



Article

# Intelligent Planning and Research on Urban Traffic Congestion

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**Abstract:** For large and medium-sized cities, the planning and development of urban road networks may not keep pace with the growth of urban vehicles, resulting in traffic congestion on urban roads during peak hours. Take Jinan, a mid-sized city in China's Shandong Province, for example. In view of the daily traffic jam of the city's road traffic, through investigation and analysis, the existing problems of the road traffic are found out. Based on real-time, daily road traffic data, combined with the existing road network and the planned road network, the application of a road intelligent transportation system is proposed. Combined with the application of a road intelligent transportation system, this paper discusses the future development of urban road traffic and puts forward improvement suggestions for road traffic planning. This paper has reference value for city development, road network construction, the application of intelligent transportation systems, and road traffic planning.



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## 1. Introduction

At present, with the continuous advancement of China's urbanization process, social development, and urban economy, the urban population is increasing rapidly, and the number of urban motor vehicles has also begun to grow rapidly, forming the current traffic situation that urban transportation infrastructure construction has not been able to keep up. With the rapid development of Shanghai city and the rapidly increasing traffic demand, the number of private cars in urban households has increased rapidly. Even adding new public transportation methods [1], such as subways, light rails, trams, and ships, or adding new public transportation routes, cannot fundamentally solve the transportation problems caused by urban development.

According to data from the China Transportation Bureau [2], the number of motor vehicles in the country has increased year by year, from 310 million in 2017 to 372 million in 2020, and the growth rate is from 5% in 2018 to 6% in 2019 to 7% in 2020. The level of car ownership has increased from 217 million in 2017 to 281 million in 2020. The number of electric bicycles has increased from 200 million in 2017 to 330 million in 2020. According to the growth trend in previous years, it is estimated that the number of motor vehicles in the country is expected to reach 400 million in 2021, which is a severe test for urban traffic conditions, as shown in Figure 1.

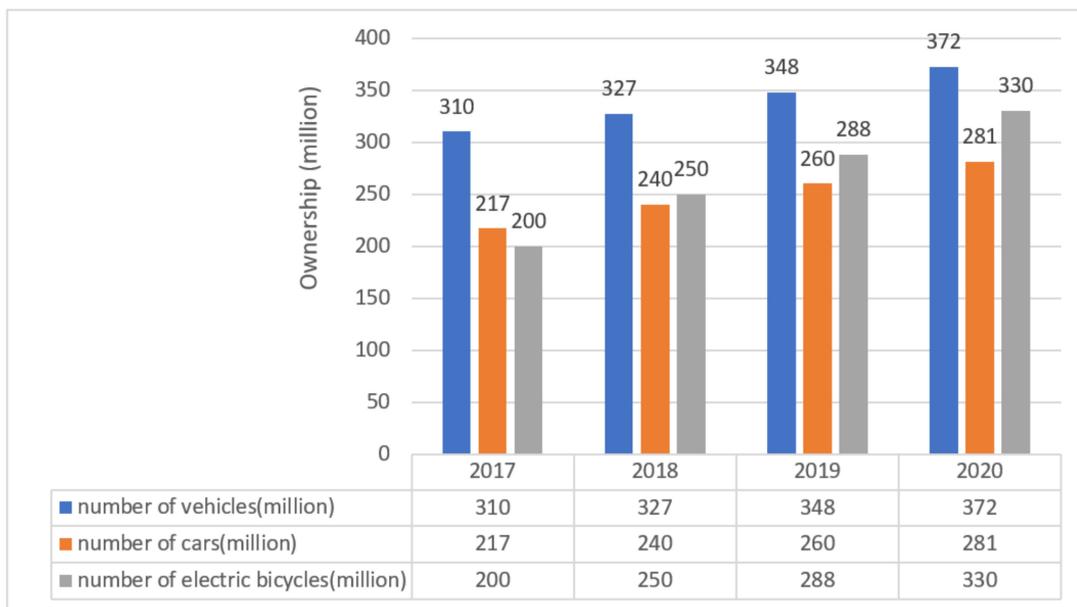


Figure 1. The inventory of motor vehicles and electric bicycles in China from 2017 to 2020.

The mismatch between urban layout and urban traffic is also a serious problem. The city is the center of economic activity and the terminal or hub of most transportation. With the development of the economy and the construction of the city, the overall scale of the city [3] is still expanding. However, most cities have not incorporated transportation planning into their overall urban planning. This will cause the distance between people’s living area and work area to become longer due to urban expansion. A common phenomenon is that the increase in the distance people travel to work [4] has caused serious road blockages in some areas during peak hours.

