Quantitative Evaluation Model about the Traffic Congestion Degree of Intersections in Wuhan

—Take Luoyu Road for Example

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Abstract

Traffic congestion is not only an issue of economic, but also a social problem. It has become a bottleneck of modern urban economic development, and has attracted widespread attention. Judgments about the degree of traffic congestion are often carried out by the general public's experience and intuition, so it lacks the quantitative methods, and has certain limitations. Therefore, evaluation of quantitative research about the degree of traffic congestion has important significance and theoretical value. The results of this study are as follows:

(1) Made the Luoyu road in Wuhan city as the research object, the writer used three ways such as ride surveys, taken with random cars surveys and questionnaires to run an integrated review on the road traffic conditions. Derived from the macro level, the writer got some causes about the serious traffic jams in Luoyu road.

(2) Made the intersection as a starting point, the writer analyzed the internal relation between traffic capacity of road junctions and traffic lights' interval, proposed quantitative criteria to traffic section (junction) congestion levels. What's more, congestion levels of Luoyu road and some important intersections were calculated, through this method the writer reached the conclusion that the unobstructed road depend on the actual traffic capacity of intersections, and the flash rule's of the traffic lights restricted the actual intersection traffic capacity, therefore, a real-time programs which will be adjusted with the size of traffic flow is quite needed.

(3) A questionnaire about the ways of people's travel was designed, and statistics and analysis of the operational status of Wuhan City taxi was taken.

This study can provide a scientific basis for the traffic control department to alleviate the pressure of traffic congestion and take measures to relieve traffic congestion, what's more, it is also very worth for those who choose to bypass congested road and meets the convenience needs of travelers. Actually, the study has practical and promotional value.

Key words: Traffic Congestion; Quantitative Evaluation Model; Capacity; Traffic Light; Investigation Table

• PART I Problems of proposed and research

Traffic is the “blood “of a city. It’s can be seen as the performance of the city life and the important symbol for urban modernization.

With the rapid growth of the national economy, the pace of urbanization is speeding up and the number of vehicles increases rapidly, at the same time the traffic jams has become an important bottleneck of restricting the economic and sustainable development of a city. To people’s worried, traffic jams seriously influence the city life, have a negative effect on the normal operation of city life, disturb the city residents' work and life, and worsen the ecological environment of the city.

Traffic congestion is not only an economic problem, but also a social problem, which has attracted widespread attention. People call "traffic jams" as "city disease”, and define it as the problem of the city (bus difficultly, driving difficultly, park difficultly). However, most citizens often rely on intuition and experience to judge the extent of traffic jams. For example, using "former see head, after see the tail", "considerable stop-and-go, walk off, like volute line", "human car huddled together" and so on to describe traffic intensity, which lack of quantification methods and contain certain subjective. The literature which evaluation the traffic congestion degree usually provides some technical terms, such as, travel impacting indicator, traffic flow parameters and service level indicator etc, these indicators let ordinary citizens disoriented and difficult to understand.

Therefore, how to score and establish a traffic congestion degree of quantitative easing traffic jams model, and give corresponding countermeasures of problem is our main purpose of the study.

Research idea:

1) Wuhan city traffic trunk road - Luoyu road as the research object, we have designed a dweller way questionnaire, taken car following investigation, random questionnaire survey of taking the bus three ways, and comprehensively investigated traffic operation condition from the angle of "people, vehicles and road". Thus, we obtained sections of traffic reasons from on macroscopic pre-figurative.
2) Through analyzing the actual crossing capacity, we established quantification model of traffic intersection congestion degree, calculated the level of the jams of the Luoyu road, concluded that the expressways depends on the actual traffic capacity of intersection: Then, according to the method of "dot, line, face" combination, we calculated the congestion degree of the Luoyu road, and think that the intersection traffic interval restricted the intersection of actual capacity, and it needs to adjust real time based on the size of the cars.
3) We collected the unified invoices in Wuhan city passenger unified invoices from 2007 to 2009, and collected average speed of taxi in Wuhan. It is concluded that the urban traffic congestion is still of overall.

The model and conclusions can provide scientific basis for transportation management department to reduce traffic jams pressure and take slow plugging measures, but also provide convenience for the bicycler to avoid congestion sections and be satisfied with the Travel demand, and the method is of practical and popularize value.

•PART 2 The traffic situation and analysis of Wuchang district Luoyu road

Wuhan, located at the interchange of Yangtze River and Hanjiang River, composed of Hankou, Hanyang, and Wuchang, is in the eastern of Hubei province. Wuhan is the biggest hub in central China, as an important role of contacting east, west, north and south, and maintaining communication of square, which is China's economic geography "heart". To it at the same time, with the economic thriving and urban growing prosperity, it is also plagued by urban traffic congestion.

For many years, citizens in Wuhan have been suffered bitterness of the traffic. In 2009, Wuhan launched a "governance of war" of national action from the mayor to citizens. However, traffic congestion conditions did not ease, and the traffic situation is not optimistic. The general public elected "ten plugging point" of Wuhan, as follows,

1)the Bridge of Wuhan Yangtze River , 2) walking street, Jianghan road 3) Wuchang Jiedaokou; 4) Wuchang small DongMen,5) XunLimen, Hankou, 6) Changqing Road, Hankou 7) Wuchang train station, 8) Wuchang YueGuZui to Liyuan, 9) Wuchang t-shaped Bridge, 10) Hankou bamboo mountain turntable.

Figure 1 is part traffic of Wuhan city, the distribution of the ten plugging point screenshots geographical position and stay of inspected at Luoyu Road sections can be seen in figure 1.

We can see that, Wuchang district contains 5 of the "ten plugging point" of Wuhan transportation, and Wuchang Luoyu Road sections takes 2 plugging points, which respectively is Wuchang Jiedaokou and Wuchang t-shaped bridge and the four other plugging points of Wuchang district, such as Wuhan Yangtze river bridge, Wuchang small dongmen, Wuchang YueGuZui to liyuan. Wuchang train station is located in the upstream of Luoyu Road or nearby, therefore, when the traffic of this route or pre-figurative sections of a crossroads once is heavy, congestion phenomenon may affect the traffic network spreads, the other areas also my be influenced. The malignant circulation of the network structure leads to serious traffic jam, and bicyclers will feel miserable. For example, on 2009 September 5, at the big rush time of east each freshmen reporting, from Wuchang Big Dongmen to Wuchang Luxiang, about 9.29 kilometers long, there was a traffic paralysis, which made the Luoyu Road like a parking.(From: http://hb.qq.com/a/20090906/000006.htm). By the above analysis, we can conclude that we choose Luoyu road sections to investigate the city traffic jam problem has typical significance.

