (QR) code for enabling the ticketing process for travelling. This would ensure that Covid-19-positive or

quarantined persons do not travel in the PT system, as a safety measure for the travellers.

The second aspect focuses on strategy for the public transport operating system. In this regard, there is a need to encourage travellers to purchase tickets online using their unique identification number (UID) so that the ticket will be linked to the database suggested above. A discounted ticketing option would help in attracting travellers towards online ticketing. In-vehicle tickets should be avoided to encourage using the online ticketing system. Also, travellers can be encouraged to purchase weekly or monthly passes. Efforts should be made for exploring the possibility of smart mobility cards for allowing travellers to use same card for multiple modal transport systems such as buses, underground trains, and metro. There is also a need for dynamic routing of vehicles based on demand and zoning of Covid-19 pandemic in the city or district (viz., zones with restricted movement can be avoided in the routing, and this should be modified dynamically as the situation changes over some time).

The third aspect is focussed on control measures for the public at stations and vehicles. This can include a thermal screening system at entry and exit points at stations and entry of vehicles for preliminary screening out of potential Covid-19 positive travellers. Additionally, the boarding can have a traveller health status check through a tracking application linked to the unique identification number (UID) and ticket QR code. Some features through ICT-based technologies for detection of face masks (to allow entry to various zones in stations and vehicles), limiting the number of people in the queue and various zones in stations, as well as to ensure travellers maintain social distancing would help in the strict implementation of safety measures in stations and vehicles (viz., buses, metro, etc.). The fourth aspect would be to ensure proper public transport disinfection. This would include regular disinfection of high touch points at stations and vehicles, disinfection of passengers at entry points, toilets, etc. Additionally, measures such as a staggered work schedule for the crew, provision of special personal protection equipment (PPE) for the crew, and special social distancing measures for drivers of vehicles for added safety can be undertaken to ensure safety and for building public confidence in PT system.

Finally, efforts are also required to strengthen the public transport system and improve ridership. Some measures in this direction would include the implementation of intelligent transportation system (ITS) applications for improving the efficiency of the PT system, exploring strategy for reducing crowd, and integration of different public transport systems such as bus, metro, and sub-urban trains. Further, it is also necessary to provide an effective feeder accessibility system to public transit. The crowd can be reduced by the implementation of staggered working hours in the public

Fig. 1 Suggested methodology for post-lockdown PT system operation

and private sectors by local authorities in coordination with industries and commercial establishments, and odd–even concept for staggering operations, encouraging people to use active modes for short distances, etc.

Conclusions

The public transportation (PT) system always plays an important role in urban areas for the safe movement of people and goods. During the pandemic conditions like COVID-19, the transportation system has to play a crucial role in support of the health care emergency and movement of the emerging workforce. However, the operating condition of the PT system and the public risk perception leads to a reduction of ridership and increases the operational cost of the system during the pandemic. Hence, the policymakers

have to suggest preventive measures for creating safe operating conditions in and out of the system with minimum impact on the economy of the country. The present paper reviews the effect of the COVID-19 pandemic on the PT system and the post-lockdown measures implemented by different countries. The paper also suggests a methodology for smooth easing for the PT system post-lockdown for quickly restoring the normalcy situation for the PT system. The following conclusions can be obtained from the understanding of the PT scenario around the world during the Covid-19 pandemic.

The COVID-19 pandemic has significantly affected the PT system including revenue and ridership. The post-lockdown scenario of the PT system varies in different countries. Different countries have adopted different preventive measures for the safety of passengers and the transit workforce. Some of the common measures include complete

disinfection of the transit stations and vehicles as well as sanitization of high touch points at regular intervals. Some countries have adopted advanced techniques like ultraviolet light systems (Moscow in Russia, Shanghai in China) and robots fleet cleaning systems (Hong Kong) for identifying virus-infected persons, which clearly shows the role of technology in controlling the pandemic. In developing countries, most of the PT systems are run with their maximum capacity. Hence, it is necessary to follow some protection measures while running the PT system during these difficult situations. Some of these measures are staggered seating arrangement, boarding and alighting from different gates, contactless ticketing system, mask detection, ensuring social distancing, etc. Further, usage of tracking applications should be made compulsory for travellers for tracking their health status to ensure the safety of non-infected persons through GPS, Bluetooth, or similar alternate technology.

