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*Research Paper*

# Impact of Inter-city Population Mobility and Public Transport Policies on Infectious Epidemics

## Talking about Public Health and Safety from COVID-19

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### Abstract

*This study takes the COVID-19 outbreak in early 2020 as the research object, and obtains the population outflow data of Wuhan from January 1 to February 1, 2020 based on the Baidu Migration Big Data system, and compares the data on the number of epidemics in each city published on the official website, studies the relevance of population movement between cities and epidemic infection, and analyzes the role of policy-oriented epidemic control by controlling public transportation during special periods of infectious diseases. The results show that the spread of the infectious epidemic between cities in the early outbreak stage is strongly correlated with the population outflow from the source city of the infection. After the traffic connection is cut off in the later stage, it is more related to crowd gathering and prevention and control measures; During the special epidemic period, we should not blindly advocate the "public transportation priority" policy. We should distinguish between passenger and freight transportation, formulate rough rules at the inter-regional and intra-city traffic levels, and specify corresponding safeguards under the framework of the "Healthy City".*

### Keywords

*Migration, Infectious outbreak, Public transit, Healthy city*

## 1. Introduction

In the development of urban planning, large-scale public health incidents always bring shocking problems and at the same time play an important role in promoting. The smallpox epidemic in Greece in the 5th century BC, the Black Death in medieval Europe, cholera in England in the 19th century<sup>[1]</sup>, and the SARS virus and Ebola virus in recent years have all brought huge losses to human life, health and property. The urban problems and related response measures brought about by this infectious disease have also become an important aspect of planning scholars. On December 31, 2019, the Wuhan Municipal Health and Health Commission of Hubei Province, China, reported 27 cases of unknown pneumonia. On January 22, Wuhan City implemented the strategy of "closed city" to cut off the communication between Wuhan and the outside areas. Subsequently, there was a nationwide outbreak of infection in China.

This research takes the spread of the COVID-19 as the research object, obtains the population migration data of Wuhan City from January 1 to February 10, 2020 through the mobile phone positioning system, compares the published data of the epidemic situation in each city, and studies the population between cities Relationship of mobility and epidemic infection, and analyzes the role of policy-oriented epidemic control by controlling public transportation in special periods of infectious diseases.

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## 2. Data sources and methods

### 2.1. Data sources

There are two data sources for this study. The first group is the population outflow data from Wuhan to other cities; the second group is the confirmed infection data of COVID-19.

The number of people flowing out of Wuhan is derived from the big migration data of Baidu Maps (<https://qianxi.baidu.com>). Baidu Maps Migration Big Data is a large population flow data collected based on individual geographic location services (Liu Wangbao etc., 2016). It maps the population flow trajectory through the location information of mobile phone users. From the perspective of breadth of use, as of 2020, Baidu Maps Open Platform has provided location services for more than 500,000 APPs. Therefore, Baidu Maps Migration Big Data has a high user coverage rate, which can fully cover users of all ages and classes (Niu Xinyi etc., 2019). The author uses python to capture the daily number of the top 30 cities and the number of population outflows from Wuhan from January 1, 2020 to February 1, 2020 in the big data of Baidu migration, as Wuhan Basic data of the city's outflow population.

The confirmed infection data for COVID-19 comes from the daily data published on the official website of the National Health Commission of China, as well as the daily data published on relevant websites of provinces and cities. These data include the number of confirmed infections, the number of suspected infections, the number of new infections, etc. The author selected the number of confirmed new infections as the basic measure of the city's epidemic situation.

### 2.2. Methods

This study mainly involves two aspects: one is to express the daily population flow from Wuhan to other cities, and to analyze the correlation between the population flowing out of Wuhan and the spread of the initial epidemic between cities; the second is for special public transportation (inter-city, intra-city) strategy during the epidemic prevention period.

Since the COVID-19 epidemic has an incubation period of up to 14 days, the time range of population movement data and pneumonia confirmed data are not consistent. In China, the Spring Festival travel season (the phenomenon of large-scale and high traffic transmission pressure caused by family reunions during the Lunar New Year holiday) is a special phenomenon once a year. The 2020 Spring Festival travel season begins on January 10. However, since January 22, the government has implemented measures to "closed city" in Wuhan, and most of the provinces and cities have completed data from January 22. Therefore, for the epidemic diagnosis data, January 22 is selected as the beginning time of the range, and this is pushed forward 14 days as the start date of the time range of Wuhan outflow population data, that is, January 8. And take February 1 as the end time of the population data, and push back 14 days, that is, February 14 as the end time of the epidemic data.