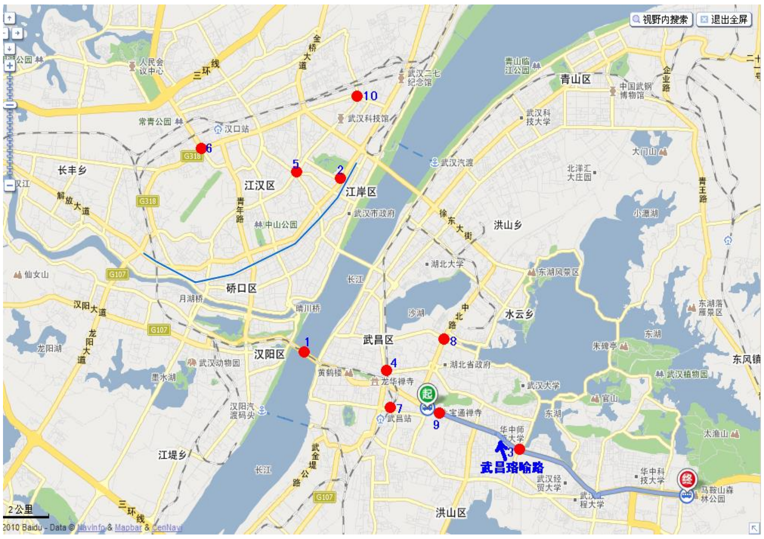


Figure 1: screenshots on the distribution of the ten plugging point

• 2.1 The basic characteristics of Luoyu Road sections in Wuchang

Wuchang Luoyu Road is the important traffic artery in Wuhan, connecting East Lake hi-tech development area and Gedian economic development area in the east, next to Wuluo Road and First Bridge of Yangtze Rriver in the west, next to Wuchang train station in the south, and next to provincial government and the East Lake scenic area in the north. The span is about 8.5km, along with eight important crossroads. (1: t-shaped bridge, 2: the trade square station, 3: Jiedaokou, 4: Guangbutun station, 5: Zhuodaoquan station, 6: East Lake development zone station, 7: Luxiang station, 8: Guanshan station), as figure 2 shows:

Figure 2: the traffic map of Luoyu Road

Near main streets at Luoyu road, urban activity has the following several features:

1) Huge commercial circle. From t-shaped bridge to Guanshankou station (HUST), along the streets, there are zhongnan business circle, Jiedaokou business circle,

Guangbutun computer city, Luxiang Guanggu center and other super bazaar activity center. These centers integrating shopping, leisure and entertainment have a large number of facilities to attract consumers.

2) Huge technological and cultural center. According to a survey, Circled Luxiang Guanggu center, 5km as radius range, there gathers more than 80% of Wuhan universities, gathered in the Huazhong university of science and technology, Huazhong normal university, China university of geosciences, Wuhan university, central China university of political science &law, central China national finance university, Wuhan university of technology, Wuhan university of engineering etc approximately 42 colleges. In Wuhan the number of college students reaches 104 million, which has leapt national first (2008 statistical data). Wuhan is the world's highest intensive degree of regional college students. College students constitute large and fixed consumers, who also have large traffic demand.
3) The national east lake high-tech development area of the prosperous development (Wuhan, China Guanggu). Luoyu Road Guanggu Square is the heartland of the development zone, gathering over 2,000 high-tech enterprise, like NEC, Siemens, c.p group, ChangFei fiber and other international large-scale enterprise area. The development of New city has attracted a lot of residents and practitioners. And as an imporant urban road, the Luoyu Road and parallel road will become the main links of conveying the crowds.
4) Gradually perfect public services. Along the Luoyu Road , there are maternity and child care centers of Hubei province, four 3 amour hospital including Wuhan Army general hospital, Wuhan university Oral cavity hospital, the traditional medicine hospital; five five-star hotel as May flower hotel, Luojiashan, lakeside garden and Huamei grenada, Hongshan Xiongchu international hotel. In addition, there are east lake national hi-tech zone, science and technology exhibition center and Huazhong university of Guanggu stadium and other large conference and sports facilities.
5) Continuously improving deliver system. According to the statistical data provided by 8684 Wuhan bus ChaXunWang (http://Wuhan.8684.cn/), we can obtain the following: In 2009, bus lines were 245 bar (excluding far city passenger line and minibus lines), the number of public transport vehicles were 5,700 (excluding far city buses, excluding minibus), and, on the main road in Wuhan there were a number of 55 different bus lines (excluding Limit-range car and all night cars), with car was about 1650 vehicles, 23100 measurements for average per around. The longest 715 bus lines, the span about 28.9 kilometers, transfix Hankou and Wuchang, along through Luoyu road sections as table 1. Road traffic facilities are good. In bearing the citizens to work, shopping, hiking, various kinds of traffic demand, it plays a big role. In addition, there are Wu-Huang expressway, Shanghai-Chengdu Expressway Company, Beijing-Zhuhai expressway, 107 state roads, and other adjacent Wuhan high-tech development zone.

Table 1: the list of the key transportation site along Luoyu Road

Serial number	Station	Site position and bus lines	Note
1	T-shaped bridge	Located at the front of the May flower hotel, Hongshan park south gate. Lines for: 15 18 25 59 66 308 401 413 503 510 518 519 521 536 538 540 564 576 581 583 586 590 593 596 601 608 702 703 709 710 715 723 728 729 804 806 811 907 913	39 lines in all
2	The trade square station	Located at the front of Wushang and trade square before Wuhan army general hospital front door. Lines for: 15 18 25 59 66 308 318 401 413 503 510 518 519 521 536 538 564 576 581 583 586 593 596 601 608 702 703 709 710 715 723 728 729 804 806 811 901 907 913	39 lines in all
3	Jiedaokou	Located in circle of Wuhan university of technology, Hubei maternity and child care centers, Jiedaokou business. Lines for: 15 18 25 59 66 308 317 318 401 413 510 518 519 521 536 538 564 576 581 583 586 593 596 601 608 702 703 709 715 728 729 804 806 901 907 913	36 lines in all
4	Guangbutun	Located in Huazhong normal univercity gate Guangbutun, at the front of Wuhan Surveying college, computer city in Guangbutun. Lines for: 15 18 25 59 66 308 312 318 401 510 518 521 536 538 552 572 581 583 593 596 601 702 703 709 715 724 728 804 806 810 901 907 913	33 lines in all
5	Zhuodaoquan	Located in the intersection Zhuodaoquan at Wuluo road, Zhuodaoquan park. Lines for: 15 18 25 59 66 72 308 312 318 401 510 518 521 536 538 552 572 581 583 591 593 596 601 702 703 709 715 724 728 804 806 810 901 907 913	35 lines in all