The development of a city must meet the overall needs of the city [5], and the same should be true for urban transportation [6]. In recent years, domestic urban built-up areas have often paid too much attention to the expansion of the road network [7] in the planning and construction of transportation, thus ignoring the transportation needs of all traffic participants [8] in the city. The traffic demand [9] cannot be met, and merely expanding roads [10] and building new roads [11] cannot fundamentally solve urban traffic problems. Urban transportation needs need to be met by improving the service level of urban transportation, improving travel efficiency [12] as much as possible, and avoiding non-motor vehicle interference [13], as shown in Figure 2.

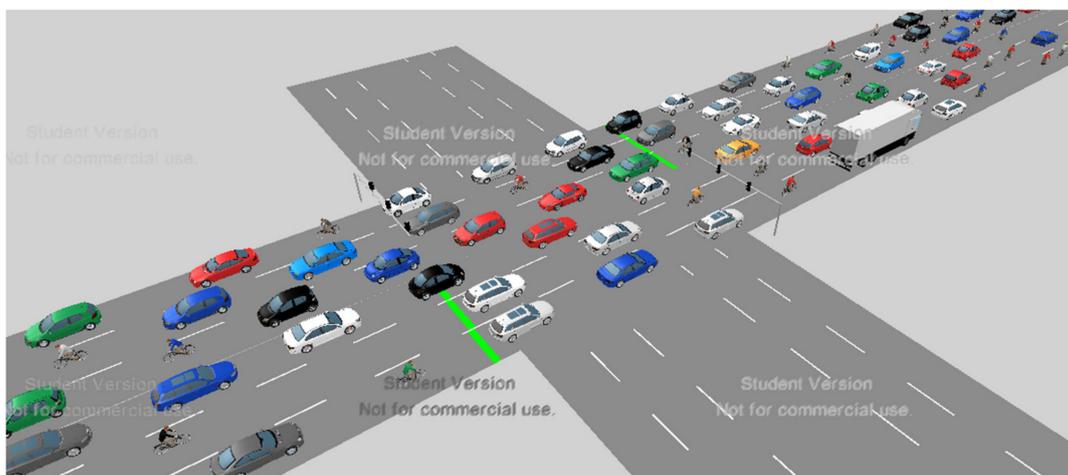


Figure 2. Simulation of low green traffic rate at intersection.

Non-motorized vehicles are convenient and flexible, and bicycles are easy to use. In most cities, bicycles and other non-motorized vehicles have become important means of transportation for citizens during work and travel. At present, the number of bicycles in the country is more than 400 million, of which urban residents account for more than half of the total. The number of bicycles in most cities has been saturated. Due to the poor safety of bicycles and low transportation efficiency, the originally unsatisfactory traffic conditions have become worse. This happens in particular at intersections, where the phenomenon of motor vehicles and non-motor vehicles mixing frequently occurs, especially during peak hours [14].

Therefore, traffic congestion is no longer just a problem of “urban diseases” [15] such as difficulty in driving and parking, which is unique to large cities, but has also become an inevitable obstacle to the development of small and medium-sized cities. Because of their small scale and weak economic foundation, it is impossible to invest all of the city’s construction forces on new roads. Urban traffic problems need to be solved with smarter and more efficient methods.

With the advancement of urban development and urbanization, the demand for urban road traffic continues to increase, and traffic congestion in large cities is becoming more and more serious, especially during the morning and evening peak periods of working days. To solve the various problems of urban road traffic, especially the road traffic in the old city that is prone to traffic congestion, it is necessary to increase investment in the construction of intelligent transportation systems and formulate roads that can support urban roads while rationally planning the urban road network through the transportation informatization construction framework, development plan [16], and technical standards [17] of the transportation development strategy [18]. Today, the overpass can be said to be an important part of the urban transportation system. As a modern and effective three-dimensional transportation system, it is an inevitable product of a city’s development to a certain stage. Its capacity can directly affect the traffic flow and traffic congestion on the arterial road. The function of the urban overpass is to rationally divert vehicles that are far away from their destination at the road intersection to ensure the smooth progress of traffic and avoid a large amount of traffic concentrating on the same traffic network, causing traffic congestion. The structural characteristics of the highway overpass determines that it can make the straight turns and U-turns of vehicles not cross on the same plane when the vehicles are diverted, so that each vehicle can go on its own way without interfering with each other, so as to realize the vehicle diversion function of the overpass [19]. When designing an overpass, consideration must be given to the rationality, functionality, feasibility, economy, and aesthetic characteristics of the plan. In the design and planning, if the planning is not properly designed, it may cause interference to the traffic of vehicles in the urban transportation system and form a bottleneck area of traffic flow [20]. Overpasses with different structures and ramp design methods have different capacities for passing vehicles and have different degrees of impact on the traffic road network [21].