This study uses GIS to make an OD map of the outflow population from Wuhan to other cities based on the population size to reflect the population outflow; the daily number of confirmed diagnoses in each city is also expressed in GIS; SPSS software is used to analyze the correlation between them. Through literature review and related model simulation examples, the strategy and system guarantee of public transportation during the special epidemic prevention period are analyzed, too.

### 3. Analysis of Wuhan's outflow population and the spread of the epidemic

#### 3.1. Wuhan outflow population

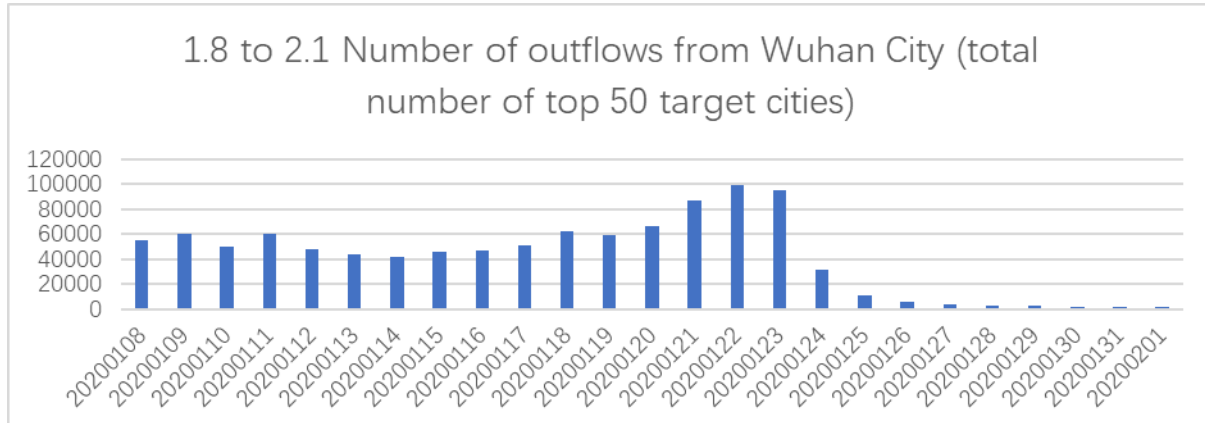


Figure 1 outfolws from Wuhan. Source: Baidu Migration Big Data

Beginning on January 8, 2020, it has entered a large-scale "return to home" period during the Spring Festival. Workers in developed cities will return to their hometowns for reunion. In the floating population report, Wuhan, as the ninth-ranked city in terms of population inflow, is not only accepting inflows but also outflowing populations, and acts as a population between large cities and regions or small cities in the province in the population flow distribution system. In a mobile distribution center, a large number of people will return home during the Spring Festival<sup>[2]</sup>. It can be seen from Baidu Migration Data that from January 8 to January 22, the outflow population of Wuhan showed an increasing trend. When only calculating the top 50 target cities, Wuhan reached the peak of population outflow on January 22, exceeding 100,000.