Many countries have announced emergency relief funds for the support of their public transit systems and to improve/create an active transport system in urban areas. These policy changes from the government are going to make the public transit system more accessible and attractive to the users. But, at the same time, the local government needs to create awareness among the people to travel only for making essential trips by maintaining social distance, especially during the active phase of the pandemic.

It has been identified that promoting active travel mode during pandemic conditions not only ensures the safety of passengers but also improves the urban air quality. Further, scheduling and crowd management (viz., access control at the transit station, queue control at stations, and phased resumptions), management of road travel by adopting some of the world's best practices (e.g. Avoid-Shift-Improve plans), and disinfection and hygiene in public transit (viz., transit staff, passengers, station and transit units) would help in improving the effectiveness of PT system and restore the confidence of the passengers toward PT system post-lockdown.

A methodology has been recommended in this paper to address important measures such as developing public data for screening, strategy for public transport operating system, control measures at stations and vehicles for public and crew safety, disinfection of public transport system, and strengthening of the public transport system and improving ridership. It is opined that the proposed methodology would help in the effective restoration of the PT system ridership without compromising on the safety of passengers. Though the present paper explored strategies for the ease-out plans for the operation of PT, the work could not identify a few aspects. The present study could not identify the impact of the COVID-19 outbreak on other modes of transportation like rail and air. Also, the present study could not capture the details of the transmission of COVID-19 cases after

ease-out on the utilization of public transportation has been implemented. There are further studies required to understand the impact of the social distancing on the operation of public transportation in terms of the frequency as well as the economic efficiency of public transit operation. It is also noted that research on the role of technology in improving the safety of ridership in the PT system is required for its successful implementation. Despite these limitations, the study identified the ease-out strategies for the operation of the PT system and restoration of the ridership and public confidence in the PT system during the current pandemic of COVID-19.

Acknowledgements The authors wish to acknowledge Dr. Kannan Iyer, Assistant Professor, IITRAM, for his suggestions and also reviewing the draft manuscript.

Author contributions The authors confirm contribution to the paper as follows: A review of articles, study conception and preparation of the manuscript: Dr B Raghuram Kadali; review of articles, study conception and manuscript preparation: Dr Saladi SV Subbarao. Both the authors reviewed the manuscript and approved the final version of the manuscript.

Funding The authors have no relevant financial or non-financial interests to disclose. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article. The authors have no conflicts of interest to declare that are relevant to the content of this article.

Declaration

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

References

1. Saxena S (2019) Moving Millions with the Mumbai Metro. Asian Development Bank, Report No 114. <https://www.adb.org/sites/default/files/publication/525821/adb-brief-114-moving-millions-mumbai-metro.pdf>
2. ICT (2018) Public Transportation Linked to the Spread of Flu-Like Illnesses. Infection Control Today. <https://www.infectioncontroltoday.com/influenza/public-transportation-linked-spread-flu-illnesses>
3. WHO (2014) Travel and transport risk assessment: Interim guidance for public health authorities and the transport sector, World Health Organization (WHO).
4. GAVI (2020) Why is coronavirus lockdown necessary? <https://www.gavi.org/vaccineswork/why-coronavirus-lockdown-necessary>, last accessed on 08–05–2020.
5. IRU (2020) Impact on freight and passenger transport of the global Coronavirus (COVID-19) outbreak <https://www.iru.org/resources/tools-apps/flash-info/impact-on-freight-and-passenger-transport-of-the-global-coronavirus-covid-19-outbreak-889>, last accessed on 08–05–2020.