In order to make urban traffic more convenient and faster, and to solve the traffic congestion problem of people’s travel to a certain extent, we need to set up an overpass for shunting the control of vehicles [22], so that vehicles in different planes do not interfere with each other and to ensure the intersection of vehicles onto the overpass in advance, so that the diversion of vehicles eases the flow of cars on surface roads [23]. This will ensure collisions between pedestrians, electric vehicles, bicycles, and cars are avoided at ground traffic intersections. Therefore, how to choose the construction location of an overpass and what type of overpass to build [24] will directly affect the traffic situation of the entire urban road traffic network. If the site selection is correct, it will effectively alleviate the traffic situation in the surrounding area. If the location is not correct, not only can it not achieve the original desired goal, but it will also cause a waste of resources. The road network, built at great expense, is not working as well as it should. Thus, it is very important to build overpasses in reasonable places and to give full play to the role of overpasses.

In order to realize the traffic signal adaptive control of intelligent traffic [25], it is necessary to obtain real-time traffic flow information [26] first. The intelligent traffic system will collect traffic flow data through A/D conversion [27] to send to the control center for analysis and comparison, and to obtain the ratio of traffic flow [28] size comparison. The traffic light time can be controlled according to the ratio, so the system can change according to the real-time traffic flow [29], which, coupled with the role of the overpass, can greatly improve the efficiency of the intersection [30] and improve the quality of the traffic service of the city's overall road network.

This paper takes Jinan City, Shandong Province, China as the research object, combined with the experience of other urban road construction planning [31], and then, based on the daily traffic congestion problems in Jinan City, after research and analysis, the road traffic problems in Jinan City are found. Quantitative and qualitative analysis based on real-time, daily road traffic data of Jinan City, combined with the existing road network and planned road network of Jinan City, proposes the application of a road intelligent transportation system. Based on the use of a road intelligent transportation system, we discussed the future development of road transportation in Jinan. In addition, based on the simulation results of the model, suggestions for improving road traffic planning are put forward and verified by experiments to ensure persuasiveness.

The content discussed in the rest of this article is as follows: The second part (related work) deeply analyzes the concept of the intelligent transportation system and expands it horizontally. The third part (methods and materials) demonstrates the mathematical principles of intelligent transportation systems. The fourth part (experiment) elaborates on the specific experimental process in detail. The fifth part (discussion) makes a preliminary analysis of the causes of traffic congestion. The sixth part (conclusion) gives suggestions for improving urban traffic and uses the model to verify the theory proposed in this article.

## 2. Related Work

### 2.1. Intelligent Transportation

The intelligent traffic system (ITS), also known as the Intelligent transportation system, includes the advanced fields of science and technology (information technology [32], computer technology [33], data communication technology [34], sensor technology [35], electronic control technology [36], automatic control theory [37], computer simulation [38], Artificial Intelligence [30], etc.) that are effectively integrated into transportation [39], service control, and vehicle manufacturing, in order to strengthen the relationship between vehicles, roads, and users, thus forming a comprehensive transportation system that plays a large and all-round role.

The intelligent passenger flow guidance system [40] is applied in airports and other places with large passenger flow. In urban traffic networks/expressways, the automatic motor vehicle control system, operation vehicle scheduling management system, non-motor vehicle intelligent management system, intelligent scheduling system, and so on can be used. Their function is to rationally plan the road for people and vehicles through the intelligent system [37], improve the transportation efficiency and capacity of the road network, alleviate traffic jams, reduce the occurrence of traffic accidents, and reduce energy consumption and environmental pollution. According to one regional forecast, using ITS can reduce traffic jams by 30%, save energy by 10%, reduce air pollution by 25%, and reduce traffic accidents by 50%.

ITS consists of three parts: information collection, information processing, and information release. In China, ITS systems have begun to take shape in traffic management, electronic toll collection, traffic information services, traffic safety, operation management, traffic infrastructure management, and ITS data management. An intelligent transportation system is a complex comprehensive system, which can be composed of the traffic management system, public transportation system, vehicle control system [41], electronic toll collection system, park and ride facility [42], traffic information service system [43], and emergency rescue system, as well as other subsystems.

Many scholars at home and abroad have proposed many corresponding measures and solutions for various outstanding problems at different intersections. One is prevention-oriented, studying the causes of congestion, mainly starting from the characteristics of traffic flow, through construction and planning road routes to alleviate road congestion problems, such as: building viaducts, building public transport lanes, broadening main roads, building roundabouts, etc.; the other is based on control, by controlling signal lights, controlling vehicle directions, etc., to alleviate traffic congestion problems, such as implementation of the prohibition of left, “U-shaped” turns, the harbor-style left turn lane method, shift left, and change to left, etc.

## 2.2. Research Development History

In the 1960s, the United States restricted the flow of cars on its roads to keep cars moving and avoid congestion, a technology that has since spread to developed countries around the world. On this basis, there are also some other similar algorithms, such as the timing control algorithm and induction control algorithm, and there have also been derived a variety of ramp control methods, e.g., the help-based ramp control algorithm [44] and ZONE ramp control algorithm [45].