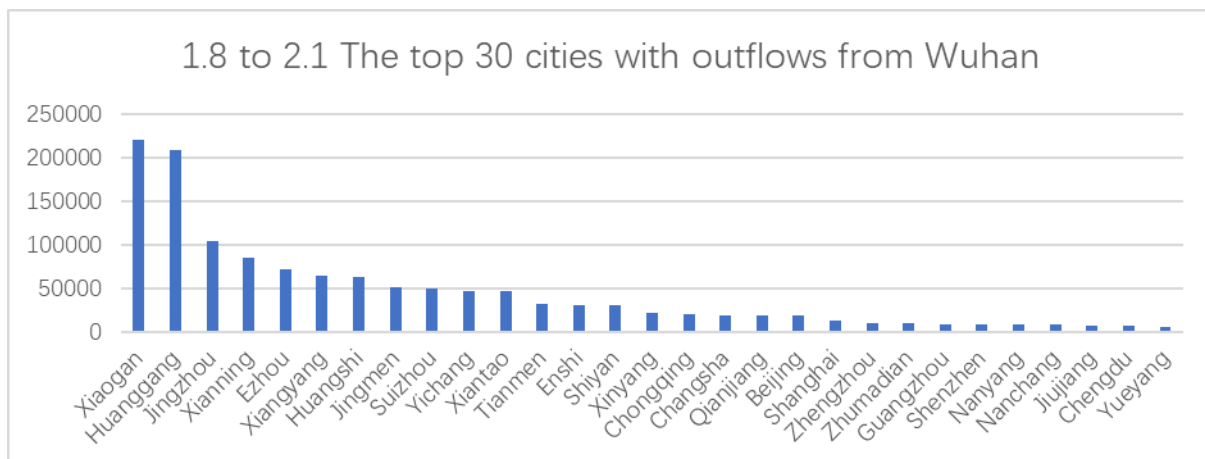


Figure 2 top 30 cities with outflows from Wuhan. Source: Baidu Migration Big Data

The Wuhan Municipal Government began to implement the "closed city" measures on January 22. It can be seen that a large number of people still "flee" from Wuhan on January 23. With the tightening of control, the outflow population has decreased significantly since January 24. It has been stable at the position of 1,000 people, and the population flow between cities is strictly controlled.

Most of the population flowing out of Wuhan moved within the province, which is related to the characteristics of migrant workers. Most of the migrant workers will choose to go to developed cities in the province, while a small part will choose to move across provinces. This is also the corresponding phenomenon when returning home during the Spring Festival: the outflow of population from developed

large cities is mostly concentrated in the province, while a small number of people go to outside the province. After the outbreak, the outflow situation will change from previous years. The reason is that due to the impact of the epidemic, some people will choose to flee to more developed areas to obtain better medical services.

