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Controlling urban traffic—one of the useful methods to ensure safety in Wuhan based on COVID-19 outbreak

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\section*{A R T I C L E   I N F O}

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\section*{A B S T R A C T}
Coronavirus disease 2019 (COVID-19) broke out in Wuhan, China. As of March 9, 2020, this epidemic has occurred in 102 countries and caused 3584 deaths with global serious concern. To cope with the outbreak, Chinese governments have strictly controlled urban traffic at all levels, especially in Wuhan. This article firstly reviews the urban traffic situation from January 23, 2020 to March 8, 2020, including safety problems of urban public transportation, traffic control methods, and emergency public transportation planning. Based on this, we present some emergency traffic control measures that are very urgent in the early stage of epidemic. Between cities, we strongly recommend blocking and controlling the flow of traffic in the early stage of epidemic. Inside a city, it is imperative to suspend the public transports, block all roads, restrict private cars, and close bridges and tunnels. Material isolation transfer stations are suggested to be established. A number of public transports should be organized to ensure transport of medical workers, patients, and daily necessities. We also give suggestions about the long-term planning and improvement methods. Considering the great success China has achieved in fighting COVID-19, we believe that this article offers a valuable reference of urban traffic control.

\section*{1. Background}

The Coronavirus disease 2019 (COVID-19) broke out in Wuhan, China, in late January 2020. COVID-19 has now spread in many parts of the world (Lei, 2020). Although the epidemic situation in China has been brought under control, the number of confirmed cases is rising dramatically in the world. The infection is still showing a horribly elongated flow and concentration. The spread speed of the virus is not only related to the virus itself (Phan, 2020), but also closely related to the population flow and contact. Public transportation is easy to accelerate the spread of the epidemic. How to effectively control urban public transportation is an urgent problem for large cities to solve during the epidemic. The safety of the urban transportation system plays an important role in the prevention and control of epidemic. For example, some measures were carried out during the SARS outbreak in 2003 (Chi, 2003; Tian et al., 2020; Yuesheng, 2003). In order to prevent SARS from spreading in cities and villages by means of transportation, local governments controlled public transportation. They used individual vehicles and taxis in the prevention and control of SARS. In addition, in order to ensure timely delivery of emergency supplies for the prevention and treatment of SARS, the ministry of communications issued "special permits" to vehicles. At the peak of the SARS epidemic, the Centre for Disease Control (CDC) developed a new mechanism for integrated infectious disease control, namely Traffic Control Bundling. This mechanism included triaging and dispatching patients before they entered the hospital. All the confirmed cases were confined in a contamination zone (Yen et al., 2014). During the outbreak of Ebola and H1N1 virus, the
governments carried out traffic quarantine and inspection to ensure safety (WHO, 2020a). A study about the spread of Ebola virus revealed that travel restrictions could delay the further international spread of the virus to some extent (Poletto et al., 2014). Due to the plague in Yumen City, Gansu Province, a 9-day “city lockdown” decision was made in July 2014 (Thepaper, 2014).

In order to cope with COVID-19, Chinese governments at all levels have strictly controlled urban transportation. Many transportation policies are aimed at preventing the spread of the virus and protecting people’s health more effectively. As long as the epidemic situation can be quickly controlled, people can accept and support temporarily staying at home (Jinwei, 2020; Xingbin, 2020). As of March 8, only 40 newly confirmed cases were reported in China (Xiaobo and Xin, 2020). As of April 27, the death rate is less than 5.5% (Ji, 2020), far lower than many European and American countries. World Health Organization Director-Dr. Tedros Adhanom Ghebreyesus said that “What happening in the rest of the world, outside China, is now of our greatest concern.” “My message to each of these countries is that this is your window of opportunity. If you acted aggressively now you can contain this virus”. “But this virus is not influenza. With right measures, it can be contained” (WHO, 2020b).

The epidemic in China has been excellently controlled. This article firstly reviews the urban traffic situation from three aspects including the safety problems of urban public transportation, the traffic control methods, and the emergency public transportation planning. Based on these, we present the suggestions about the emergency traffic control measures and the long-term planning methods.

2. Current urban traffic situation under COVID-19

After the outbreak of COVID-19, the control of urban traffic can be divided into three aspects. (A) At the beginning of the epidemic, urban public transport is an important way for transmission of the virus. We discuss the existing problems and potential dangers of public transport. (B) Realizing the seriousness of the epidemic, Wuhan and other cities issued very strict traffic control methods to strongly prevent spread of the virus. (C) After the strict traffic control, it is necessary to formulate some emergency public transportation planning to ensure normal operation of the city. This section reviews and shares the urban traffic situation from the mentioned points.