6. Science (2020). What Can Previous Lockdown Strategies Tell us About Ending the Rise of COVID-19? <https://science.thewire.in/health/covid-19-coronavirus-lockdown-strategy/>, last accessed on 08–05–2020.
7. Mohr O, Askar M, Schink S, Eckmanns T, Krause G, Poggensee G (2012) Evidence for airborne infectious disease transmission in public ground transport—a literature review. *Eurosurveillance* 17(35):20255
8. Nasir ZA, Campos LC, Christie N, Colbeck I (2016) Airborne biological hazards and urban transport infrastructure: current challenges and future directions. *Environ Sci Pollut Res* 23:15757–15766
9. Pestre V, Morel B, Encrenaz N, Brunon A, Lucht FD, Pozzetto B, Berthelot P (2012) Transmission by super-spreading event of pandemic A/H1N1 2009 influenza during road and train travel. *Scand J Infect Dis* 44:225–227
10. Zhang N, Huang H, Duarte M, Zhang JJ (2016) Dynamic population flow based risk analysis of infectious disease propagation in a metropolis. *Environ. Int.* 94:369–379. <https://doi.org/10.1016/j.envint.2016.03.038>
11. Troko J, Myles P, Gibson J, Hashim A, Enstone J, Kingdon S et al (2011) Is public transport a risk factor for acute respiratory infection? *BMC Infect Dis* 11(1):1–16
12. Kroesen M, Chorus C (2020) A new perspective on the role of attitudes in explaining travel behavior: a psychological network model. *Transp Res Part A* 133:82–94
13. Hotle S, Murray-Tuite P, Singh K (2020) Influenza risk perception and travel-related health protection behavior in the US: insights for the aftermath of the COVID-19 outbreak. *Transp. Res. Interdiscip. Perspect.* 5:1–14. <https://doi.org/10.1016/j.trip.2020.100127>
14. Beck MJ, Hensher DA (2020) Insights into the impact of COVID-19 on household travel and activities in Australia – the early days under restrictions. *Transp. Pol.* 96:76–93. <https://doi.org/10.1016/j.tranpol.2020.07.001>
15. Irawan MZ, Belgiawan PF, Joewono TB, Bastarianto FF, Rizki M, Ilahi A (2021) Exploring activity-travel behavior changes during the beginning of COVID-19 pandemic in Indonesia. *Transportation*. <https://doi.org/10.1007/s11116-021-10185-5>
16. Tirachini A, Cats O (2020) COVID-19 and public transportation: current assessment, prospects, and research needs. *J. Public Transp.* 22(1):1–34. <https://doi.org/10.5038/2375-0901.22.1.1>
17. Bucsky P (2020) Modal share changes due to COVID-19: the case of Budapest. *Transp Res Interdisciplin Perspect.* <https://doi.org/10.1016/j.trip.2020.100141>
18. Shakibaei S, de Jong GC, Alpkökin P, Rashidi TH (2021) Impact of the COVID-19 pandemic on travel behavior in Istanbul: a panel data analysis. *Sustain Cities Soc.* <https://doi.org/10.1016/j.scs.2020.102619>
19. Shamshiripour A, Rahimi E, Shabanpour R, Mohammadian A (2020) How is COVID-19 reshaping activity-travel behavior? evidence from a comprehensive survey in Chicago. *Transp. Res. Interdiscipl. Perspect* 7:100216. <https://doi.org/10.1016/j.trip.2020.100216>
20. Sun C, Zhai Z (2020) The efficacy of social distance and ventilation effectiveness in preventing COVID-19 transmission. *Sustain Cities Soc.* <https://doi.org/10.1016/j.scs.2020.102390>
21. Kim M-H, Lee J, Gim T-HT (2021) How did travel mode choices change according to Coronavirus disease 2019? lessons from Seoul, South Korea. *Int J Urban Sci* 25(3):437–454. <https://doi.org/10.1080/12265934.2021.1951823>
22. Park B, Cho J (2021) Older adults' avoidance of public transportation after the outbreak of COVID-19: Korean subway evidence. *Healthcare* 9:448. <https://doi.org/10.3390/healthcare9040448>