### 3.2. City-to-city spread of the epidemic

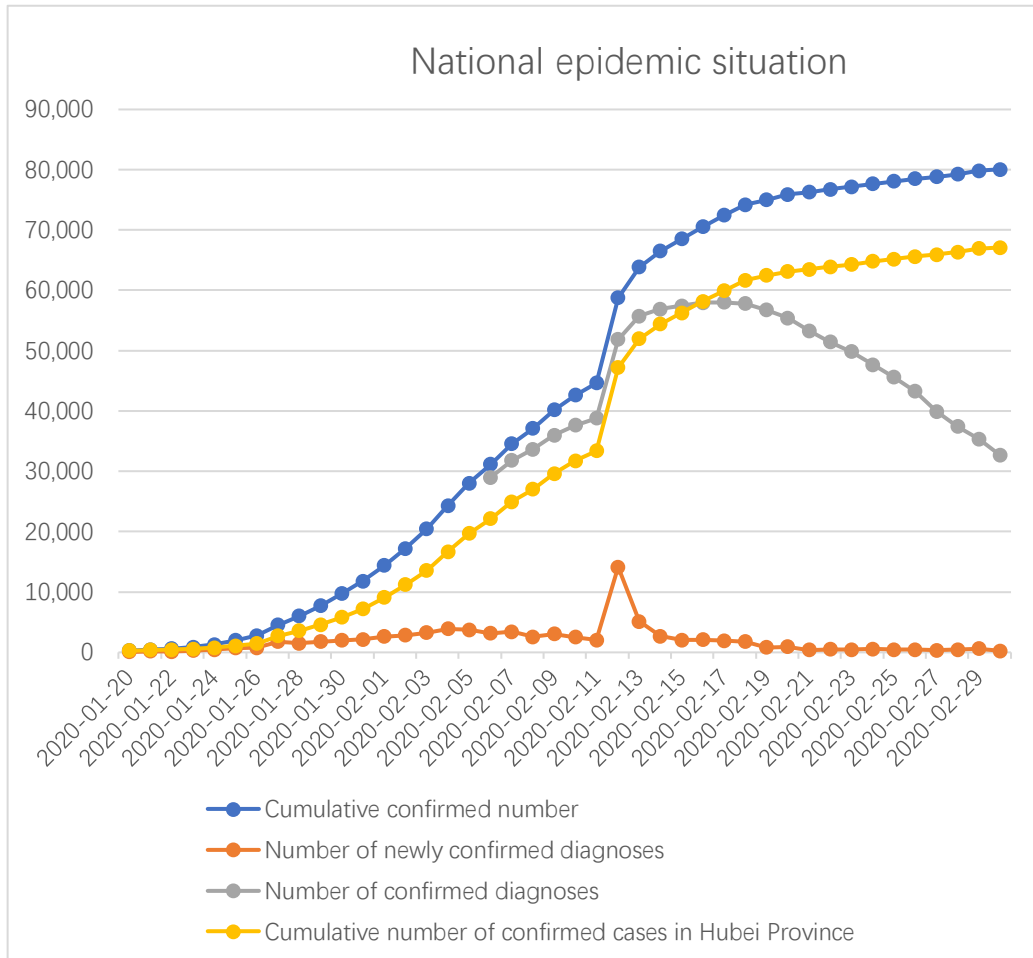


Figure 3 national epidemic situation. Source: Health Commission of China

On January 20, Academician Zhong Nanshan determined the infectiousness of COVID-19<sup>[3]</sup>. It can be seen that the number of newly confirmed cases in China reached a small peak around February 4th, and then began to slowly decline. The number of existing confirmed cases began to decline around February 19, that is, the number of cured cases exceeded the number of new cases. The inflection point on February 12 was caused by the revision of the diagnostic criteria by the Chinese official agency and was not considered in this study.

The number of confirmed cases in Hubei Province is much higher than that in other parts of the country. This is also an important reason for the blockade of Hubei after the lockdown of Wuhan. After experiencing the large-scale population movement within Hubei Province, curbing the population



movement from Hubei Province to outside the province is also blocking the source of infection. It can be known that the initial inter-city sprawl mainly comes from population movement, while the infection that starts in the middle period mainly comes from crowd gathering. Obviously, this study mainly focuses on the early inter-city spread.

### 3.3. The correlation between the outflow population and the spread of the epidemic

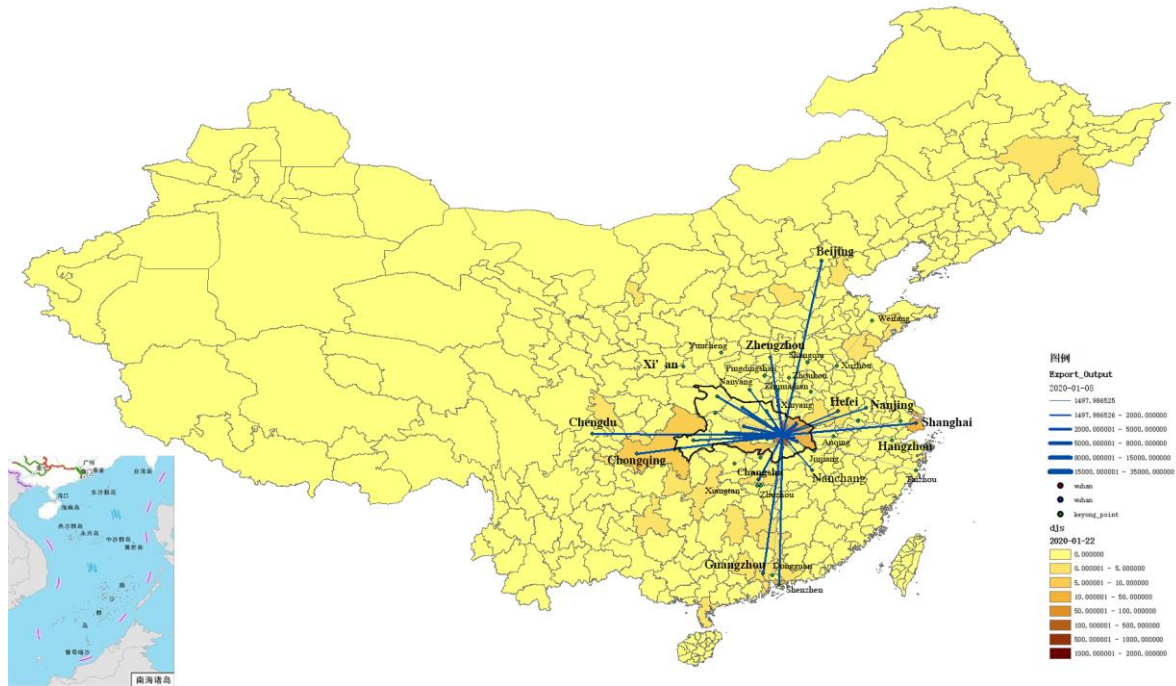


Figure 4 1.8 population outflow number and 1.22 epidemic data. Source: author's self-painted