2.1. Safety problem of urban public transport

Conventional public transport mainly refers to buses. The bus compartment is a relatively narrow space with large population flow. Some studies have shown that the concentration of particulate matter in the range of 0.5 m around a human body is relatively dangerous. The risk outside the range of 0.5 m is greatly reduced (Villafruela et al., 2016; Yang, 2019). However, the number of passengers in large cities is huge. Every bus is full of passengers. It is impossible for all of them to maintain a distance above 0.5 m.

It is now clear that the main modes of the transmission of COVID-19 include droplet and contact (Dalin, 2020). Some scholars have carried out dynamic numerical analysis on virus transmission in cockpit environment (Xie, 2013). In the study, the velocity of cough airflow was set to be 1.5–28.8 m/s, and the temperature of droplets produced by cough was set as 31 °C (Gupta et al., 2009). In the simulation, the droplet was assumed to be 1 μm, and large particles were ignored. As a result, the droplets can reach as far as 8 m in a relatively short time. They can stay in the air for about ten minutes. The seat of the cockpit has a limited blocking effect on the spread of droplets. Owing to the high exhalation temperature during coughing, the airflow density carrying droplets is lower than the cabin air density, which makes droplets continue to spread forward around the seat (Salmanzadeh et al., 2012). As the outbreak of COVID-19 was in the cold winter, the vast majority of buses were unventilated. The air inside the buses was poor in circulation, which sharply increased people’s risk of catching the disease through air and droplet (Salmanzadeh et al., 2012).

A patient was infected with COVID-19 because he did not wear a mask when taking a bus. He boarded the same bus 16 s later than a confirmed case (Sogou, 2020). Another example also proves the promotion of public transport on the spread of the virus. From the end of January to the beginning of February of 2020, the CDC of Hunan province received 6 suspected cases of COVID-19. Investigations revealed that these cases were all on a same bus with a confirmed patient on January 22 (Qi, 2020). In addition, there were 13 infected people taking a same bus as reported, illustrating the possibility of aerosol transmission on buses (Sohu, 2020b). The study found that coronavirus is highly infectious within a maximum distance of 4.5 m of a closed air-conditioned compartment. The virus can float in the air for at least 30 min and cause infection. There are still many cases of this kind of infection, which deeply remind people of conventional safety problem of urban public transport. The existing buses can’t ensure the public health and safety of passengers at current situation. Based on this, Italian Lombardia President Attilio Fontana said he and 12 other regional mayors believed that public transportation should be suspended to prevent the spread of COVID-19, according to France24 (Boyi, 2020).

Rail rapid transport mainly refers to light rail and subway transportation systems. Large passenger flow has become the norm in this transport (Xinyi, 2015). Subways have characteristics of unventilated space, complex structure, large carrying capacity, and wide network distribution. Owing to relatively unventilated space and insufficient natural ventilation, it is not conducive to the dilution of produced pollutants. According to spread of SARS virus, which is very similar to COVID-19, experts estimate that each SARS patient exhales up to one million SARS viruses per second on average. If one stays in an unventilated space with a size of 2*6*2.8 m³ for ten minutes, the density of SARS virus will be 17.8 million per cubic meter (Shuangjing, 2004). However, the number of subway passengers is about 5 times that of buses (Yi et al., 2020). Therefore, once the virus is introduced, it is extremely easy for the virus to spread. The airborne transmission is also related to temperature and humidity. Places with relatively low air temperature (lower than 26°C) and high relative humidity, like subways and underground stations, are conducive to spread of the virus (Yi et al., 2020).

Massachusetts Institute of Technology (MIT) economics professor and doctor Jeffrey Harris pointed out that there is a correlation between the high subway carriage occupancy rate and the “rapid, exponential surge in infection” (Sinovision, 2020). He said “We know that the close contact in subways is the main transmission mode of COVID-19”. According to a report of the New York Times on April 8, at least 41 subway employees in New York have died, and 1500 subway employees have been tested positive for COVID-19. In addition, other 5604 employees were undergoing self-isolation owing to symptoms (Tencent, 2020a). Obviously, the current urban public transport cannot ensure the safety of passengers under the epidemic situation.

