

# Research on Traffic Congestion Management in Small and Medium-sized Cities —Taking the Central Urban Area of Huangshi City as an Example

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**Abstract:** Taking Huangshi City as an example, this article analyzes the current situation, causes, and strategies for managing traffic congestion in small and medium-sized cities. It puts forward measures for managing traffic congestion applicable to Huangshi City and other similar cities. These measures include strengthening road traffic planning and management and accelerating the construction of multi-level traffic facilities in traffic supply management. In traffic demand management, it proposes implementing a public transportation priority strategy, strengthening traffic diversion and illegal management.

## 1. Introduction

Efficient and convenient transportation is a significant characteristic of modern urban life. It is also an important reference indicator for improving the quality of life for urban residents, enhancing the reputation and attractiveness of cities. With the excessive concentration of modern economy and population in cities, traffic congestion has become a common problem in most major cities worldwide to varying degrees. It has had a significant impact on the sustainable development of cities and the mobility of residents, becoming a stumbling block hindering rapid urban economic development and a persistent concern for commuters in modern cities.

Along with the rapid growth of the Chinese economy and the accelerated urbanization process, the issue of traffic congestion in most cities in China has become increasingly prominent. Previously, small and medium-sized cities had a few advantages, such as convenient travel and livability, in competing with larger cities. However, in recent years, the problem of traffic congestion has also spread to small and medium-sized cities, posing certain challenges and pressures to their transportation and economic development. If not effectively contained or resolved, they will lose more resources and opportunities in the new round of urban competition. Therefore, it has significant practical significance and theoretical value to address the issue of traffic congestion in small and medium-sized cities.

## 2. The current situation and characteristics of traffic congestion in Huangshi urban area

There is no unified and fixed concept of traffic congestion in the academic community. Different countries and even different cities within the same country do not use the same standards. Generally, it refers to the phenomenon where the traffic flow exceeds the road capacity, causing slow or complete stagnation of vehicle movement. Depending on the source, traffic congestion can be classified as endogenous congestion and exogenous congestion. Endogenous congestion refers to congestion caused by factors such as excessive traffic flow, high vehicle density, and slow speed, mainly concentrated in urban areas. This type of congestion usually occurs during peak commuting hours, repeatedly appearing at specific road sections, intersections, and fixed times. It is a periodic congestion with fluctuating duration within a certain range and can be somewhat predictable<sup>1</sup>. Exogenous congestion refers to congestion caused by extreme weather, vehicle breakdowns, traffic accidents, road construction, and other factors, such as heavy rain, snow disasters, large-scale events, road closures, etc. This type of congestion is usually not caused by the traffic flow itself, and the occurrence time and location are relatively random, without regularity and predictability.

Based on the severity of traffic congestion, it can be classified as congested, very congested, severely

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congested, and gridlock. During gridlock, vehicles can hardly move, and traffic comes to a standstill<sup>[1]</sup>. However, due to the lack of fixed concepts and standards, the perception of congestion level can be subjective and may vary from person to person and place to place.

## **2.1. The current situation of traffic congestion in Huangshi urban area**

In recent years, Huangshi's economy has been growing against the trend, with significantly improved comprehensive strength. It has been listed as one of the livable and business-friendly cities in China, and is one of the five cities in the province with a positive population growth. The city's reputation and attractiveness have significantly increased. However, like residents in other cities, Huangshi residents also deeply feel that traffic congestion is becoming more and more severe, especially in recent years. Although measures such as building pedestrian bridges and tunnels have greatly alleviated the traffic congestion in the urban area for a certain period of time, it still feels congested.

So, what is the actual situation of traffic congestion in Huangshi? Through field research and interviews with professionals, it is known that according to the local traffic police department's definition of traffic congestion (usually waiting for three or more traffic light cycles at intersections to be considered congested), most of the roads in the urban area are relatively smooth for most of the day. There are congestion phenomena at intersections and sections near primary and secondary schools on several main roads during peak hours and holidays, but the congestion level is mild. This is somewhat different from the perception of citizens, because the intuitive feeling is that "there are more and more vehicles, many roads are closed, and there is congestion." In addition, the perception of congestion level is subjective. For example, in mega-cities like Beijing, Guangzhou, and Wuhan, it is considered good if you can pass through intersections in two traffic light cycles. However, for residents of medium-sized cities, it may be very frustrating to have to wait for a traffic light cycle at several consecutive intersections.