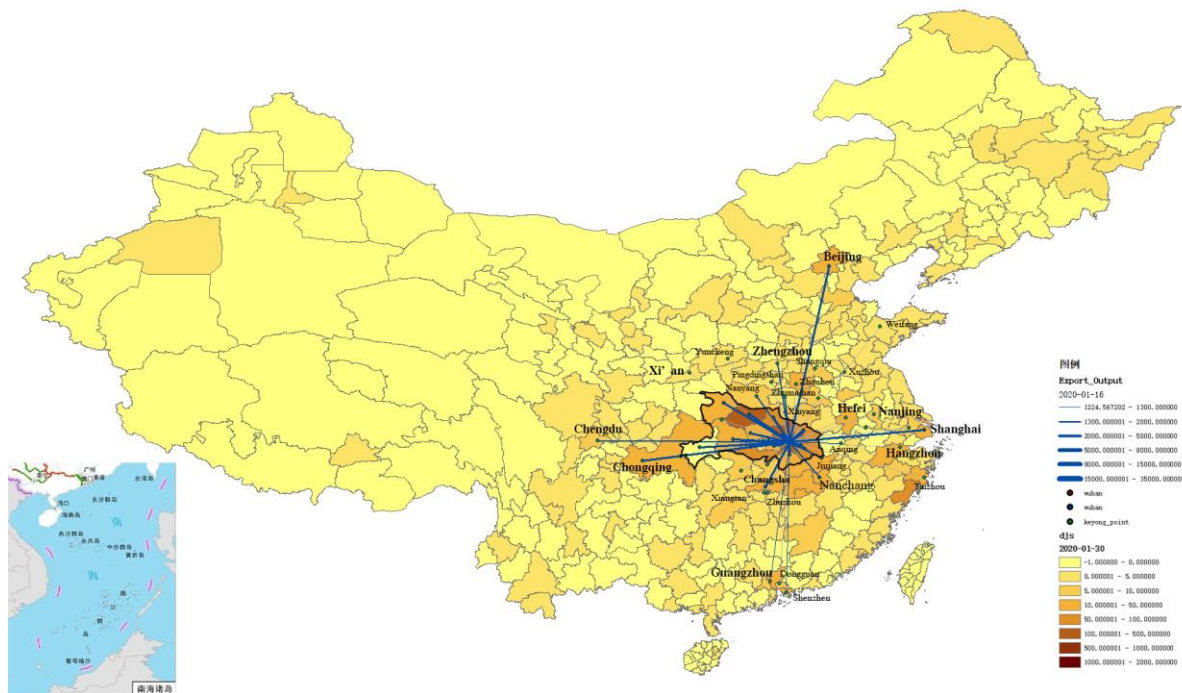


Figure 5 1.16 population outflow number and 1.30 epidemic data. Source: author's self-painted





can truly show the trend, the author uses the same interval division for the OD data and epidemic situation of the population outflow on the four days, instead of using the natural break point method.

On January 8, when the Spring Festival travel began, the population outflow of Wuhan began to increase on a large scale. The main population flowed to Hubei Province, while the cities outside the province were mainly major provincial capitals and developed cities, and flowed to Beijing, Chongqing, Chengdu, Shanghai, and Guangzhou. , Shenzhen, etc. As of January 16, the number of newly diagnosed cities across the country has shifted from Wuhan as the center, showing a spread of population outflow axis. It is even more serious in Hubei Province.

On January 24, the number of migrants from Wuhan city began to drop sharply. The decrease in inter-provincial mobility was particularly noticeable, and the main flow was still within the province. It can be seen that the number of newly diagnosed people across the country began to be connected by lines. It spreads in a plane shape, forming a development law of "point (Wuhan)-backbone (Wuhan to the central city)-branch (central city to surrounding cities)-surface (connected to form a surface)". As of February 1, the blockade had achieved initial results. The outflow population of Wuhan dropped to an extremely low level. Together with the guarantee of other non-proliferation measures within each city, the number of newly diagnosed cases in each city was under control.