In 2005, Kerner, B.S. Klenov, and Sergey L. proposed a model of discontinuity in traffic flow at an expressway ramp junction [46]. The average time delay at the bottleneck and the related nucleation rate of the speed collapse were discovered and studied. The relationship between the nucleation rate of traffic interruption and the flow to the ramp and upstream of the bottleneck was studied.

In 2010, Chen Xuwen proposed a single-point optimization control method for urban expressway ramps [47]. On this basis, the on-ramp single-point optimization control method, the exit-ramp control method, and the adjacent on-ramp linkage control method were studied in detail, and the proposed method was verified by VISSIM. Then, a coordinated control method for expressway ramps was proposed.

In 2014, Wenbin Hu, Huan Wang, and others proposed a practical AUTM model for traffic jam prediction and urban traffic jam avoidance simulation [48]. This included maps and transmission MT conversion methods, optimizing spatial evolution rules, and avoiding congestion routing algorithms. The experimental results showed that the prediction accuracy of traffic congestion was close to 89%, and the variance of the predicted road density was less than 0.15.

A review of the domestic and foreign literature shows that when analyzing the causes of traffic congestion, researchers mainly focus on the analysis of road system traffic flow, and the results obtained are only a broad theoretical study. Research is mainly performed to provide people with a way of thinking. In practical applications, the research needs to be considered and modified according to the actual conditions of the road network.

Through reading the literature, it is found that domestic and foreign researchers have mainly researched the on-ramp control of the elevated overpass. During the peak period of traffic congestion, when the on-ramp and down-ramp vehicles merge into/out of the main road, this causes the elevated ramp. Too many vehicles and long queues can even affect the normal passage of overpass vehicles and ground arterial road vehicles, reduce the efficiency of overpass vehicles, and affect the overall traffic situation of the urban road network. Therefore, when designing an overpass, it is necessary to consider not only the construction of the overpass itself but also the design of the entrance and exit ramps of the overpass, so as to minimize the impact on the ground arterial road to which it is attached.

## 3. Materials and Methods

### 3.1. Traffic Congestion Index Evaluation Strategy

As expressways and main roads are the main roads in Jinan, we focus on the evaluation criteria of these two roads. The traffic congestion model based on fuzzy comprehensive evaluation is used to analyze the congestion of each main road.

### 3.1.1. Determine the Evaluation Factor Set and Comment Set

Determine the evaluation factor set as  $U = \{u_1, u_2, u_3\}$ , where  $u_1, u_2$ , and  $u_3$  respectively, correspond to the distance passed by the traffic flow per unit time, the time difference between the actual traffic flow passing the unit mileage and the road design traffic flow passing the unit mileage, the actual road capacity and the road design capacity ratio.

Here, five levels are used to classify the traffic congestion situation, and the evaluation set is set as  $P = \{p_1, p_2, p_3, p_4, p_5\}$ , where  $p_1, p_2, p_3, p_4$ , and  $p_5$  correspond to the five evaluation levels of unobstructed, relatively unobstructed, relatively congested, congested, and severely congested.

### 3.1.2. Constructing an Average Travel Speed Evaluation Standard Table

According to the relevant theories of traffic flow model, 85% speed is usually regarded as the maximum speed limit of the observed section, 50% speed can be used as the boundary between congestion and smooth traffic, and 15% speed as the minimum speed limit.

We selected Hero Mountain Road as a sample. The traffic speed data was processed by MATLAB (Version: 2018A) software to obtain 85%, 50%, and 15% speeds of the highway. We found that the speed of 15% position is 37.21 km/h, that of 50% position is 42.57 km/h, and that of 85% position is 47.13 km/h. Therefore, the design speed error between the speed at 50% of Yingxiong Mountain Road and the traffic flow model is

$$e = \frac{42.57 - 40.735}{42.57} = 0.0431$$

Since the error is less than 5%, we consider the return parameters obtained from the traffic flow model to be reliable. Finally, we obtain the speed evaluation standard through the road design standard and return parameters, as shown in Table 1.

**Table 1.** Judgment Standard Table of Average Travel Speed of Road Section.

Road Grade	Unblocked	Smoother	More Congested	Congestion	Severe Congestion
Main road	(42,+∞)	(37,42]	(25,37]	(15,25]	(0,15]

### 3.1.3. Constructing an Average Delay Evaluation Standard Table

According to traffic flow model correlation theory and average delay calculation formula

$$t = \begin{cases} 3600\left(\frac{1}{v} - \frac{1}{v_{mid}}\right) & v \leq v_{mid} \\ 0 & v > v_{mid} \end{cases}$$

where  $v$  is the current velocity and  $v_{mid}$  is the saturation velocity. We obtained the evaluation standard of average delay per unit mile of road section, as shown in Table 2.