6	East Lake development zone station	Located in front of Wuluo road Hubin garden hotel, Wuhan science and technology exhibition center. Lines for: 15 18 25 59 72 312 401 510 518 521 536 583 591 593 702 703 709 728 810 901 913	21 lines in all
7	Luxiang Station	Located in cricle of Luxiang Guanggu square, Huameida five-star hotel, Guanggu center business. Lines for: 15 18 25 312 510 518 521 536 591 593 702 703 718 755 756 789 903 912	18 lines in all
8	Guanshankou Station	Located in the southern gate of Huazhong university of science and technology. Lines for: 15 18 25 312 510 518 521 536 591 593 702 703 718 755 756 789 903 912	18 lines in all

• 2.2 Traffic generation – The quantities of Wuhan motor vehicle

Urban traffic is a large complicated system constituted by people, vehicles, road, management technology and other factors. The traffic is smooth or not needs organic coordination of each element in the system. For example, modern urban traffic appeared "the road building every year, travel is also is blocking" which is vividly illustrates that the speed of the road construction is far below the growth speed of the car, the growth of the transportation vehicles demand is bigger than traffic supply, and then formed a new traffic congestion phenomenon.

According to the city traffic "blue book" issued by Wuhan land planning bureau in 2009, the data shows as:

1) In Wuhan, the number of motor vehicle rises quickly. At the end of 2008, the automobile of Wuhan motor vehicles increased to 76.9 million vehicles. Among them, private ownership reached 55.9 million vehicles, which is 71.5 per cent of the total number of the city; it increased about 4.8 million vehicles about 9.3% than 2007. Among them, the private is about 30.8 million, increased 6.2 million vehicles than 2007, and is about 25.3% of motor vehicles, the increase of motor mainly came from private coach. The ownership of motor vehicles and yearly growth rate in Wuhan at 2000-2009 is shown in Table 2.
2) Improvement of urban road traffic facilities and parking facilities. City road area from 4771 million square meters in 2007 to 5809 million square meters in 2008 in Wuhan, with a growth of 42.7%; Per capita roads area increased from 9.30 square meters to 975 square meters, the growth was 4.83%. According to incomplete statistics, there is about 22.6 million parking in 2008, which increased about 1 million than those of in 2007, the increase rate is about 4.6%. In addition, Luoyu Road sections Zhuodaoquan overpass, was also completed and opened to traffic on November 20th, 2009, along three footbridge with two

pedestrian underpass were built.

However, with the improvement of the urban traffic facilities and traffic, many important sections (or crossing) are still present different degrees of traffic congestion and jam phenomenon, which become the bottleneck of urban development process in Wuhan.

1) During peak hours, the number of intersection more than 1 million at 2008 is 19 instead of 16 at 2007 in wuhan. The number of urban traffic more than 7000 cars increased from 45 to 50 places.
2) The intersection of congestion led directly to driving speed slowing down, which is 23.3 kilometers per hour on average. Among them, Wuchang road average speed is 24.7 km/h, and the fist Luoyu Road is the most jammed, where the average speed is only 18.8 kilometers per hour.
3) The daily average time of residents of transportation is approximately 77 minutes, which is 15 minutes longer than 62 minutes of 1998.

By the analysis above, it can be found that, along with the development of national economy, the supply of the area of the road is limited. The infrastructure construction has a long period, and compared with the rapid growth of traffic, especially the rapid increase of the private vehicle ownership, the road assumes more traffic in the urban, traffic congestion still faces challenges.

It is worth noting, though the control of Wuhan motor vehicle traffic congestion will play a certain degree of alleviating function, the point is not to reduce the number of motor vehicle ownership, but to reduce road traffic and transportation cost.

Table 2: Wuhan motor vehicle quantities

Year	Motor vehicle quantities (car)	Growth rate (%)
2000	353，251	
2001	447，505	26.68188
2002	506，010	13.07360
2003	560，649	10.79801
2004	623，302	11.17508
2005	653，023	4.768315
2006	703，012	7.655014
2007	730，228	3.871342
2008	769，344	5.356683
2009	792，345	2.989690

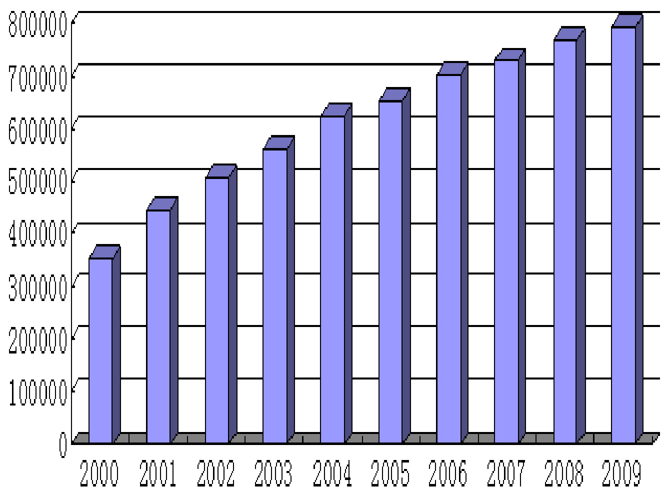


Figure 3: Motor vehicle quantities figure in Wuhan

• 2.3 Traffic generation - the dweller way of Luoyu Road

At the background of increasingly serious urban traffic congestion, studying dweller features and internal regularity is very meaningful. It is of practical value to reason allocation urban traffic resource, to ease traffic congestion and enhance the urban road utilization.

• 2.3.1 Dweller way - design of questionnaire

According to different region characteristics, Wuhan city can be divided into four types of activity areas as follows:
(1)Commercial residential area, (2) live industrial mixed zone, (3) college area, (4) suburban combining area.

On both sides of Luoyu road, there gathered Wuhan University of Technology, Wuhan University, Huazhong Normal University, Wuhan Sports Institute, China University of Geosciences, Huazhong University of Science and Technology University and other such as junior colleges, universities, and Hongshan middle school, Zhuodaoquan middle school and other secondary education. It has a large population density and it is a genuine cultural education abnormal. Accordingly, we will divide sections surrounding areas of Luoyu road into university area.

Dweller way composition is relatively complex, influence of transportation mode option bicycler is more also. Inspecting dweller characteristics from the static and dynamic behavior attributes these two aspects, we design a dweller way questionnaire.