According to statistics, there are more than ten slow-moving or congested sections in the urban area of Huangshi during peak hours. In Huangshi Port Area, primary schools, secondary schools, kindergartens, and markets are concentrated on Yan'an Road, resulting in a large flow of people and vehicles. During morning peak hours, motor vehicles can only move slowly. At the intersections of the People's Social Security Bureau on Hubei Riverside Avenue, Xincheng Intersection, Daqiao Roundabout, Wuchang Road, Guangchang Road, and Mingzhu Plaza, there will be varying degrees of traffic congestion during morning peak hours, and some sections may also experience congestion during evening peak hours. In Xisaishan District, the congested sections are mainly distributed at Baguazui Intersection, Aikang Hospital Intersection, the intersection of Huangshi Avenue and Feiyun Street, and the intersection of Huangshi Avenue and Yanjiang Road. The congestion is mainly concentrated during the morning peak hours, around 7 to

8 in the morning. Compared to the two central old districts of Huangshi Port Area and Xisaishan District, the traffic congestion situation in Tuanchengshan District is significantly better. The roads in Tuanchengshan District are relatively wide, and traffic congestion rarely occurs. Even when there is heavy traffic, all vehicles can be cleared in about 2 traffic light cycles. Since last year, the main congested sections have been at Xiaopu Intersection, Guilin Road, and Suzhou Road, which are related to the construction of tram tracks and viaducts.

## **2.2. The characteristics of traffic congestion in Huangshi urban area**

The characteristics of traffic congestion in Huangshi city area may differ greatly from those in large cities, but they share many similarities with most medium and small-sized cities.

Firstly, the occurrence of traffic congestion tends to be at fixed locations. Through research conducted on the city's overall traffic situation, it has been found that the locations where congestion regularly happens are comparatively consistent. By analyzing and summarizing the congested road segments and areas, it can be concluded that these congestion-prone points are concentrated at intersections of main city arteries, intersections near commercial centers, areas surrounding key schools and hospitals, segments with heavy pedestrian and electric scooter traffic, as well as segments with dense traffic lights.

Secondly, the occurrence of traffic congestion follows a relatively regular pattern in terms of time. Unlike large cities, medium and small-sized cities rarely experience all-day and long-lasting congestion. The time periods during which congestion is most likely to happen generally follow a predictable pattern. Firstly, congestion is prone to occur during peak commuting hours. Public buses, taxis, commuter vehicles, private cars transporting children to school, vehicles going out for work or on business, and vehicles entering or leaving the city tend to travel during this time period. Secondly, traffic congestion is likely to happen during peak holiday periods, particularly during public holidays such as New Year's Day, Qingming Festival, Mid-Autumn Festival, as well as longer holidays like the May Day holiday, National Day holiday, and Spring Festival. During these holidays, there is a high influx of people traveling for tourism or family visits, leading to a significant increase in private car usage. The combination of commuting flows, family reunion flows, and tourism flows during this time period results in a sudden surge in traffic volume, causing immense pressure on high-speed rail stations, train stations, bus stations, and highway entrances and exits, leading to congestion in the surrounding areas. Thirdly, the beginning and end of holiday periods are the peak times for outbound and return travel. Queues and slow-moving traffic occur at various entrances and exits of the city, leading to congestion on main roads in the urban area.

Thirdly, the development of urbanization has a significant impact on traffic congestion. The population influx resulting from urbanization in terms of migration,

employment, education, and healthcare exacerbates the issue of traffic congestion in cities. This also raises new requirements for expanding urban capacity and improving urban infrastructure. As the population continues to grow in the city center, travel demands are becoming increasingly diverse and personalized. People have more transportation options, and the number of private car users has increased, further intensifying traffic pressure on city roads. On one hand, the increase in traffic volume exacerbates congestion; on the other hand, it puts forth the need for the improvement and expansion of road infrastructure. The construction and improvement projects themselves also contribute to traffic congestion during the construction period.

### 3. An analysis of the causes of traffic congestion in the urban area of Huangshi

For a city with an average travel distance of around 3 km, non-motorized vehicles such as bicycles, electric bikes, and scooters are the most suitable means of daily transportation [2]. Compared to larger cities, residents in medium and small-sized cities have shorter average travel distances, and walking and non-motorized transportation should be the main modes of daily travel. However, with the rapid increase in the number of motorized vehicles, the previously designated non-motorized lanes have gradually been converted into roadside parking spaces, leaving slow-moving traffic with no dedicated lanes and forcing them to compete with motor vehicles on the road. Traffic congestion, difficulties in taking public transportation, and

challenges faced by non-motorized vehicles are issues that have gradually emerged in medium and small-sized cities. Based on research and analysis, the main reasons for traffic congestion in Huangshi City are as follows:

Firstly, there has been a dramatic increase in the number of motorized vehicles. As one of the important industries in the national economy, the automobile industry's consumption accounts for over 10% of the total retail sales of consumer goods, and its contribution to GDP exceeds 4%. With factors such as the increasing disposable income of households and government policies promoting new energy vehicles, the number of motorized vehicles in medium and small-sized cities is still in a phase of high-speed growth, with an average annual growth rate of 20% to 35% [2]. In recent years, due to the continuous economic growth, population increase in the urban area, and improvement in the living standards of residents, the demand for motorized vehicles has also increased rapidly. By the end of 2022, the total number of motorized vehicles in the city has exceeded 450,000, while the city's permanent population is 2.44 million (as of the end of 2021), resulting in a motor vehicle ownership rate of 18.4 per hundred people, which is higher than many large cities. From 2019 to 2021, the number of motorized vehicles in Huangshi increased by 9.17%, 10.39%, and 13.28% respectively, while the length of roads only increased by 4.99%, 5.35%, and 3%, falling behind the speed of motor vehicle growth (refer to Table 1). The rapid increase in the number of motorized vehicles without a corresponding expansion of road infrastructure within a short period of time has increased the pressure on urban road traffic, which is the main cause of recurrent congestion during peak hours.

**Table 1** Statistics on Traffic-related Information in Huangshi City

Year	Motor vehicle ownership		Private car ownership		Road mileage	
	Quantity (units)	Growth rate	Quantity (units)	Growth rate	Quantity (kilometers)	Growth rate
2018	302,989	7.32%	199,257	13.40%	7347.8	4.27%
2019	330,773	9.17%	221,220	11.02%	7714.325	4.99%
2020	365,124	10.39%	232,271	5.00%	8128.603	5.35%
2021	413,627	13.28%	259,963	11.92%	8372.566	3.00%

Note: The data is from the "Huangshi Statistical Yearbook" of 2018-2022, published on the official website of the Hubei Provincial Bureau of Statistics.

The second reason is the lagging urban infrastructure development. Due to historical limitations as an industrial and mining city, roads in the old city area of Huangshi are generally narrow, and most of the old residential communities do not have underground parking lots. As a result, vehicles are often parked by the roadside. The construction speed of parking spaces in newly built communities cannot catch up with the increasing number of cars, leading to numerous cars occupying a large amount of sidewalks and non-motorized lanes, forcing a significant number of non-motorized vehicles to travel on motor vehicle lanes, resulting in varying degrees of traffic congestion and safety accidents. Due to the high cost of demolishing and renovating old residential communities, it is difficult to extensively widen the roads, which greatly contributes to the congestion in the old city area.

Additionally, the long and narrow spatial form of the main urban area of Huangshi, combined with outdated transportation planning that failed to keep up with the changing situation, leads to repeated renovations and upgrades of existing roads, which inevitably hinder traffic flow during the construction period.

The third reason is the impact of major construction projects. In recent years, several main urban areas have witnessed the renovation of old cities and urban redevelopment projects, resulting in multiple roads undergoing renovations and upgrades. During the construction period, road surfaces become narrower, leading to congestion. The construction of projects such as underpass tunnels beneath the Hubei Lakefront Avenue, the construction of the Yangtze River Avenue, and the construction of the Guilin Road overpass bridge,

especially the construction of the tram project, often occupy a large area of existing road surfaces and frequently require the closure of roads for vehicular detours. It seems that wherever there is construction, there is congestion.

The fourth reason is the impact of traffic violations. In various major traffic arteries within the city, there is often a phenomenon of pedestrians and private vehicles disregarding traffic rules. Pedestrians jaywalk, fail to use sidewalks, and ignore traffic signals, while vehicles change lanes randomly, weave in and out, park haphazardly, and electric bicycles take advantage and compete with motor vehicles for road space. These behaviors seriously endanger traffic safety, particularly on accident-prone sections of the roads, increasing the likelihood of accidents. Once an accident occurs, the vehicles involved are often left in the middle of the road, causing temporary traffic congestion. Especially during peak hours in the morning and evening, this phenomenon becomes more severe, resulting in widespread traffic congestion and seriously affecting the safety and efficiency of citizens' travel.

#### 4. Strategies for managing traffic congestion in Huangshi City

The essence of traffic congestion is when the real-time traffic volume on the roads exceeds their maximum capacity. In other words, the demand for road usage surpasses the supply. Based on various measures for congestion control both domestically and internationally, traffic congestion management can be summarized from two perspectives: supply management and demand management. Supply management includes increasing new road resources and improving the operational efficiency of existing roads. Demand management includes limiting the number of motor vehicles, restricting motor vehicle usage, and encouraging the public to use public transportation (refer to Table 2)<sup>[3]</sup>.