2.2. Traffic control methods

The COVID-19 was first detected in Wuhan on December 23, 2019. In the beginning, the disease appeared in a relatively small area, and its impact was not familiar to the public. With the spread, the disease has drawn wide attention. On the evening of January 20, Zhong Nanshan, academician of the Chinese Academy of Engineering, made it clear in an interview that there is a phenomenon of human-to-human transmission for COVID-19 (Chenxi, 2020a, 2020b). Facing this dangerous virus, many cities of China carried out strict traffic control.

2.2.1. Traffic control in Wuhan-the epidemic center city

On January 23, 2020, Wuhan Epidemic Command Center issued the first announcement (Netease, 2020a). According to the announcement, the city’s public transport, including buses, subways, ferries and long-
From the outbreak of the epidemic to the city lockdown, Wuhan took only six days. Many experts and scholars, including World Health Organization Director-Dr. Tedros Adhanom Ghebreyesus, believed that the lockdown would efficiently prevent the spread of the epidemic. The move was very appropriate and important (WHO, 2020c). On March 9, Italy imposed a blockade of Northern Lombardia and 14 other provinces (Sohu, 2020d). This is undoubtedly a positive move, but the effect of the lockdown has been weakened to some extent due to untimely actions. The virus has spread in Italy and some surrounding regions for a period of time. This serves as a warning to us when similar major emergencies occur in the future.

2.2.2. Traffic control in moderate and mild epidemic cities

In addition to the cities with serious epidemic situation in Hubei Province, some cities with moderate or slight impact of the epidemic have also implemented urban traffic control to limit the spread of COVID-19. Xuzhou shut down the city subway from 00:00 on January 27, 2020. Subsequently, Hohhot, Wenzhou, Urumqi, Ningbo and other cities also suspended their subway systems. Xi’an, Changzhou, Shenyang and other cities had successively introduced the real-name registration in public transport. Other cities had also implemented control of some rail transit lines (Sohu, 2020e). Kaifeng city in Henan province had suspended the operation of all buses since January 26. Taxis and online taxi-hailing services were also suspended. All bus stations in the city were temporarily closed (Henan, 2020). Shantou city, Guangdong province, had suspended the operation of passenger cars, buses, taxis, free rides and ferries since 14 o’clock on January 26. From January 27, vehicles, ships and persons were prohibited from entering Shantou city, except for those allowed for emergency, special and material necessities (Sohu, 2020f). From January 26, 2020, Shandong province would suspend inter-provincial and inter-city transport. Passenger stations that were not equipped with temperature testing facilities should not run inter-city buses (Qianwen, 2020).

2.3. Emergency public transportation planning

From the previous section, the public transportation was banned, and many traffic control methods have been carried out. However, a city still needs to maintain normal operation, and thus emergency public transportation planning is needed. This section mainly reviews the policies and methods designated by Wuhan and other cities for emergency public transportation planning.

In this outbreak, local government of Wuhan has taken timely and efficient actions. According to the general goal of “preventing imported cases and domestic re-infections”, Wuhan city preferentially ensures the transport for materials and medical workers (Chinanews, 2020). An emergency public transportation dispatch system temporarily supports the basic operation of the whole city. Its main policies are summarized in three aspects, including the establishment of material isolation transfer stations, the organization of vehicles to ensure emergency response, and to ensure transportation of daily necessities (Qianwen, 2020). The specific contents are shown as follows.

Firstly, Wuhan city has set up a logistics transfer station for emergency supplies. Drivers from other places will not enter the city or be required to conduct isolated observation after leaving the city.

Secondly, Wuhan organizes buses, taxis and other public transports to ensure the conveyance of medical workers and the cured patients. Wuhan organized 623 buses, which were distributed to 15 districts to undertake emergency support tasks. These buses also provided commuter service for medical workers in 100 hospitals such as Huoshenshan hospital. On February 22, another 256 taxis were organized to ensure the emergency conveyance of medical workers between hospitals and more than 150 hotels. In addition, Wuhan Transportation Bureau had collected 6000 taxis and dispatched them to 1159 communities in the central urban area to provide basic life services for residents. With the strengthening of the lockdown measures in the
Fig. 2. Traffic flow of Wuhan's main ring roads and bridges after 2020.1.23.

Fig. 3. Important measures and timing of traffic control in Wuhan affected by epidemic.
residential areas, 130 additional taxis were sent to 15 districts to transport recovered patients to isolation points.