23. Aloï A, Alonso B, Benavente J, Cordera R, Echániz E, González F, Ladisa C, Lezama-Romanelli R, López-Parra Á, Mazzei V et al (2020) Effects of the COVID-19 lockdown on urban mobility: empirical evidence from the city of santander (Spain). *Sustainability* 12:3870
24. Orro A, Novales M, Monteagudo Á, Pérez-López J-B, Bugarín MR (2020) Impact on city bus transit services of the COVID-19 lockdown and return to the new normal: the case of a Coruña (Spain). *Sustainability* 12:7206
25. Ahangari S, Chavis C, Jeihani M (2020) Public transit ridership analysis during the pandemic. *MedRxiv.* 6(3):100166. <https://doi.org/10.1101/2020.10.25.20219105>
26. Rasca S, Markvica K, Ivanschitz BP (2020) Impacts of COVID-19 and pandemic control measures on public transport ridership in European urban areas – the cases of Vienna, Innsbruck, Oslo, and Agder. *Transp. Res. Interdiscipl. Perspect* 10:1–16. <https://doi.org/10.1016/j.trip.2021.100376>
27. Jenelius E, Cebecauer M (2020) Impacts of COVID-19 on public transport ridership in Sweden: analysis of ticket validations, sales and passenger counts. *Transp. Res. Interdiscipl. Perspect.* 8:100242. <https://doi.org/10.1016/j.trip.2020.100242>
28. Przybylowski A, Stelmak S, Suchanek M (2021) Mobility behaviour in view of the impact of the COVID-19 pandemic—public transport users in Gdansk case study. *Sustainability* 13(1):364. <https://doi.org/10.3390/su13010364>
29. Boroujeni M, Saberian M, Li J (2021) Environmental impacts of COVID-19 on Victoria, Australia, witnessed two waves of Coronavirus. *Environ. Sci. Pollut. Res* 28(11):14182–14191. <https://doi.org/10.1007/s11356-021-12556-y>
30. Tan L, Ma C (2020) Choice behavior of commuters' rail transit mode during the COVID-19 pandemic based on a logistic model. *J Traffic Transp Eng.* <https://doi.org/10.1016/j.jtte.2020.07.002>
31. Teixeira JF, Lopes M (2020) The link between bike sharing and subway use during the COVID-19 pandemic: the case-study of New York's Citi Bike. *Transp. Res. Interdiscipl. Perspect.* 6:100166
32. Wilbur M, Ayman A, Ouyang A, Poon V, Kabir R, Vadali A, Pugliese P, Freudberg D, Laszka A, Dubey A (2020) Impact of COVID-19 on public transit accessibility and ridership. Preprint, [physics.soc-ph], available at. <https://arxiv.org/abs/2008.02413>
33. Almlöf E, Rubensson I, Cebecauer M, Jenelius E (2020) Who Is Still Travelling by Public Transport During COVID-19? Socioeconomic Factors Explaining Travel Behaviour in Stockholm Based on Smart Card Data. Preprint, available at SSRN. <https://doi.org/10.2139/ssrn.3689091>
34. Rubin GJ, Amlöt R, Page L, Wessely S (2009) Public perceptions, anxiety, and behaviour change in relation to the swine flu outbreak: cross sectional telephone survey. *BMJ* 339:1–8
35. Tang CSK, Wong C-Y (2003) An outbreak of the severe acute respiratory syndrome: predictors of health behaviors and effect of community prevention measures in Hong Kong, China. *Am J Public Health* 93:1887–1888
36. Lau JTF, Yang X, Tsui H, Kim JH (2003) Monitoring community responses to the SARS epidemic in Hong Kong: from day 10 to day 62. *J. Epidemiol. Community. Health* 57:864–870
37. Hou Z, Du F, Jiang H, Zhou X, Lin L (2020) Assessment of public attention, risk perception, emotional and behavioural responses to the COVID-19 outbreak: social media surveillance in China. *MedRxiv.* <https://doi.org/10.1101/2020.03.14.20035956>
38. Roy S (2020) How cities can manage travel demands in post-COVID-19 societies. <https://www.downtoearth.org.in/blog/urbanisation/how-cities-can-manage-travel-demands-in-post-covid-19-societies-70678>, last accessed on 08–05–2020