**Table 2** Urban Traffic Congestion Management Measures

Supply management	Increase new road resources	Expand urban transportation main roads, arterial roads, etc.
	Improve road operation efficiency	Use modern intelligent transportation systems, increase underground passages and pedestrian bridges at intersections, etc.
Demand management	Management of motor vehicle ownership	Restrict the number of private cars through methods such as auction or lottery-based license plate systems.
		Cancel or reduce the number of general government vehicles.
	Management of motor vehicle usage	Restrict the use of private cars through measures such as license plate-based restrictions, congestion charges, and parking fees.
		Encourage the use of public transportation: Promote the development of public transportation with priority given, expand the coverage area of public transportation, improve the efficiency of public transportation operations, and enhance the quality of public transportation services.

In order to address the issue of traffic congestion, supply management focuses on expanding the road capacity. This includes increasing the supply of roads through the construction of urban primary and secondary roads, which helps to disperse traffic and alleviate congestion in core areas. Additionally, it can be beneficial to adopt a road system similar to the pattern of Paris, where arterial roads are complemented by a radial network, in order to avoid congestion caused by single channels. Furthermore, strengthening traffic operation management can enhance the capacity and efficiency of existing roads<sup>[3]</sup>. Approaching traffic issues from a supply perspective can maximize social welfare without compromising individual benefits. However, it is important to note that road expansion requires significant government investment and time. Moreover, in transportation economics, there is a well-known law called "The Downs Law"<sup>[4]</sup> which suggests that new supply will induce new demand, resulting in newly constructed roads quickly becoming congested. Therefore, another important aspect of

managing urban traffic congestion is demand management. The key to demand management lies in guiding people to change their travel modes, reducing the number of vehicles on the road and consequently minimizing traffic demand. Demand management includes managing the number and usage of motor vehicles. Managing the number of motor vehicles involves implementing certain policy measures to control the rapid growth of vehicle numbers, preventing future congestion and further aggravation. Motor vehicle usage management involves direct restrictions and reductions in the use of motor vehicles. Direct restrictions can yield immediate results, or one may induce a reduction in motor vehicle usage through road pricing policies. Andersson and Nassen investigated the application and effects of road pricing policies in Gothenburg<sup>[5]</sup>. However, in practice, measures such as auctions, license plate lotteries, and limited driving times also have some drawbacks and criticisms.

Through examining advanced congestion management models in domestic cities, it can be observed that the key

to managing congestion lies in "facilitation" rather than "restrictions." Measures such as purchase restrictions and driving restrictions are only applicable for short periods of time, and the level of congestion in most small and medium-sized cities does not necessitate the implementation of such strict measures. In the long term, we should focus on optimizing supply, regulating demand, and strengthening management. We should adopt a problem-oriented, systematic, and socially-oriented approach to implement comprehensive governance, with a focus on addressing the root causes rather than just symptoms. Taking Huangshi City into consideration, the following recommendations are proposed:

#### **4.1. Increase the construction of multi-level transportation facilities**

In the central urban area, especially in the old city area where it is difficult to build new roads or expand existing ones, the construction of multi-level transportation facilities is a relatively fast and cost-effective method to alleviate traffic congestion. Traffic congestion is most likely to occur at intersections. Building pedestrian bridges, underpasses, or elevated roads at intersections with high traffic volumes and prone to congestion can significantly improve traffic congestion. For example, the newly built pedestrian bridges on Huangshi Avenue and Wuhan Road, the underpasses and elevated bridges on Hubei Riverside Avenue, and the elevated bridge at Xiaopu Intersection have greatly alleviated the previous traffic congestion. Currently, the ongoing construction of tram tracks and elevated bridges on Jiangjun Avenue and Guilin Road may cause certain congestion during the construction period until completion, but it is anticipated that these projects will not only eliminate the existing congestion but also greatly improve traffic efficiency.

#### **4.2. Strengthen road traffic planning and management**

The relevant departments responsible for urban planning, highway management, and public transportation companies should coordinate and strengthen road traffic planning and management. Firstly, at the macro-strategic level, the construction of new urban areas and development zones should pay attention to supporting related living facilities to avoid a large number of people commuting between different areas, which significantly increases traffic flow. Secondly, at the mid-level perspective, in addition to the construction of main roads, the development of secondary and branch roads should not be neglected. By increasing the density of urban road networks, the traffic capacity of the road system can be improved. Thirdly, at the micro-technical level, modern technology methods should be fully utilized. For example, expanding the coverage of smart traffic information software, optimizing traffic signal lights, adjusting bus routes and bus stops, and establishing non-motorized vehicle lanes. Currently, there are hardly any dedicated lanes for non-motorized vehicles on the roads in Huangshi city. Most electric bicycles and bicycles have to share the