**Table 2.** Standard Table of Average Extension of Unit Mileage.

Road Grade	Unblocked	Smoother	More Congested	Congestion	Severe Congestion
Main road	(0,0]	(0,8.921]	(8.921,55.624]	(56,151.624]	(151.624,+∞)

### 3.1.4. Construct the Saturation Evaluation Standard Table

Determination of saturation

$$c = \frac{Q}{Q_{mid}}$$

Among them,  $Q$  is the current flow, and  $Q_{mid}$  is the design flow.

We mainly refer to the “Technical Standards for Highway Engineering” [49] to determine the road saturation evaluation standards, as shown in Table 3.

**Table 3.** Judgement criteria for road section saturation.

Road Grade	Unblocked	Smoother	More Congested	Congestion	Severe Congestion
Main road	(0,0.4]	(0.4,0.6]	(0.6,0.7]	(0.7,0.8]	(0.8,+∞)

3.1.5. Determine the Weight Vector of the Evaluation Index

We mainly refer to the “Urban Road Traffic Congestion Evaluation Research Based on Fuzzy Comprehensive Evaluation” [14], and determine the weight vectors of the three indicators of the average travel speed of the road section, the average delay per unit mileage, and the saturation as

$$W = (0.42, 0.30, 0.28)$$

3.1.6. Determine the Index Membership Degree

For the larger the better the index, the ascending half-gradient method is used. For the smaller the better the index, the descending semi-trapezoidal method is adopted. Among them, the average formation speed of the road section belongs to the larger the better index, and the other two evaluation indexes belong to the smaller the better index.

The membership function for the larger and better indicator is

$$r = \begin{cases} \frac{\chi_{ij}-L_{ij}}{H_{ij}-L_{ij}} & H_{ij} > \chi_{ij} > L_{ij} \\ 0 & \text{Other} \end{cases}$$

The membership function for the smaller and better indicator is

$$r = \begin{cases} \frac{H_{ij}-\chi_{ij}}{H_{ij}-L_{ij}} & H_{ij} > \chi_{ij} > L_{ij} \\ 0 & \text{Other} \end{cases}$$

3.1.7. Fuzzy Comprehensive Evaluation

Through the above analysis, the fuzzy evaluation matrix is determined as follows

$$R = \begin{pmatrix} v1 & v2 & v3 & v4 & v5 \\ t1 & t2 & t3 & t4 & t5 \\ c1 & c2 & c3 & c4 & c5 \end{pmatrix}$$

where  $v_i$ ,  $t_i$ , and  $c_i$  are elements  $u_1, u_2$ , and  $u_3$  in  $U$ , respectively, meaning average travel speed, average delay per mile, and saturation, respectively.

Finally, the evaluation matrix is

$$B = W \circ D = (0.42, 0.30, 0.28) \circ \begin{pmatrix} v1 & v2 & v3 & v4 & v5 \\ t1 & t2 & t3 & t4 & t5 \\ c1 & c2 & c3 & c4 & c5 \end{pmatrix} = (b1, b2, b3, b4, b5)$$

Assign grade values to  $b_1, b_2, b_3, b_4$ , and  $b_5$ , respectively, as shown in Table 4.

**Table 4.** Assignment table.

Congestion State	Unblocked	Smoother	More Congested	Congestion	Severe Congestion
Assignment	1	2	3	4	5

We define  $b$  as the traffic congestion index and set

$$b = b_1 + 2b_2 + 3b_3 + 4b_4 + 5b_5.$$

Among them, the closer the  $b$  index is to 5, the more congested the road; otherwise, the smoother the road. The corresponding relationship between the congestion index and the degree of congestion is shown in Table 5.

**Table 5.** Correspondence between congestion index and congestion degree.

Congestion State	Unblocked	Smoother	More Congested	Congestion	Severe Congestion
Congestion index	[0,1)	[1,2)	[2,3)	[3,4)	(4,5)

Through the above methods, we can calculate the congestion index of each road section. We defined severe congestion as red, smooth traffic as green, and other congestion as excessive color between red and green, so as to carry out data visualization in the experiment.

### 3.2. Strategies to Alleviate Traffic Congestion

We use a forced diversion strategy based on maximum flow to simulate traffic congestion mitigation. In order to simplify the problem, we assume that the flow and capacity on the expressway between gateways are the same, then this problem can be transformed into the maximum flow problem in graph theory, and its basic model is as follows

$$s.t. \begin{cases} \sum_{j=1}^n f_{sj} = F \\ \sum_{j=1}^n f_{jt} = -F \\ \sum_{ij} f_{ij} - \sum_{vj} f_{ji} = 0, v_i \neq s, t \\ 0 \leq f_{ij} \leq c_{ij}, c(v_i, v_j) \in A \end{cases}$$

Constraints 1 and 2 indicate that the flow from the source is the same as the flow into the sink. Constraint 3 indicates that the outgoing and incoming flows at each node balance each other. Constraint 4 indicates that the flow on each arc does not exceed the capacity of that arc.

Through the maximum flow model above, we can simulate the forced shunting of traffic flow at each pass, obtain the congestion index at each pass after the forced shunting, and compare it with the congestion index before regulation, so as to achieve the improvement in traffic congestion.