Thirdly, Wuhan organized buses to transport citizens’ daily necessities. According to the instructions of the city’s epidemic prevention and control headquarters, from February 24, Wuhan Public Transport Group Co., Ltd. quickly deployed and arranged 520 buses to connect 165 supermarkets and e-commerce platform outlets in Wuhan, including Longting store, Zhongbai store, Changqing Road store, etc. This is conductive to undertake timely transportation and distribution of daily necessities purchased by citizens online. The specific vehicle arrangement is shown in Fig. 4.

As the region most seriously affected by the epidemic, Wuhan city’s emergency adjustment of public transport operation is a very wise choice. It can not only avoid cross infection and prevent the spread of the epidemic, but also ensure the orderly progress of medical work and the timely transportation of daily necessities.

Shantou city in Guangdong province, which was also affected by the epidemic, adopted traffic control and emergency transportation on January 26. Its specific statistics are shown in Fig. 5. Since the incubation period of COVID-19 is 14 days, the data from January 26 to February 9 are counted. From the data in the figure, we can see that there are no new cases in the local area. Until February 14, Shantou city has not reported new cases for 7 consecutive days. The decline of the epidemic is not entirely due to the traffic control and emergency transportation, but we have to say that it indeed plays an important role in emergency public health safety.

3. Discussion and suggestions of safety for urban public transportation

In the previous analysis, we can see that most cities in China, especially Wuhan, have done a lot of work on urban traffic control. Based on this, we obtain that some emergency traffic control measures are very urgent in the early stage of epidemic. We also give the suggestions about the long-term planning and improvement methods when faced with similar events again.

3.1. Emergency traffic control measures

We strongly recommend blocking and controlling flow of the traffic between cities in the early stage of epidemic. In Wuhan, the hardest-hit area in China, the city was quickly blockaded. Only through the closure of the city can 10 million people in Wuhan be prevented from leaving. The virus therefore can be effectively controlled within the city. The measures cut off the virus’ transmission in a wider scope. Only by strict control of the infection source can a pandemic of infectious diseases be prevented.

Inside a city, it is imperative to suspend the public transports, block all roads and restrict private cars. From the previous analysis on safety problems of urban public transport in Section 2.1, suspension of buses and subways is easy to be understood and taken for granted. In addition, Wuhan also stopped the operation of car-hailing service, while taxis were restricted to an odd–even car ban. Although the passenger capacity of cars is small, the passengers and drivers are in a narrow and unventilated environment. Direct or indirect contact is inevitable, which increases the risk of further spread of the virus. These measures can not only reduce the spread of the virus, but also release occupation of the public resources for centralized dispatch. Obviously, in public health and safety emergencies, the existing public transport can’t ensure the health and safety of passengers. Therefore, it is imperative to suspend the operation of public transport to limit the spread of the virus.

In some cities with rivers and lakes, closing bridges and tunnels also need to be considered. During this period, the major bridges and several tunnels across the Yangtze River in Wuhan were closed. All the private cars are prohibited from crossing the bridges and tunnels except for epidemic prevention vehicles. Wuhan is a big city with many districts located on both sides of the Yangtze River. Some of Wuhan’s districts are connected by bridges and tunnels across the Yangtze River. For example, the Yangtze River Bridge connects Wuchang and Hankou districts. By closure of the cross-river tunnel, the population flow from both sides can be stopped so as to better control the source of infection.

As an emergency transportation planning method, it is necessary to
establish a material isolation transfer station, which greatly improves the efficiency of material transfer and reduces waste of public resources. It is suggested that a transportation department should also participate in the deployment and transport of emergency materials, and quickly establish a centralized transportation command and dispatch mechanism.

A number of buses, taxis and other public transports should be organized to ensure the transport of medical workers, patients, and daily necessities. Facing the new changes and demands during the epidemic, urban transportation should not only reduce the risk of epidemic spread, but also ensure effective transportation. This can ensure timely care and treatment of patients in hospitals, reduce the possibility of infection of medical workers and ensure the normal life of healthy residents. Therefore, it is suggested that emergency management agencies should quickly establish emergency plans in conjunction with transportation departments. In particular, medical care and hierarchical management in emergency situations should be stable and efficient.

Wuhan experienced a lockdown and strict traffic control of 76 days, and the epidemic has been effectively controlled. Wuhan has reopened on April 8. As of April 17, the number of asymptomatic patients and newly confirmed cases were 0. This shows that once we realize the emergence of infectious diseases, we must strengthen the restrictions on traffic flow immediately. Including the authors of this paper, the vast majority of people in Wuhan have resumed a normal life. We can enter and leave Wuhan freely now. The cost of the closure is huge, but we have to do it to halt the spread of the virus as much as possible.