same lane with motor vehicles, significantly increasing the risk of accidents and the accident rate, and not conducive to promoting the use of green transportation. It may not be realistic to create new dedicated lanes for non-motorized vehicles based on the existing infrastructure, but it is possible to transform and utilize the pedestrian pathways on both sides of the road, especially the road ramps that are much higher than the road surface, to create accessible slopes for bicycles, wheelchairs, and other non-motorized vehicles. This also reflects the importance of caring for vulnerable groups such as disabled people and the elderly, and contributes to improving the city's image. Furthermore, installing electronic identification devices on important traffic sections to accurately identify buses can give them priority passage. In addition, adjusting the duration of traffic signal lights in real-time using relevant technology methods can minimize bus stopping and maximize fast passage, highlighting the superiority of public transportation to encourage more people to use public transport for travel.

#### **4.3. Strongly Implementing the Priority of Public Transportation Strategy**

The priority of public transportation is the fundamental measure to solve urban traffic congestion and optimize urban transportation structure<sup>[6]</sup>. Public transportation includes buses, taxis, subways, and so on. It features a large carrying capacity and low per capita resource consumption. It also has the advantage of overall safety over private transportation. Therefore, public transportation should be the dominant mode of transportation in future cities<sup>[7]</sup>. If people's first choice for traveling is public transportation, the purchase and use of cars will gradually decrease, thus solving the problem of traffic congestion. For example, Tokyo, the capital city of Japan, has a highly developed public transportation system, especially the subway. On workdays, the public transportation travel rate can reach 80% to 90%. Therefore, even with rapid urban expansion, the average driving speed has doubled compared to 30 years ago. To encourage people to use public transportation more and better utilize its advantages and backbone role in transportation, it is essential to not only increase the supply of public transportation but also improve its attractiveness and convenience.

Firstly, it is necessary to increase bus routes and frequency, aiming for full coverage of all residential areas. Secondly, improving the comfort of buses is important, such as enhancing the internal environment of buses to provide more spaciousness, comfortable seating, better air circulation, and a cleaner environment. Thirdly, improving the speed and convenience of buses is the most crucial aspect. The two main reasons why most people are unwilling to take the bus compared to private cars are the slowness and inconvenience. According to estimates, the average travel time for buses is 2.8 times longer than that of taxis and private cars in motorized modes. Moreover, the waiting time outside the bus accounts for 65% of the entire bus travel process<sup>[3]</sup>.

Therefore, it is necessary to implement the addition of dedicated bus lanes on main roads, appropriately increase the speed of buses in different areas and sections, and reasonably add bus stops without mechanically enforcing the requirement to stop at every station (stations without waiting passengers or passengers getting off can be skipped). Practical measures should be taken to facilitate the use of public transportation by citizens. It is only when people feel that public transportation is both affordable and convenient that they will abandon private cars and switch to using buses. For example, the current road obstacles and road fence settings in Huangshi are all oriented towards facilitating the rapid passage of motor vehicles, which makes it very inconvenient for pedestrians to go to the other side of the road to take the bus. Often, they have to take a long detour. The setting of road fences in the middle should be more scientifically and reasonably designed, and pedestrian crossings should be placed in the middle of same-named bus stops on both sides of the road to avoid the need for a long detour to catch a bus on the opposite side.

#### **4.4. Strengthening Traffic Guidance and Law Enforcement**

The traffic management department should make full use of road traffic big data to analyze road congestion, traffic accidents, and traffic violations, in order to understand the periodic traffic operation patterns, road congestion indices, traffic accident occurrence patterns, and key vehicle traffic patterns. Through effective traffic analysis and judgment, timely traffic risk prediction can be made, and contingency plans can be developed to respond quickly and solve actual traffic issues, effectively alleviating traffic congestion. During the morning and evening peak hours, combined with real-time road conditions from Amap and "Huangshi Broadcasting and Television" contact group data, video inspections of city-wide traffic conditions can be conducted. By monitoring congested road sections, particular attention can be given to tram lines and congested sections in urban areas, with timely coordination with local police forces to clear congestion and ensure smooth traffic flow. At the same time, traffic management authorities should be on duty during peak hours and strictly enforce measures to curb traffic violations, with a focus on cracking down on illegal parking, occupying lanes, jaywalking, and reckless driving. For important traffic nodes and areas, enhanced traffic control measures should be implemented and targeted traffic guidance plans should be carried out to minimize the occurrence of accidents and avoid sudden and severe congestion.

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