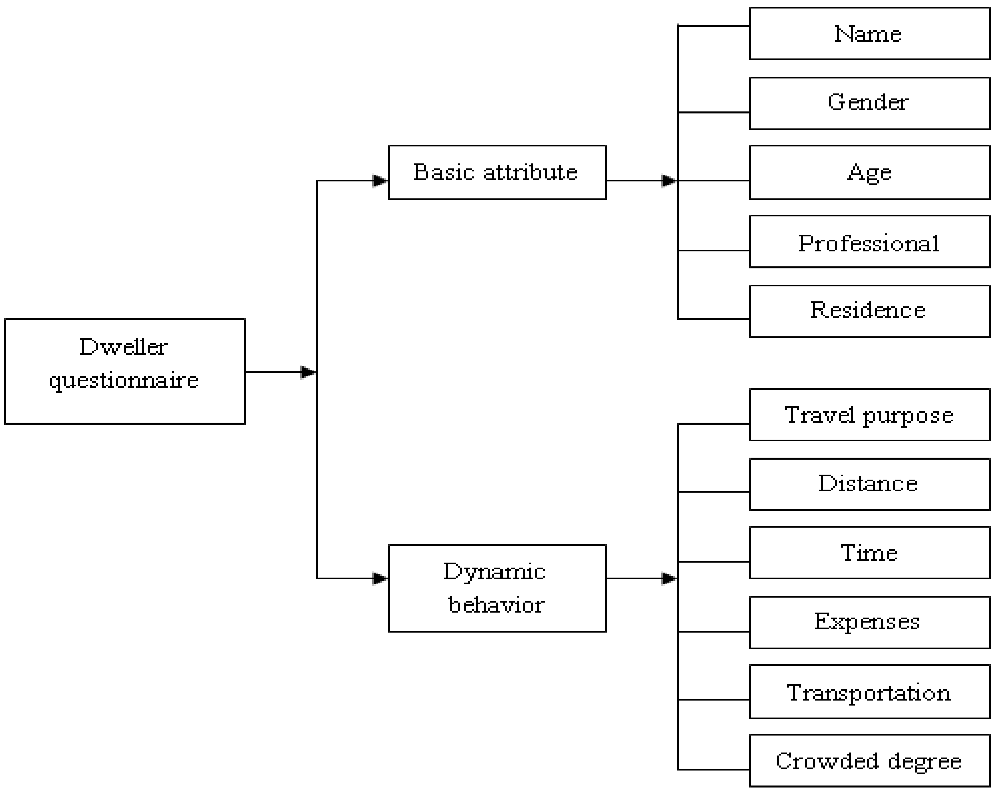


Figure 4: Dweller questionnaire schemes

Among them,

Travel purpose: refers to work (including work, school, business, etc.), life (shopping, relatives and friends, etc.), entertainment (entertainment, tourism, etc.).
Transportation: refers to the bus and taxi, private cars, bicycles, walking, including that of 5 kinds of daily travel tools.

Congestion degree: refers to the dweller traffic operation condition, is divided into four congestion level, it is respectively: unblocked (with green said), crowded (with yellow expresses), blocked (with orange said), severe blockages (indicated in red).The definition see behind instructions.

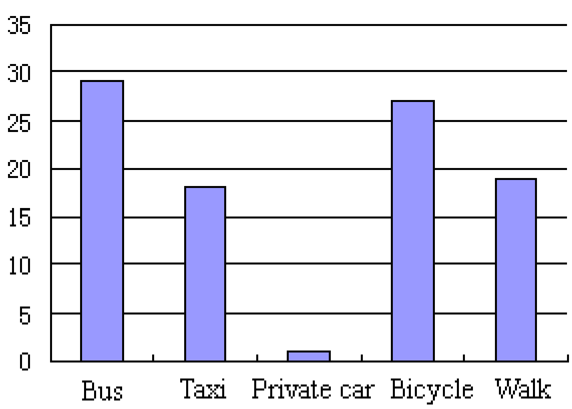
To question the pedestrians of Luoyu road section, the spot distributing and fill out and withdraw a total of 110 surveys.

- **2.3.2 Dweller ways -- the questionnaire of statistics**

(1)Traffic tools selection

The contents above show that the buses, bike are still as the become the main mode of transportation and the proportion of the total travel is 59. 6%. Among them, the bicycler will chose bicycle or walk when the residence is close to the destination, and with the increase of travel distance, transportation "motorization" degree gradually increases. Generally speaking, people will choose walking firstly within 20 km. More than three kilometers, bikes way gradually reduced, when the distance between 3 kilometers to 6 km, the number of taking a taxi is increased, when the distance is more than 6 km, the number of choosing public buses is significantly increased. Meanwhile, the most respondents are students.

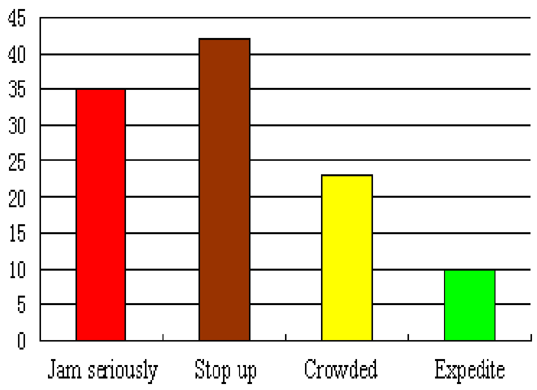
Table 3 the questionnaire of dweller traffic tool option

Options	Questionnaire quantity(94 reports)	Percent (%)	Chart
(a) Bus	29	30.9	
(b) Taxi	18	19.1	
(c)Private car	1	1.1	
(d) Bicycle	27	28.7	
(e) Step did	19	20.2	
blank	16		

(2) Statistics of traffic jams degree

Traffic jams degree is a fuzzy concept. Questionnaire to traffic congestion degree's judgment mainly depend on personal intuition and subjective experience.

Table 4: Residents of traffic congestion level experience questionnaire

Options	Questionnaire quantity(110 reports)	Percentage (%)	Chart
(a)Severe blockages	35	31.8	
(b) Jam	42	38.2	
(c) Crowded	23	20.9	
(d) Unblocked	10	9.1	

• 2.4 The macroscopic reason causing Luoyu road's traffic jams

Luoyu road is the most important city road in Wuchang district, where motor vehicle has a big flow rate, the population density and land development intensity is big. Traffic attract is big also. Each cause makes the road become traffic congestion sections.

• Part III Quantitative Evaluation Model for the degree of traffic congestion of intersection.

The Luoyu Road is a very crowded street. Its intersection is the place for traffic assembling, changing and going through, and also a bottle-neck for traffic capacity and traffic safety. Therefore, we make the important intersection of the Luoyu road—Jiedaokou as the standpoint to investigate the degree of traffic congestion for interval.

Concrete thinking:

1) Introduce the basic concepts for traffic capacity; give a definition and a classification for traffic congestion.
2) Use collected data of operational status of Wuhan city taxi to calculate the average speed at different time interval, preparing for the calculation of traffic capacity.
3) Establish a Quantitative Evaluation Mode for traffic congestion of intersection by

the traffic capacity at different intersection, and then calculate the degree of traffic congestion of Jiedaokou.