39. de Haas M, 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. *Transp Res Interdiscipl Perspect.* <https://doi.org/10.1016/j.trip.2020.100150>
40. Parady G, Taniguchi A, Takami K (2020) Travel behavior changes during the COVID-19 pandemic in Japan: analyzing the effects of risk perception and social influence on going-out self-restriction. *Transp. Res. Interdiscipl. Perspect.* 7:1–18. <https://doi.org/10.1016/j.trip.2020.100181>
 41. Nguyen MH (2021) Factors influencing home-based telework in Hanoi (Vietnam) during and after the COVID-19 era. *Transportation (Amst).* <https://doi.org/10.1007/s11111>
 42. Beck MJ, Hensher DA, Wei E (2020) Slowly coming out of COVID-19 restrictions in Australia: implications for working from home and commuting trips by car and public transport. *J Transp Geogr.* <https://doi.org/10.1016/j.jtrangeo.2020.102846>
 43. UITP (2020) Public Transport Authorities and COVID-19 Response from the Front Line. The International Association of Public Transportation (UITP). https://australia-newzealand.uitp.org/sites/default/files/V1_COVID-19%20impacts_AJ_v03.pdf, last accessed on 05–04–2020
 44. ITDP (2020) Post-Pandemic, Chinese Cities Gradually Reopen Transport Networks. <https://www.itdp.org/2020/03/26/post-pandemic-chinese-cities-gradually-reopen-transport-networks/>, last accessed on 20–04–2020.
 45. Liu D, Xue L, Huang T (2020). 3 Ways China's Transport Sector Is Working to Recover from COVID-19 Lockdowns <https://thecityfix.com/blog/3-ways-chinas-transport-sector-working-recover-covid-19-lockdowns/>, last accessed on 04–04–2020.
 46. Mangan E (2020) 2.8 million essential workers use transit to get to their jobs. <http://t4america.org/2020/03/27/2-8-million-essential-workers-use-transit-to-get-to-their-jobs/>, last accessed on 08–05–2020.
 47. Connelly CA (2020) COVID-19 & Public Transit. <https://www.abettercity.org/news-and-events/blog/covid-19-response-how-is-the-public-transit-system-measuring-up>, last accessed on 20–05–2020.
 48. APTA (2020) Public Transit Response to Coronavirus or COVID-19. American Public Transportation Association (APTA). <https://www.apta.com/public-transit-response-to-coronavirus/> last accessed on 08–05–2020.
 49. NCHRP (2020) A Guide for Public Transportation Pandemic Planning and Response. National Cooperative Highway Research Program, NCHRP-769, Transportation Research Board, Washington, USA. <https://www.nap.edu/download/22414>, last accessed on 04–04–2020.
 50. ET-Zones (2020) Red, orange, green zones may come up during extended lockdown. <https://economictimes.indiatimes.com/news/politics-and-nation/red-orange-green-zones-may-come-up-during-extended-lockdown/articleshow/75101054.cms>, last accessed on 20–05–2020.
 51. Eco-mobility (2020) COVID-19: Focus on cities and transport responses – India. <https://ecomobility.org/covid-19-focus-on-cities-and-transport-responses-india/> last accessed on 20–05–2020.
 52. Mohan, V (2020) Govt. prepares post-lockdown norms for use of public transport. <https://timesofindia.indiatimes.com/india/govt-prepares-post-lockdown-norms-for-use-of-public-transport/articleshow/75544877.cms>, last accessed on 20–05–2020.
 53. CRRI (2020) Guidelines for Public Transport and Feeder Modes considering Social Distancing Norms- Commuting in Urban Area during Covid-19 Pandemic. Central Road Research Institute (CRRI), New Delhi, India.
 54. Kumar VD (2020) Remodelling awaits public transport system post lockdown. <https://www.newindianexpress.com/states/kerala/2020/may/09/remodelling-awaits-public-transport-system-post-lockdown-2140957.html>, last accessed on 08–05–2020.