Since the incubation period of the epidemic is 14 days, it does not mean that the correlation between the outflow population and the spread of the epidemic between cities will reach the highest in 14 days. Therefore, the author passes the population outflow data and the epidemic data by 0 days to 14 days. After calculation, it can be seen from the SPSS Pearson correlation coefficient that the correlation reaches the highest in 4 days apart, the correlation coefficient is -0.818, and the P value is 0.000, which indicates a significant negative correlation. That is to say, in the early stage of the spread of the epidemic, the population flowing out of Wuhan is relevant to the spread of the epidemic between cities, and it reaches the maximum on the fourth day, which coincides with the incubation period of the epidemic mostly being 3-7 days.

	flow
0	-0.724*
1	-0.791**
2	-0.805**
3	-0.813**
4	-0.818**
5	-0.774**
6	-0.686**
7	-0.545*
8	-0.435
9	-0.239
10	-0.040
11	0.010
12	0.161
13	0.244
14	0.260

\* p<0.05 \*\* p<0.01

Figure 8 Pearson relationship. Source: author's self-painted

The author uses 4 days as the number of days apart, and uses February 4 as the center value at the initial stage of infection (the period when the number of new people rises) to average the epidemic situation in each city, and displays it in the GIS based on the outflow population on January 22, as the picture shows. The correlation coefficient reached -0.864, showing an obvious correlation. It can be seen that most of the population outflow in Wuhan is within the province, and destination cities with a larger outflow population have more newly confirmed cases.