3.2. Long-term planning and improvement methods

Wuhan has taken many positive and effective measures in urban traffic control to deal with the epidemic, but some aspects can be further improved. Through the following suggestions, epidemics can be better prevented and controlled if similar emergencies occur in the future.

An advanced big data technology is in need. In this epidemic, when an infected patient was confirmed, local governments released the information to public to find close contacts. This is inefficient and detrimental to privacy. If a big data system is established, information of close contacts will be obtained efficiently and quickly. They can be treated as soon as possible. Therefore, on the basis of big data technology, collecting and processing of public transportation passenger information should be strengthened. Under the background of the big data development, decision makers should consider how to make efficient use of massive public transportation data, so as to realize the orderly dispatch of public transport. In the future, if sudden public health and safety emergencies occur again, such as COVID-19, efficient prevention and control can be achieved.

A real-time monitoring and feedback system for viruses and abnormal conditions should be established. For example, sensors can be installed in vehicles and stations to monitor viruses or passengers’ temperature. Once the virus or some abnormal situation is detected, the area can be sealed off and disinfected medically (Yanjing, 2020). The overall emergency procedure is shown in Fig. 6.

When a person is detected carrying the virus, the infected person and the current transportation vehicle should be isolated and disinfected immediately. At the same time, through big data technology, the government could find the transportation information that the infected person has recently taken, and further obtain close contacts. Finally, the government needs to conduct a virus test on the close contacts, and decides on the follow-up medical blockade and related measures based on whether the test is positive.

In the future, it is necessary to carry out appropriate public transportation device improvement. The existing public transports and facilities cannot satisfy needs in emergency situations. Some existing technologies can be introduced to improve public transportation facilities and optimize public transportation stations. For example, buses can be equipped with an open ventilation system. A separate closed compartment can be introduced for the drivers to protect them. A fresh air system can be added or the air exchange rate of the air conditioner can be appropriately increased. On the other hand, the existing lines and stations should be further optimized to guide flow of passengers. If necessary, stations with potential risk should be redesigned to eliminate the hazards.

Moreover, in order to ensure the safety of drivers and passengers, we should strengthen the research and technological innovation of advanced vehicles. It is reported that Geely Auto Group has set up a research and development project of “omni-directional healthy car” to prevent virus (Netease, 2020b). The car can isolate harmful substances from outside. It also focuses on virus prevention function and technology inside the vehicle. Jianghuai Automobile Co., Ltd. developed a high-end all-electric vehicle named iC5 (Tencent, 2020c). The car is equipped with the newly developed “solid alkali epidemic prevention system”, which has functions of strong filtration, advanced oxidation and air purification. In addition, Tesla Model X also has its own negative ion generator, which can effectively filter and rapidly purify the air inside the vehicle (Sohu, 2020g). If the relevant technologies can be applied to urban public transports, such as buses, subways, taxis, etc., cross infection can be more effectively avoided and the epidemic can be quickly controlled.

4. Conclusions

The outbreak of COVID-19 has proved to be a disaster for all human beings. Wuhan has controlled the epidemic well in a short period of time. Its urban traffic control experiences are good references for other countries and cities in the future. Based on the situation in China, we carry out discussion, and obtain suggestion about emergency traffic control measures and long-term planning from the authors’ points of view. The main conclusions are summarized as follows:

1. Between cities, we strongly recommend blocking and controlling the flow of traffic in the early stage of epidemic. In this way, a pandemic is controlled within a limited area, and thus we can pool medical resources for fighting the pandemic.
2. Inside a city, it is imperative to suspend the public transports, block all roads, restrict private cars. In some cities with rivers and lakes, closing bridges and tunnels also need to be considered. Material isolation transfer stations are suggested to be established. A number of buses, taxis and other public transports should be organized to ensure transport of medical workers, patients, and daily necessities.
3. In the future, in order to deal with similar emergencies well, an advanced big data technology is in need. A real-time monitoring and feedback system for viruses and abnormal conditions should be established. It is necessary to carry out appropriate public transportation device improvement. For the safety of drivers and passengers, we should strengthen the research and technological innovation of advanced vehicles.

From the outbreak of COVID-19 to now, the epidemic has been well and quickly controlled in China. Our purpose is not to emphasize that these methods are the only correct ones. At least these measures have a very positive effect and important reference value on the control of COVID-19. We hope these suggestions drawn from the country provide valuable references to the scholars and decision makers around the world in the future.

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