## 4. Experiment

In this article, the first step was to use Python [50] to crawl traffic on the Gaode map development platform. The obtained data were stored in the MangoDB database [51], which was then transferred locally through Studio 3T. Through the modification and sorting of local data, various road traffic data needed were obtained, and the data were imported into arcmap [52] for data image processing, and, finally, the desired effect picture was obtained.

It was necessary to collect and save data on the road traffic in Jinan. Then, we processed the collected data to obtain the current road speed, direction, time, traffic conditions, and congestion coefficient. After several weeks of data collection, the data were collected in one-hour intervals from 7 a.m. to 8 a.m. The collected data were then saved in the database for future data processing.

Then, we carried out data reading, data preprocessing, and data feature extraction on the collected data. We performed data concatenation of the required data, split the data, extracted the required key data, and organized and saved the extracted key data. We imported the saved key data into a new database, and then performed data image processing on the imported new data in the software database to draw the required image.

The above is the general idea, the specific operation details are described as follows.

#### 4.1. Traffic Situation Interface

Traffic Situation interface: Traffic situation is the HTTP interface of the Web service [53] provided by AmAP development platform, which can obtain road parameters in a certain area. Firstly, apply for the Key of “Web service” on AmAP API developer platform. In the second step, fill in the URL according to the HTTP requirements. Note that the Key you applied for must be filled in the corresponding area of the URL. The third step is to receive the returned data, usually in JSON [54] or XML [55] format, and then analyze the data to obtain the data information required. For example: road summary and evaluation, road congestion, road description, road name, driving speed, road coordinate set, etc.

In order to determine the area to collect information in Jinan, firstly, we used arcGIS software [56] (<https://developers.arcgis.com/rest/>, accessed on 4 November 2021) to create fishing nets, and then used the fishing net diagonal mark acquisition tool to obtain the diagonal marks of each fishing net, that is, the coordinates corresponding to the fixed points in the lower left and upper right corners of the rectangle.

#### 4.2. Data Extraction Using Python

Due to the large terrain, the terrain size of the data to be climbed was limited, so we cut the whole area of Jinan into small squares, and then queried the traffic situation information in each small square.

After cutting the map, we used the Python program to extract data from the AutoNavi Map API port and return it to JSON format.

Then we extracted all the required traffic information from the JSON format data, such as name, status, direction, speed, and polyline.

When the data collection code was completed, we saved the collected data to the database for later recall. To create a database and a data file, you need to write this code before the data collection and cutting separation program.

Next, we only needed to run the general program to start capturing real-time road traffic data in Jinan.

When the code appears, the process is finished with exit code 0. This means that the program has finished running perfectly without errors, and the data have been saved in the MongoDB database. The next job is to extract the data in the MongoDB database and proceed to a certain extent.

#### 4.3. Use Studio 3T for MongoDB to Open and Extract Data Files

To open the MongoDB database, you need to use the MongoDB database visualization tool. In this design, studio 3T is used as the visualization tool for the MongoDB database. First of all, we need to open studio 3T for MongoDB before the Python program runs, and create a database for us to receive data. When we have determined that the obtained data are what we need, and want to save the data from the MongoDB database to the local database, we enter the extraction storage location code to enter the target directory.

#### 4.4. ArcMap Tool Is Used to Image the Collected Data

After the data are converted into the form of coordinate points through the above operations, we add the data coordinate points to the arcmap layer. After we add the coordinate point data to the layer, we need to export the coordinate point data to the local library. When the export is successful, the new table will be added to the current map.

After screening, several representative images were selected from nearly a hundred data images. Among them, green means unblocked: speed > 40 km/h; yellow means slow driving: 40 km/h > speed > 20 km/h; yellow means severe congestion: speed < 20 km/h.

Figures 3 and 4 were drawn according to the data in Table 6. During the morning rush hour (7:00–8:00), the overall road traffic in Jinan entered a slow-moving situation. In Jingyi Road and Shunhedong Street, the road conditions were red. The traffic network in this area was seriously congested, and the speed of vehicles was extremely slow.



**Figure 3.** Road condition of early morning rush hour in Jinan city. (The closer the road color is to green, the smoother the road. The closer the road color is to red, the more congested it is).



**Figure 4.** Road condition in the late morning rush hour in Jinan city. (The closer the road color is to green, the smoother the road. The closer the road color is to red, the more congested it is).

In other time periods on weekdays, most of the road network traffic in Jinan is smooth. Only in the sections from Jiluo Road to Chengfengqiao and Lishan Road, was the situation red. The traffic network in this area was seriously congested, and the vehicle speed was very slow, as shown in Figure 5.