 55. TMT (2020) Coronavirus in Russia: The Latest News. The Moscow Times (TMT). <https://www.themoscowtimes.com/2020/06/22/coronavirus-in-russia-the-latest-news-june-22-a69117>, last accessed on 10–06–2020.
 56. WEF-London (2020) London bus travel now free after 20 drivers die from COVID-19. World Economic Forum (WEF). <https://www.weforum.org/agenda/2020/04/london-bus-travel-coronavirus/>, last accessed on 20–05–2020.
 57. Forster A (2020) Social distancing on bus and rail likely to prolong home working. <https://www.transportxtra.com/publications/local-transport-today/news/65333/social-distancing-on-bus-and-rail-likely-to-prolong-home-working>, last accessed on 15–05–2020.
 58. IT COVID-19 (2020) COVID-19: Transport industry latest news and analysis. Intelligent Transport's COVID-19. https://www.intelligenttransport.com/topic_hub/covid-19-transport-news-analysis/, last accessed on 08–05–2020.
 59. TTT (2020) Covid-19: London to rapidly expand space for cycling and walking, post-lockdown. Traffic Technology Today, <https://www.trafficechnologytoday.com/news/covid-19-news/covid-19-london-to-rapidly-expand-space-for-cycling-and-walking-post-lockdown.html>, last accessed on 05–04–2020.
 60. Lades LK, Kelly A, Kelleher L (2020) Why is active travel more satisfying than motorized travel? evidence from Dublin. *Transp Res Part A* 136:318–333
 61. Hayward Andrew C, Beale, Sarah, Johnson, Anne M, Fragaszy, Ellen B and Group (2020) Flu Watch, Public Activities Preceding the Onset of Acute Respiratory Infection Syndromes in Adults in England - Implications for the Use of Social Distancing to Control Pandemic Respiratory Infections. Available at SSRN: <https://ssrn.com/abstract=3551361> or <https://doi.org/10.2139/ssrn.3551361>
 62. UITP (2020) Management of COVID-19: Guidelines for Public Transport Operators. Factsheet, March 2020. International Association of Public Transport (UITP).. <https://www.uitp.org/management-covid-19-guidelines-public-transport-operators>
 63. Leung K (2020) Hong Kong commuters to get subsidy boost after government lowers threshold as part of coronavirus relief scheme. <https://www.scmp.com/news/hong-kong/transport/article/3079480/hong-kong-commuters-get-subsidy-boost-after-government>, last accessed on 04–04–2020.
 64. VRT News (2020) <https://www.vrt.be/vrtnews/en/2020/04/25/mouth-masks-for-al-land-the-shops-to-reopen-from-11-may-what-ar/>, last accessed on 08–05–2020.
 65. Coro-Belgium (2020) Belgium outlines its exit strategy. <https://www.info-coronavirus.be/en/news/nsc-24-04/> last accessed on 20–05–2020.
 66. Price S (2020) South Korea Has Flattened The Curve, But 'Normal' Is Still Some Way Off. <https://www.forbes.com/sites/steveprice/2020/04/01/south-korea-has-flattened-the-curve-but-normal-is-still-some-way-off/#10e51a05760e>, last accessed on 15–05–2020, last accessed on 05–04–2020.
 67. 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
 68. Sundria S (2020) Singapore Gets Stricter on Enforcement to Curb Spread of Virus <https://www.bloombergquint.com/business/sbi-agrees-to-extend-moratorium-to-nbfc>
 69. CUTA (2020) COVID-19 Resources-COVID-19 Guidance for the Public Transit Industry. Canadian Urban Transit Association (CUTA). <https://cutaactu.ca/en/COVID-19>
 70. RSA (2020) Travel - Coronavirus Covid-19. Republic of South Africa (RSA). <https://www.gov.za/Coronavirus/travel>
 71. Whiting K (2020) France's plan to push pedal power to keep post-pandemic pollution levels low. <https://www.weforum.org/agenda/2020/05/france-air-pollution-cycling-public-transport-bike-coronavirus/>, last accessed on 08–05–2020.