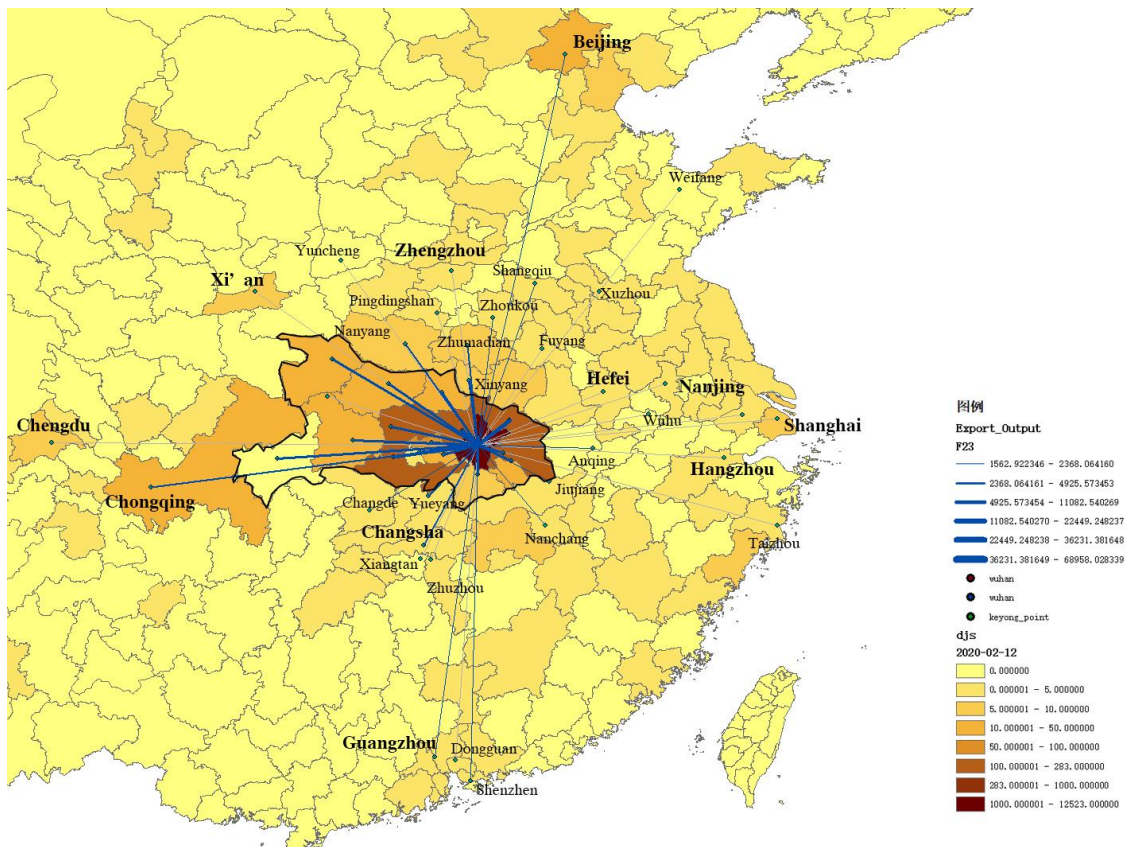


Figure 9 Average population outflow number and 2.4 epidemic data. Source: author's self-painted

## 4. Strategy

### 4.1. Urban transportation strategy during a major epidemic

From the above analysis, we can know that in the early stage of the epidemic, the epidemic spread among cities mainly through regional population flow. The first outbreak in Wuhan city was the source of infection. The population outflow brought the epidemic situation into the target city through inter regional public transportation, and the crowd spread through the gathering of public places. The extraordinary prevention and control measures adopted by the country to prevent and control the epidemic have reduced the average population migration intensity, average population migration intensity, and average intra-city travel intensity of all cities by 71.21% ( $1 - e^{-1.2452}$ )、72.62% ( $1 - e^{-1.2952}$ ) 和 45.99% ( $1 - e^{-0.6160}$ ) [4]. Obviously, in the early stages of the epidemic, decisively cutting off interregional public transportation is an important aspect of China's rapid containment of the epidemic.

Tabel 1 Public traffic control measures in cities

Intensity of control	City
Public transport is operating normally	Chengdu, Guangzhou, Shanghai, Beijing, etc.
Only urban and rural lines closed	Xi'an, Chongqing, Changsha, Hangzhou, Tianjin, etc.
City branch line closed	Suzhou, Hefei, Anqing, Fuyang, Lianyungang, etc.
Complete shutdown in two stages or with only a few lines left at a time	Yancheng, Jiaxing, Qingdao, Taiyuan, Shenyang, etc.
Completely shutdown	Wuhan, Xiatao, Xinyang, Yueyang, Nantong, Yuncheng, etc.





The mode of transportation determines the mode, speed and scope of the spread of infectious diseases<sup>[5]</sup>. When the urban area and global transportation system has not yet been developed, diseases are mainly spread based on the proximity effect of space. At present, newly emerging infectious diseases are flowing in the developed and integrated urban network connection, and highly interconnected urban hubs have become the nodes of disease transmission; the urban regional structure affects the mode of transmission based on social processes<sup>[6]</sup>. During the special period of infectious disease, public transportation should consider the following:

- (1) To suppress passenger traffic. The epidemic is spread by crowds, so mass public transportation should be restrained to a certain extent. From the regional level, the traffic to and from the infection source area should be strictly controlled or appropriately prohibited to cut off the spread of the infection source; the rest of the inter-regional traffic should be reduced with strict protective measures. From the city level, reduce the proportion of public transportation trips, appropriately relax the TOD policy on the suppression of car trips, and disinfect public transportation regularly to ensure that the risk of riding is reduced.
- (2) To guarantee freight transportation. During the special period of the epidemic, the lifeline system plays an important role, which should be different from the freight transportation policy. In order to transport important anti-epidemic supplies and living supplies, freight arrangements should still be strengthened and protective measures should be added. In addition, in the context of social 5.0 changes, smart technology should be used to increase new transportation methods such as contactless distribution and unmanned transportation.
- (3) To construct resilient transportation. A resilient city refers to the ability to take flexible response measures to maintain the vitality of development, attract resource accumulation, and avoid potential losses through the independent regulation of the social system to deal with challenges and changes under external disturbances. And resilient transportation is an important part of resilient cities<sup>[7]</sup>. Although single-function traffic resilience is important, only by integrating the traffic system into the resilient city system and conducting comprehensive planning and construction can the resilience of traffic be truly improved. In the case of epidemic prevention, it is necessary to assess and measure the traffic resilience in epidemic prevention and control, improve transportation resilience and respond to emergencies through traffic management measures, promote epidemic prevention and control by improving transportation methods, and ensure rapid recovery after the epidemic<sup>[8]</sup>. We should plan to build a diversified, multi-system transportation system to ensure that sustainable, flexible, and barrier-free transportation services can be provided in daily and emergency situations.