4) Establish a Quantitative Evaluation Mode for traffic congestion of interval by generalizing the Quantitative Evaluation Mode for traffic congestion of intersection; calculate the degree of traffic congestion for Luoyu road.

• 3.1 The basic concepts for traffic capacity and the classification for traffic congestion

• 3.1.1 The concepts of capacity

Capacity is also defined as traffic capacity, denoting traffic capacity for a road's consecutive vehicle and pedestrian passing at a unit time under certain traffic condition.

Capacity consists of intersection capacity and road capacity, among which intersection capacity refers to the maximum traffic volume for an hour or a day. Road capacity refers to the maximum volume for an hour or a day at certain road surface.

• 3.1.2 The classification of traffic congestion

Traffic congestion is people's feeling of time and vehicle speed, namely a phenomenon for vehicles waiting in a crossing or moving very slowly.

Presently, there is no unified criterion for traffic operation condition and traffic congestion quantitative evaluation and classification. Different area adopts different criterion:

(1) Based on the average speed

At home and abroad, smoothness of road is always measured by the average speed of vehicle at main streets. The smoothness of road is classified into smooth, crowded, congestion and heavy congestion. Crowded, jam and heavy jam is called congestion.

In China, many cities adopt the speed criterion, however, criterion of cities with different size are not the same, because people's acceptance for traffic congestion in different cities is different from each other. Our country take the 20km/h as a division for crowded and jam, 10km/h for jam and heavy jam. In order to make it clear, we make a table as follows:

Table 5 the relations between degree of traffic congestion and speed

Urban trunk road	Speed km/h	Characteristics
Unblocked	$v \geq 30$	Vehicles run by external restriction are lesser, and traffic is stable.
Crowded	$20 \leq v < 30$	Vehicles running speed is low. The traffic has certain delay. Queuing frequently occurs. The flow is unstable. It can be accepted.

Jam	$10 \le \boldsymbol{v} < 20$	Vehicle speed is low. Delay is large. Queuing frequently occurs. The traffic has bigger delay and saturation is higher. It can be endured.
Seere blockages	$\boldsymbol{v} < 10$	Vehicle speed is extremely low. Cars can hardly move forward. Queuing frequently occurs. The traffic is basic saturated or super saturated. It is unbearable.

(2) Based on the waiting line's length and traffic lights

According to <<The Public Safety Standard of People's republic of China—the evaluation Criterion for the degree of traffic congestion >>:

Criterion for city signal at intersection: jam refers to a vehicle's not passing intersection with green light on for three times. 5 times refers to heavy jam. Waiting line accounts to 400m refer to heavy jam at intersections without traffic signal.

Criterion for city interval jam: waiting line accounts to 1000m refers to jam; 1500m refers to heavy jam.

• 3.2 Average speed Statistics of Wuhan taxi at different interval

According to previous analysis, speed is the most important one among the factors that affect the traffic capacity,. The feature of traffic congestion at some interval is that vehicle's speed becomes very slow, and the road becomes very crowded. Therefore, it's very useful to analyze the speed at different interval in Wuhan for knowing the traffic operation condition and features.

We have collected 176 operational status of Wuhan City taxi, with 21 in 2007,96 in 2008, 69 in 2009. The operation status recorded the date, entering time and leaving time, miles and pays. These rental cars have different travel aims, type, driving route, and running state. Despite the traffic running state is complex, various traffic running states still have some characteristic tendency through a lot of statistic analysis.

Known from the data sheets: the average speed of 2007 is $24.9\boldsymbol{km/h}$. The average speed of 2008 is $25.8\boldsymbol{km/h}$. The average speed of 2009 is $28.2\boldsymbol{km/h}$. According to the survey, the average speed of Wuhan motor vehicle is $25.7\boldsymbol{km/h}$ in 2006, $24.5\boldsymbol{km/h}$ in 2007. These results is closer to the average speed of taxi we havw obtained statistically.

From Table 6, the average speed of taxi in Wuhan is increased year by year, this demondates,that the road condition and facilities are improved; on the other hand, this shows that the road running state is still in the crowded degree.

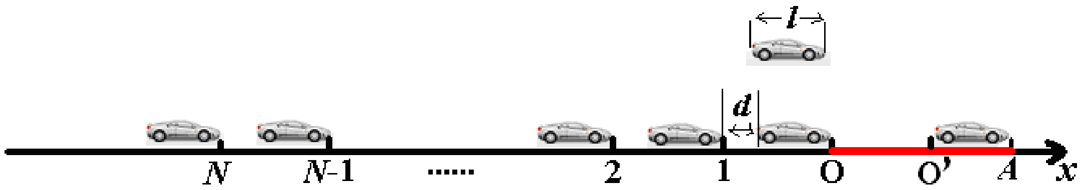
Table 6: Wuhan taxi at different times of the speed table

Time / Speed / Year	a.m.	midday	p.m.	dusk	evening	Late at night
2007	/	21.6	27.6	25.5	/	/
2008	24.1	23.9	26.3	19.2	25.8	35.6
2009	28.8	24.6	25.4	23.8	28.2	38.2

· 3.3 Congestion degree of quantification model and analysis

· 3.3.1 How to determine the shortest green time of the traffic crossing to get intersection traffic capacity

Suppose traffic jams occurs in the certain traffic intersection, and N cars in the same stranded type appear in this path. When the green light of traffic intersection starts light, vehicle waiting move in the x positive direction. How to determine the shortest green time T , making the intersection traffic capacity for N/T ?



Picture 5 : All N cars to pass conflict crossroads schemes

As the picture above shows, we use origin OO 'to denote traffic intersection conflict zone, OA is the driving distance actual required to say cars after conflict zone, i.e. the distance between the vehicle parking cord.

Suppose:

1) The length of every car is adjacent to constant l , the safe distance between cars is d ;
2) When the green lights is on, the car first moves with acceleration a , then moves along a straight line with a constant speed., Note that the invariable speed denoted as V is the highest speed prescribed by urban traffic management departments;
3) In the road, due to the small spacing, car's speed in the team section is limited by the car before. The driver can only move at the corresponding speed by using relevant the information provided by limber car. That is to say, when a car states, the driver of next car has some reaction time or delay time to start the car.