72. Yang S (2020) Taiwan MRT passengers down over 50% since start of coronavirus outbreak. <https://www.taiwannews.com.tw/en/news/3917253>, last accessed on 20–04–2020.
73. Wang CJ, Ng CY, Brook RH (2020) Response to COVID-19 in Taiwan: big data analytics, new technology, and proactive testing. *J. American Med. Assoc.* 323(14):1341–1342
74. CCD (2020) China launches coronavirus 'close contact detector' app. Close Contact Detector (CCD). <https://www.bbc.com/news/technology-51439401>, last accessed on 08–05–2020
75. Mozur P, Zhong R, Krolikin A (2020) Coronavirus Fight, China Gives Citizens a Color Code, With Red Flags. <https://www.nytimes.com/2020/03/01/business/china-coronavirus-surveillance.html>, last accessed on 08–05–2020
76. Chaturvedi A (2020) The China way: Use of technology to combat Covid-19. *Geo-Spatial World (GSW)*. <https://www.geospatialworld.net/article/the-sino-approach-use-of-technology-to-combat-covid-19/> last accessed on 28–05–2020
77. Klippe NV (2020) China using high-tech surveillance in battle against spread of coronavirus. *The Globe And Mail (TGAM)*. <https://www.theglobeandmail.com/world/article-china-employing-high-tech-surveillance-in-battle-against-spread-of/> last accessed on 08–05–2020
78. Aljazeera (2020) Coronavirus: China uses facial recognition and infrared scanners. <https://www.aljazeera.com/programmes/newsfeed/2020/02/coronavirus-china-facial-recognition-infrared-scanners-20224092119453.html>, last accessed on 08–05–2020
79. PYMNTS (2020) App Lets Singapore Track Virus Patients' Movements. <https://www.pymnts.com/coronavirus/2020/app-lets-singapore-track-virus-patients-movements/>, last accessed on 10–04–2020, last accessed on 08–04–2020
80. DW (2020) Coronavirus tracking apps: How are countries monitoring infections? <https://www.dw.com/en/coronavirus-tracking-apps-how-are-countries-monitoring-infections/a-53254234>, last accessed on 20–05–2020
81. MyGov (2020) Aarogya Setu Mobile App. <https://www.mygov.in/aarogya-setu-app/>, last accessed on 04–04–2020
82. Tripathi Y (2020) What Is Self Assessment Test In Aarogya Setu App? Here's A Guide To Using It. <https://www.republicworld.com/technology-news/apps/what-is-self-assessment-test-in-aarogya-setu-app-guide-to-using-it.html>, last accessed on 08–05–2020
83. CONT (2020) Combating COVID-19: Telangana Police Set To Roll Out AI-Based System To Track Those Not Wearing Masks At Public Places. *Coronavirus Outbreak, News, Telangana (CONT)*. <https://swachhindia.ndtv.com/combating-covid-19-telangana-police-set-to-roll-out-ai-based-system-to-track-those-not-wearing-masks-at-public-places-44571/>, last accessed on 20–05–2020
84. Mandal A (2020) United States tracking mobile phones to map spread of COVID-19. *News-Medical Life Sciences (NMLS)*. <https://www.news-medical.net/news/20200330/United-States-tracking-mobile-phones-to-map-spread-of-COVID-19.aspx>, last accessed on 08–05–2020
85. Nguyen T (2020) Should you take public transit during a pandemic? <https://www.vox.com/the-goods/2020/3/13/21177324/public-transit-pandemic-coronavirus>, last accessed on 08–05–2020.
86. TUMI (2020) The COVID-19 outbreak and implications to sustainable urban mobility – some observations. *Transformative Urban Mobility Initiative (TUMI)*. <https://www.transformative-mobility.org/news/the-covid-19-outbreak-and-implications-to-public-transport-some-observations>, last accessed on 08–04–2020.
87. Kvashilava G (2020) The effects of COVID 19 on Georgia's public transport system. *Eastern Alliance for Safe and Sustainable Transport (EASST)*. <https://www.easst.co.uk/the-effects-of-covid-19-on-georgias-public-transport-system/>
88. Null S, Smith H (2020) COVID-19 Could Affect Cities for Years. Here Are 4 Ways They're Coping Now. <https://www.wri.org/blog/2020/03/covid-19-could-affect-cities-years-here-are-4-ways-theyre-coping-now>, last accessed on 04–05–2020
89. Ponkshe A (2020) Steps to restart public transit after lockdown ends. *Observe Research Foundation (ORF)*. <https://www.orfonline.org/expert-speak/steps-restart-public-transit-lockdown-ends-65814/>, last accessed on 20–05–2020
90. Papandreou T (2020) Is The Coronavirus The Transportation Industry's Opportunity? <https://www.forbes.com/sites/timothypapandreou/2020/03/27/is-the-coronavirus-the-transportation-industrys-opportunity/#37af9bbb752b>, last accessed on 04–04–2020
91. Metro (2020) FTA makes \$25B available to aid public transit during COVID-19. <https://www.metro-magazine.com/government-issues/news/738017/fta-makes-25b-available-to-aid-public-transit-during-covid-19>, last accessed on 20–05–2020
92. Mallett WJ (2020) Emergency Funding for Public Transportation Agencies Due to COVID-19. <https://crsreports.congress.gov/product/pdf/IN/IN11269>, last accessed on 08–05–2020
93. Hawkins AJ (2020) Coronavirus is taking a big bite out of public transportation ridership in the US. <https://www.theverge.com/2020/3/13/21179032/public-transportation-coronavirus-covid-19-ridership-nyc-sf-la-dc>, last accessed on 08–05–2020
94. WEF (2020) How public transportation provides key lifelines during COVID-19. *World Economic Forum (WEF)*. <https://www.weforum.org/agenda/2020/04/public-transportation-provides-lifelines-during-covid-19-heres-how/>, last accessed on 28–05–2020
95. Welle B, Avelleda S (2020) Safer, More Sustainable Transport in a Post-COVID-19 World. <https://www.wri.org/blog/2020/04/coronavirus-public-transport-stimulus-packages>, last accessed on 08–05–2020
96. TA (2020) Safer, More Sustainable Transport in a Post-COVID-19 World. *Transport Advancement (TA)* <https://www.transportadvancement.com/press-statements/safer-more-sustainable-transport-in-a-post-covid-19-world/>, last accessed on 08–04–2020