**Table 6.** Data on major road junctions during morning rush hour.

Road Name	Road Information	Speed	Traffic
Jingshi Road	Bayi overpass to Weiyi Road	10 km/h	Severe congestion
Luoyuan Street	Near Shunhe West Street	10 km/h	Severe congestion
Jingsi Road	Shunhe East Street to Weier Road	10 km/h	Severe congestion
Jingshi Road	Weiyi Road to Minsheng Street	15 km/h	Severe congestion
Victory Street	Jingqi Road to Jingba Road	10 km/h	Severe congestion
Shanda Road	Near Jingshi Road	10 km/h	Severe congestion
Jingyi Road	Wuyingshan Road to Weier Road	15 km/h	Severe congestion
Culture West Road	Youth West road to Youth East Road	15 km/h	Severe congestion
Weisi Road	Jingyi Road to Jingsi Road	15 km/h	Severe congestion
Phoenix mountain	Near Beiyuan Street	17 km/h	Severe congestion
Foshan Street	Culture West Road to Lok Yuen Street	15 km/h	Severe congestion
Shadowless mountain road	Normal road to shadowless mountain road	15 km/h	Severe congestion
Shungeng Road	Through ten road to shun geng road south mouth	35 km/h	Congestion
Qilishan Road	Hero Mountain Road to Yuhan Road	30 km/h	Congestion
Second West Road	Second South Road to Jinan overpass	35 km/h	Congestion
Happy Street	Near Jiqi Road	25 km/h	Congestion
No shadow Mountain Middle Road	Second Ring West Road to Jiqi Road	20 km/h	Congestion
Jiqi Road	Second Ring West Road to Zhangzhuang Road	35 km/h	Congestion



**Figure 5.** Road conditions at other times of weekdays. (The closer the road color is to green, the smoother the road. The closer the road color is to red, the more congested it is).

Referring to the data shown in Table 7, at the evening peak (18:00–20:00), the road conditions in 80% of the areas in Jinan were extremely poor. Most data points on the whole map are displayed in red. There was serious congestion in many road sections and even the phenomenon of vehicles parking and waiting. Only in the direction of Shandong sports center of Beiyuan viaduct and the whole section of the Yanshan overpass, were citizens able to pass unimpeded north–south on these two viaducts, and the driving speed of vehicles was not affected, as shown in Figure 6.

**Table 7.** Partial data of main roads in evening rush hours.

Road Name	Road Information	Speed	Traffic
Jingshi Road	Shungeng Road to Lishan Road	15 km/h	Severe congestion
Weft four-way	Jingyi Road to Jingsi Road	15 km/h	Severe congestion
Beiyuan Avenue	Fenghuangshan Road to Donggonghe Road	15 km/h	Severe congestion
Culture West Road	Young west road to Baotu Spring south road	10 km/h	Severe congestion
Shanda North Road	Second Ring East Road to Hongjialou South Road	15 km/h	Severe congestion
Fengshan Road	Huancheng South Road to Jingshi West Road	35 km/h	congestion
Huancheng south road	Dingxiang Road to West Exit of Huancheng South Road	35 km/h	congestion
Qinghe Street	Dongmenli Street to Fenghuang Road	35 km/h	congestion
Wenhui Road	Tianyi to Boya Road	35 km/h	congestion
Wolong Road	Liuchangshan Road to Jianshe Road	35 km/h	congestion
Shun Geng Lu	Shun geng road south to ten road	35 km/h	congestion
Qilishan Road	Hero Mountain Road to Yuhan Road	35 km/h	congestion
Jingliu Road	Zhangzhuang Road to Wei12 Road	35 km/h	congestion
Zhangzhuang road	Jiqi Road to Jingshi West Road	30 km/h	congestion
Jingqi Road	Jingshi Road to Shunhe West Street	35 km/h	congestion
Jingshi West Road	Provincial Highway 104 to Jinan West Interchange	50 km/h	congestion
University Road	From provincial highway 104 to Jingshi West Road	40 km/h	congestion
Hero Mountain Road	Bayi overpass to 103 Provincial Road	55 km/h	congestion
Ziwei road	Ziwei Road west to Furong Road	50 km/h	congestion
Shun Geng Lu	Through ten road to shun geng road south mouth	40 km/h	congestion



**Figure 6.** Evening rush hour road conditions. (The closer the road color is to green, the smoother the road. The closer the road color is to red, the more congested it is).

Citizens mostly travel on weekends, so the overall road traffic in Jinan entered a slow-moving situation, as shown in Figure 7. Except for a few roads that were red, the regional traffic road network was seriously congested; the main road was basically in a smooth state, and other road sections could also be driven normally.



**Figure 7.** Schematic diagram of road conditions during the weekend. (The closer the road color is to green, the smoother the road. The closer the road color is to red, the more congested it is).