So, the initial coordinate location of the N th car is:

$$S_N(0) = -(N-1)(l+d)$$

Time t_a for each car from start-up to accelerate to uniform motion is :

$$V = at_a \Rightarrow t_a = \frac{V}{a}$$

The distance S_a of vehicles passed away in time t_a is:

$$S_a = \frac{1}{2}at_a{}^2 = \frac{V^2}{2a}$$

The Nth car's motion equation from static state to driver reaction condition to the car accelerated state to auto uniform motion state to the intersection is:

$$S_N(O) + OA = S_N(0) + S_a + V(T - \frac{V}{a} - (N-1)\lambda)$$
$$= -(N-1)(l+d) + \frac{V^2}{2a} + V(T - \frac{V}{a} - (N-1)\lambda)$$

where $T - \frac{V}{a} - (N-1)\lambda$ is the uniform motion time of the Nth car.

Cause $S_N(O) = 0$, we get

$$-(N-1)(l+d) + \frac{V^2}{2a} + V(T - \frac{V}{a} - (N-1)\lambda) = OA$$

So, all N cars to pass crossroads needed the shortest green time is:

$$T = \frac{V}{2a} + (N-1)\lambda + \frac{OA + (N-1)(l+d)}{V} \qquad (1)$$

Then, the minimum time of green light means that the intersection capacity is N/T.

Further analysis of (1):

1) The less the time T when all N vehicles take to pass the intersection, the larger the capacity, and the less probability for congestion. However, the more the time T when all N vehicles take to pass the intersection, the smaller the capacity, and the larger probability for congestion.

2) If the green light's lasting time $t^* < T$, this means: only part vehicle pass the intersection during time t^*, while some vehicles are detained, which causes waiting phenomenon.

3) If the distance between neighboring waiting car is bigger than the safety distance d, the time all N vehicles take to pass the intersection will be longer, so the minimum time of green light should be longer too. Similarly, he drivers' reaction time λ is longer, and then the minimum time of green light should be extended.

4) If OA=0, this means that N/T is the capacity of vehicle passing some road surface.

5) With regarded to (1), when the largest restriction speed V is the independent

variable, T is the function of V, then we have

$$T = \frac{V}{2a} + (N-1)\lambda + \frac{OA + (N-1)(l+d)}{V}$$
$$\geq (N-1)\lambda + 2\sqrt{\frac{V}{2a} \cdot \frac{OA + (N-1)(l+d)}{V}}$$

If and only if $\frac{V}{2a} = \frac{OA + (N-1)(l+d)}{V}$, T reaches the minimum

By some calculation, the appropriate speed for vehicles' constant motion is :

$$V^* = \sqrt{2a(OA + (N-1)(l+d))} \qquad (2)$$

Let $L = OA + (N-1)(l+d)$, then $V^* = \sqrt{2aL}$.

Length L with the following figure shows for:

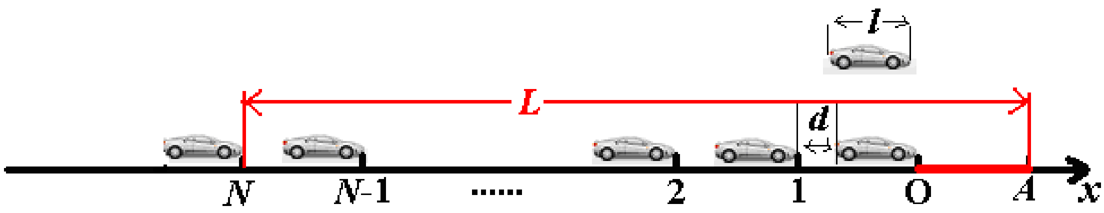


Figure 6: the length L illustration

6) Given the green light time T, then the number of passing vehicle is :

$$N = 1 + \frac{1}{\lambda}\left[T - \frac{V}{2a} - \frac{OA + (N-1)(l+d)}{V}\right]$$

We obtain,
$$N = 1 + \left[T - \frac{V}{2a} - \frac{OA}{V}\right] / \left[\lambda + \frac{(l+d)}{V}\right] \qquad (3)$$

• 3.3.2 The quantitative model on degree of congestion at intersection

In subsection 3.1.2, the boundary between crowding and congestion, congestion and heavy traffic jam are set as $20km/h$、$10km/h$, namely, the average speed of all vehicles passing the intersection during a period of time need to be counted. Obviously, it is hard to statistics and calculates the average speed. Therefore, simply relying on manual observation and statistical means on average speed cannot meet the needs, and we must find an effective method.

For this reason, we made a further research, and got a way for obtaining an average speed, which is described as follows:

During the fixed time T, the running distance of vehicle 1:

$$S_1(T) = S_a + V(T - t_a) = \frac{V^2}{2a} + V(T - \frac{V}{a})$$

The running distance of vehicle 2:

$$\tilde{S}_2(T)=\frac{V^2}{2a}+V(T-\frac{V}{a}-\lambda)$$

The running distance of vehicle 3:

$$\tilde{S}_3(T)=\frac{V^2}{2a}+V(T-\frac{V}{a}-2\lambda)$$

……

The running distance of vehicle N:

$$\tilde{S}_N(T)=\frac{V^2}{2a}+V(T-\frac{V}{a}-(N-1)\lambda)$$

So, the average speed $\overline{V}$ of the total N vehicles is:

$$\overline{V}=\frac{\tilde{S}_1(T)+\tilde{S}_2(T)+...+\tilde{S}_N(T)}{NT}$$

$$=\frac{N\frac{V^2}{2a}+NV(T-\frac{V}{a})-V(\lambda+2\lambda+...+(N-1)\lambda)}{NT}$$

$$=V-\frac{V^2}{2aT}-\frac{V}{2T}(N-1)\lambda \qquad (4)$$

From the formula (4), we can find that $\overline{V}$ is spliced by vehicle. Maximum speed limit V, the average speed $-\frac{V^2}{2aT}$ from the speeding up to uniform velocity, and $-\frac{V}{2T}(N-1)\lambda$, the average speed comes from the delayed reaction time of the entire motorcade drive Moreover, we get two inferences as follows:

1) The average running distance $\overline{S}$ of the total N vehicles.

$$\overline{S}=\frac{\tilde{S}_1(T)+\tilde{S}_2(T)+...+\tilde{S}_N(T)}{N}$$

$$=\frac{N\frac{V^2}{2a}+NV(T-\frac{V}{a})-V(\lambda+2\lambda+...+(N-1)\lambda)}{N}$$

$$=VT-\frac{V^2}{2a}-\frac{1}{2}V\lambda(N-1) \qquad (5)$$

2) The running distance of the N vehicles during the time T.

For vehicle 1, the running distance including OA is obtained by :

$$S_1(T) = S_a + V*(T - t_a) = \frac{V^2}{2a} + V*(T - \frac{V}{a}),$$

The running distance of vehicle N is defined as:

$$S_N(T) = (N-1)*(l+d) + OA,$$

So, the entire distance

$$D = (N-1)*(l+d) + \frac{V^2}{2a} + V*(T - \frac{V}{a})$$

$$= (N-1)*(l+d) + V*T - \frac{V^2}{2a} \quad (6)$$

Through the formula (4), we can get $\overline{V}$, then, compared with the record about the traffic jam boundary, we could figure out the level of congestion. Apparently, now the computation of $\overline{V}$ is simple, easy and regular.