#### 4.2. Policy Guarantee under the "Healthy City" Framework

The "healthy city" was proposed by the World Health Organization in the 1980s and mainly focused on the prevention of chronic non-communicable diseases. The new crown epidemic warned us that the prevention and control of emerging infectious diseases must be an important part of the construction of a healthy city (Wang Lan, 2020). In his speech on June 2, 2020, General Secretary Xi Jinping pointed out: "We must promote the integration of health into all policies, and the concept of full life cycle health management throughout the entire process of urban planning, construction, and management."

- (1) To establish a comprehensive healthy city framework system. Healthy city planning is closely related to land use, spatial form, road traffic, green space and open space in the built space<sup>[9]</sup>. In the process of urban development, the threat of infectious diseases always exists; the outbreak and epidemic of infectious diseases will bring many losses. In response to the epidemic, Beijing, Shanghai and other places have issued relevant opinions on strengthening the construction of urban public health

emergency management systems, emphasizing the overall planning and improvement of public health, medical treatment, material guarantee, urban operation, community governance and other links to enhance the ability to prevent and control major epidemics<sup>[10]</sup>. The discipline of urban and rural planning can provide a complex spatial intervention mechanism to prevent and control infectious diseases through facility layout and design optimization at different spatial scales.

**Table 2 Strategies to respond to the epidemic at different spatial levels**

goal	City level	Community level	Core instrument
Isolate the source of infection.	Divide epidemic prevention zone, set up sanitary isolation zone, configure regional comprehensive support center and other facilities	In the 15-minute community living circle, home isolation support facilities such as supermarkets, vegetable farms and pharmacies shall be set up, and storage space of spare epidemic prevention supplies shall be set up	The hospital for infectious diseases should be selected rationally and surrounding supporting facilities should be built
Cut off transmission routes	Travel restrictions	Set isolation protection	Time - segment flow control
Protect vulnerable people	Ensuring health equity	Conduct a health impact assessment of the community's daily space	Establish a health and epidemic prevention liaison station

(2) To establish a comprehensive prevention and control system and strengthen the combination of peacetime and disaster. The rapid establishment of the two prevention and control hospitals - Leishen Mountain and Huoshen Mountain - in China can be said to be a miracle in construction. This also explains the problems from the side that in the face of this epidemic, the public health emergency management system is out of balance in the face of a major epidemic, the existing medical facilities are not enough to respond to the epidemic, and the urban emergency system and material management are insufficiently supported in space<sup>[11]</sup>. In order to make up for related shortcomings, a composite system of urban disaster prevention planning should be established, integrated safety and emergency management ideas should be organically embedded in urban planning, design and construction, and the public health safety prevention and control mechanism in urban disaster prevention planning should be improved<sup>[12]</sup>. At the same time, epidemic prevention and control should also be regarded as a special item of disaster prevention planning.

Strengthening the the combination of peacetime and disaster is an important means that can effectively solve this problem. We should coordinate planning content, improve urban resilience, rationally arrange various facilities according to population density distribution, plan disaster relief material production and storage land, rational use of public facilities, flexible space layout, and set up emergency protection systems for special periods<sup>[13]</sup> to ensure that it can respond more quickly to emergencies.

(3) To build the 15-minute living circle and strengthen the community. At the community level, a “public health unit” can be defined based on the “15-minute community living circle”. The community has assumed important responsibilities in terms of epidemic prevention and control, healthy life maintenance, community collective psychological counseling, and community culture and spiritual cohesion. Forming a community "prevention and control chain" for the path of virus transmission, and an epidemic prevention "organizational chain" based on the characteristics of population

behavior, and the space "circulation chain" based on community protection can jointly create a "safe space unit" for grassroots security prevention and control at the neighborhood space level<sup>[14]</sup>.

According to the size of the population, the public health unit can cover one or more living circles, and consider two types of health facilities and services: one is for daily health, and the other is for emergency response to the outbreak of infectious diseases. It can respond to health incidents in a timely and orderly manner, with the main purpose of providing prevention, isolation, treatment and assistance during the epidemic, and at the same time providing necessary living materials.

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