The Jinan City Traffic Management Bureau stipulates that the maximum speed of Jinan urban expressways, i.e., elevated roads, is 90 km/h, the maximum speed limit of main roads is 80 km/h, and the speed limit of secondary trunk roads and branch roads is 60 km/h. According to the above data and image display, compared with the highest design speed of roads stipulated by the Urban Transportation Administration, it was found that the roads with serious congestion in Jinan are Jingshi Road, Quancheng Road, Tourism Road, Second Ring East Road, Shunhe East Street, Wei Second Road, Beiyuan Street, and Wuyingshan Middle Road. These roads are all surface sections; they are also the main traffic roads in Jinan, and they are the first choice for citizens to travel. On the other hand, except for a short-distance of slow congestion at the upper and lower bridge entrances, as a whole, the speed of traffic flow on the overpass was consistent with the road design speed

while ensuring that no traffic accidents occurred. The design and planning of various traffic interchanges in Jinan City are reasonable, and the actual operation conditions are good; there are no road conditions that are not conducive to the passage of interchange vehicles due to unreasonable planning. This realizes the improvement in the traffic conditions of the local road network in Jinan City. Among them, the Shunhe Overpass and the Yanshan Overpass Second Ring East Road section performed particularly well, with almost no traffic congestion, which shows that if there is no traffic accident, the overpass plays a huge role in the coordination and diversion of congested sections in big cities.

## 5. Discussions

Without considering the low peak hours and peaceful peak hours, the traffic flow in the morning and evening peak hours alone is huge on weekdays because the vast majority of citizens travel through the main road. Taking The 10th Road as an example, considering only the urban section (from The Lashan overpass to the Yanshan Overpass), the whole journey needs to travel 12 km and pass 20 red street lights without using the overpass viaduct and only driving on the ground road, which means that there will be an intersection every 600 m on average. In addition, the traffic flow in the morning and evening peak is huge, and the vehicle capacity is weak. The distance between the traffic lights is too close, and the vehicles need to start and stop for traffic lights many times, resulting in the vehicle not reaching the expected design speed of the road. Multiple branches and intersections can make more vehicles merge into the main road, but, at the same time, there are too many traffic lights because of there being too many intersections, which affects the average speed of vehicles on the main road.

Another reason for Jinan congestion is the unreasonable road network planning. In 2019, Jinan's road network density was only 4.68 km/km<sup>2</sup>, ranking 32nd and fifth from the bottom among 36 major cities in China. The congestion in Jinan is not only because the road network structure is not close enough, but also because the hierarchical structure design of the road network is unreasonable. In large-scale urban planning, a reasonable proportion of urban main road design and planning is expressway to trunk road to secondary trunk road to branch road, approximately equal to 1:2:3:6. However, according to the data released by Jinan Municipal Administration in 2016, in Jinan, the proportion of urban expressway to main road to secondary main road to branch road is 1:1:0.59:1.2. This cannot give full play to the functions of the road network that the city should have.

## 6. Conclusions

In order to solve the problem that vehicles on the main road cannot reach the planned speed of the road due to multiple fork roads and multiple intersections, we can use the intelligent transportation system proposed in this paper to control the intersection traffic lights. By monitoring the traffic flow at intersections and predicting the vehicle speed and waiting time, the information can be combined with the road information at multiple intersections, so as to achieve the purpose of reasonably controlling various traffic intersections and improving the efficiency of the road network.

For "T-shaped roads" and "deformed roads" intersections, it is necessary to strictly follow the standards of the intelligent transportation system to monitor and adjust the road network traffic in real time. The goal is to reduce the commuting time of citizens in the morning and evening peak periods, thereby improving the road traffic environment of vehicles and alleviating traffic congestion.

It is also a way to solve the problem of traffic congestion to make rational use of the public transport system, accelerate the construction of BRT rapid public transport corridors, improve bus lanes, and improve the operation speed of public transport. The intelligent transportation system can control and optimize the traffic network between the elevated overpass and the ground road. It can reduce the traffic conflict point at the intersection ramp, alleviate the problem of traffic aggregation on the elevated overpass, and avoid traffic congestion on the overpass.

In order to verify the effectiveness of the above improved scheme, we used the maximum flow model to process the data before and after the modification. The result is shown in Table 8.

**Table 8.** Road congestion index before and after adjustment.

Road	Morning Peak Congestion Index	
	Before Adjustment	After Adjustment
Shungeng Road to Lishan Road	2.5975	1.736
Jingyi Road to Jingsi Road	1.0446	1.0446
Fenghuangshan Road to Donggonghe Road	0.1776	0.1776
Young west road to Baotu Spring south road	1.4	1.4
Second Ring East Road to Hongjialou South Road	2.693	1.4
Huancheng South Road to Jingshi West Road	0.2489	0.2489
Dongmenli Street to Fenghuang Road	0.1266	0.1266
Tianyi to Boya Road	2.3529	1.736
Liuchangshan Road to Jianshe Road	0.2357	0.2357

According to the obtained data, our strategy improves the utilization rate of roads and greatly alleviates urban traffic congestion.

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