3.3.3 The mathematical model of parking ability at an interaction

Question: When the red light at a traffic crossing began to light, free movement of vehicle team began to brake and slow them down, dock at the inside red line successively. If given a red light lasts for T_r seconds, how to determine the biggest parking ability as N_r / T_r of this route?

Obviously, the above question is a reverse process of the intersection traffic capacity in section 3.3.1, but not reversible. Through the actual observation, consult several traffic police and driver, as well as read the traffic rules, I found that when the red light start light, there will be a batch of vehicle simultaneously brake and stop, and the vehicle followed react successively and gradually stop. As shown in Fig.7.

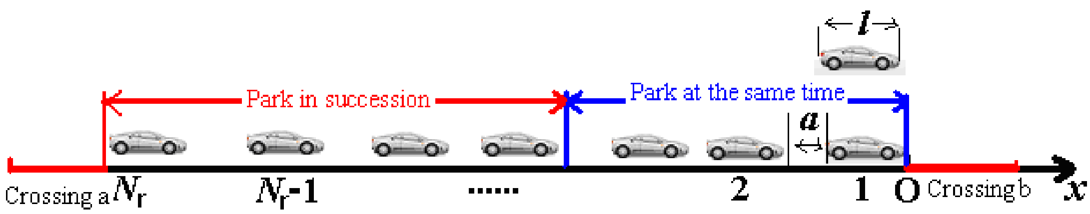


Fig. 7. Scheme of parking when the traffic light is red

Then, we further our analysis from two the following angles:

(a) The calculation of the number of cars that break and stop when the red light began to bright.

Suppose the driveway length between the two traffic intersection is L_{ab}, so the driveway have vehicle number as $\frac{L_{ab}}{l+d}$, l is the car length, d is the safe distance between two adjacent cars. If the parking probability in the same time is α, then, when the red light start to bright, the number of vehicles for parking at the same time is $\alpha\frac{L_{ab}}{l+d}$.

(b) The calculation of the numbers of the whole team parking when the right light continued to light for T_r.

The time history of the emergency braking process can be divided into two stages, that is the reaction phase and continuous braking stage.

If the reaction time of the drivers found danger signals all are λ', then, the total reaction time of the followed the cars are $\lambda'(N_r-\alpha\frac{L_{ab}}{l+d})$.

While each car slowed to stop requires time for $t_0=\frac{V}{a'}$, V is a constant speed, a' is the brake reducing speed. So the whole fleet began to slow to stop requires time for $(N_r-\alpha\frac{L_{ab}}{l+d}+1)t_0$.

In conclusion, the required time of the whole team stop is exactly equal to the red light duration, that is

$$(N_r-\alpha\frac{L_{ab}}{l+d}+1)t_0+\lambda'(N_r-\alpha\frac{L_{ab}}{l+d})=T_r$$

namely,

$$(N_r-\alpha\frac{L_{ab}}{l+d}+1)\frac{V}{a'}+\lambda'(N_r-\alpha\frac{L_{ab}}{l+d})=T_r$$

By the above equation, we can get when a red light lasts for T_r seconds, the stop running vehicles number in this section of driveway is:

$$N_r=\frac{T_r+\lambda'\alpha\frac{L_{ab}}{l+d}+\frac{V\alpha L_{ab}}{a'(l+d)}-\frac{V}{a'}}{\lambda'+\frac{V}{a'}} \tag{7}$$

We then do further analysis for Eq.7:

When the lights are red, the probability of vehicle parking at the same time in the driveway is $\alpha = 0$, parking ability in the lane is $N_r = \dfrac{T_r - \dfrac{V}{a'}}{\lambda' + \dfrac{V}{a'}}$, that is the red light time is evenly distributed to the second car to the N_r car, each car are accounted for the same reaction time λ' and braking deceleration time $\dfrac{V}{a'}$.

1) When the lights are red, the parking probability at the same time is bigger, and the number of the parking driveway mainly for $\dfrac{L_{ab}}{(l+d)}$.

(2) When the lights are red, if a car parking take nasty brake, namely, $a' = \infty$, hence, driveway parking ability are $N_r = \dfrac{T_r + \lambda' \alpha \dfrac{L_{ab}}{l+d}}{\lambda'} = \dfrac{T_r}{\lambda'} + \alpha \dfrac{L_{ab}}{l+d}$.

(3) Clearly, if the safe distance d between vehicles are big, the parking capacity is reduced, If a car length l is bigger, driveway parking ability is also reduced.

3.3.4The design scheme of traffic lights at the intersection

Firstly, the application of relevant mark in this section stated below T_g and T_r are the every cycle of green time (unit: seconds) in east-west direction respectively, and is a north-south red time for T_g (in seconds),too; the cycle of red lights per unit of time (in seconds)in East-west direction, also is a north-south green time for T_r (in seconds).

L_{ab} and L_{cd} are the length between the adjacent intersections for east-west or north-south, respectively.

α, β are the parking probability when the red lights bright.

d_a and d_b are the parking length for east-west and north-south respectively

When the vehicle run to a crossroad, under the control of traffic, may produce waiting time. If waiting for a long time, it is easy to appear traffic jam phenomenon. Therefore, how to reasonably design the traffic lights cycle and flexible distribution interval, ensure the waiting traffic queue of vehicles can safely through the intersection.

Then, we mainly do analysis on the traffic condition along the direction of north-south and the east-west direction through intersection, as shown in Fig. 7 ,the east-west direction is the main road and north-south direction is sub-road.

When the east-west red light (north-south green light) for T_r, the numbers of parking are $\dfrac{T_r + \lambda'\alpha \dfrac{L_{ab}}{l+d} + \dfrac{V\alpha L_{ab}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda' + \dfrac{V}{a'}}$, at the same time, The numbers of south-north traffic vehicles are $1 + \dfrac{T_r - \dfrac{V}{2a} - \dfrac{d_b}{V}}{\lambda + \dfrac{l+d}{V}}$.

When the east-west red light (north-south green light) for T_g, the number of parking is $1 + \dfrac{T_g - \dfrac{V}{2a} - \dfrac{d_a}{V}}{\lambda + \dfrac{l+d}{V}}$, at the same time, The number of south-north traffic vehicles is $\dfrac{T_g + \lambda'\beta \dfrac{L_{cd}}{l+d} + \dfrac{V\beta L_{cd}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda' + \dfrac{V}{a'}}$.

Then, in a traffic light cycle, make sure that the east-west and south-north queuing vehicles can safely through the intersection, it must satisfy the following relations

$$\begin{cases} 1 + \dfrac{T_g - \dfrac{V}{2a} - \dfrac{d_a}{V}}{\lambda' + \dfrac{l+d}{V}} \ge \dfrac{T_r + \lambda'\alpha \dfrac{L_{ab}}{l+d} + \dfrac{V\alpha L_{ab}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda + \dfrac{V}{a'}} \\ 1 + \dfrac{T_r - \dfrac{V}{2a} - \dfrac{d_b}{V}}{\lambda' + \dfrac{l+d}{V}} \ge \dfrac{T_g + \lambda'\beta \dfrac{L_{cd}}{l+d} + \dfrac{V\beta L_{cd}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda + \dfrac{V}{a'}} \end{cases} \tag{8}$$

Eq.(8) is the intersection traffic design scheme.

If the traffic jam appear in east-west direction, it means, the vehicle numbers stranded in a traffic light interval are

$$\overline{N} = \frac{T_r + \lambda'\alpha \dfrac{L_{ab}}{l+d} + \dfrac{V\alpha L_{ab}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda + \dfrac{V}{a'}} - \frac{T_g - \dfrac{V}{2a} - \dfrac{d_a}{V}}{\lambda' + \dfrac{l+d}{V}} - 1$$

if $N = 1 + \dfrac{T_g - \dfrac{V}{2a} - \dfrac{d_a}{V}}{\lambda' + \dfrac{l+d}{V}}$, hence, the average velocity in the east-west direction is

$$\begin{aligned} \overline{V} &= \frac{S_1(T_g) + S_2(T_g) + \cdots + S_N(T_g)}{(N + \overline{N})T_g} \\ &= \frac{N\dfrac{V^2}{2a} + NV(T_g - \dfrac{V}{a}) - V(\lambda + 2\lambda + \ldots + (N-1)\lambda)}{(N + \overline{N})T_g} \\ &= \frac{NVT_g - N\dfrac{V^2}{2a} - V\dfrac{N(N-1)}{2}\lambda}{(N + \overline{N})T_g} \end{aligned} \tag{9}$$

Because the stranded vehicles in T_g have zero speed, make the whole team's average speed less than Eq. (4).

· 3.4 Case Study——take the Street in Road Luoyu for example:

· 3.4.1 Traffic capacity of the Street

According to the formula（1）, We could get the traffic capacity

$$T = \frac{V}{2a} + (N-1)\lambda + \frac{OA + (N-1)(l+d)}{V}$$

According to the survey, we take the highest limited speed $V = 20km/h \approx 5.56m/s$（consulting the certain ratio of the average speed of taxis in Wuhan counted in Para 3.2）、the acceleration when vehicles start as $a = 2m/s^2$ 、response time of the drivers $\lambda = 1s$、green time in the Street $T \approx 65s$、the headway distance as $l + d \approx 5m$、distance between stop line $OA = 30m$.

We can get：

$$N = 1 + \left[T - \frac{V}{2a} - \frac{OA}{V}\right] / \left[\lambda + \frac{(l+d)}{V}\right]$$

According to the data, we can get:

$$N \approx 31$$

Hence, while traffic flow passes through intersection, the maximum numbers of cars in an hour is

$$N^* = 31 * n / 65 * 3600 \approx 1716n$$

Hence, the forecast of the traffic capacity of the Street is as follows:（result for the whole, errors allowed）:

Table 7：Forecast of the traffic capacity of the Street

Traffic lane	The largest number of vehicles per minute	Largest number of vehicles per hour
one-lane	29	1716
dual-lane	58	3433
3-lane	87	5150
4-lane	116	6867
5-lane	145	8584
6-lane	174	10302

Worthy to be paid attention, the traffic light vary periodically at the traffic crossing. Vehicles at the left side stop while the light at the left side is red. Just suppose that the vehicles at the right side run at this time (assuming the light is green at the right side).

Investigations show that there are about 6800 vehicles passed through during rush hour at the Street. Because the table above are the results of the traffic capacity without red light on, even if duration of green light takes half of the entire cycle time, the access capacity on six lanes is barely around 5150 per hour. As a result, the possibility of traffic jam at peak time is somewhat bigger.

In table 8, we give the access capacity in the Street when the green light time changes. (Keep other parameters as the same.)

Table 8：Relation table between duration of green light and access capacity

Duration of green light	Access capacity at one lane
60*s*	29
70*s*	34
80*s*	39
90*s*	44
100*s*	50
120*s*	60

It can be concluded that the longer green light is on, the more vehicles pass through; otherwise, more vehicles wait, the traffic jam could happen.

The analysis showed that, keep the other traffic situation stay the same, a single duration of green light at the intersection limits the real access capacity, moreover, it exhibited a linear relationship between them.

3.4.2 The parking ability at the interaction

Take time for red light at the intersection as $\boldsymbol{T_r} = 50\boldsymbol{s}$, the pilot brake reaction time as $\lambda' = 1\boldsymbol{s}$, the motor vehicle braking of reducing speed as $\boldsymbol{a'} = 5\boldsymbol{m/s}^2$, the headway distance as $\boldsymbol{l}+\boldsymbol{d} \approx 5\boldsymbol{m}$, and the length between the trade square station to intersection as $1000\boldsymbol{m}$, take the speed as $\boldsymbol{V} = 20\boldsymbol{km/h} \approx 5.56\boldsymbol{m/s}$, the red light brake probabilitity at the same time as $\alpha = 0.02$. With the parking ability formula (7), we can get

$$\boldsymbol{N_r} = \frac{\boldsymbol{T_r} + \lambda'\alpha\dfrac{\boldsymbol{L_{ab}}}{\boldsymbol{l}+\boldsymbol{d}} + \dfrac{\boldsymbol{V}\alpha\boldsymbol{L_{ab}}}{\boldsymbol{a'}(\boldsymbol{l}+\boldsymbol{d})} - \dfrac{\boldsymbol{V}}{\boldsymbol{a'}}}{\lambda' + \dfrac{\boldsymbol{V}}{\boldsymbol{a'}}}$$

$$= \frac{50 + 1*0.02*\dfrac{1000}{5} + \dfrac{5.56*0.02*1000}{5*5} - \dfrac{5.56}{5}}{1 + \dfrac{5.56}{5}}$$

$$= 27.2 \approx 28\,(\text{vehicles})$$

The following table are the different red light duration with the corresponding parking ability table. (other data do not change).

Table 9. the relationship between the red light duration and the parking ability

The red light time	Single driveway parking ability (vehicles)
50*s*	28
60*s*	32
70*s*	37
80*s*	42
90*s*	47
100*s*	51
120*s*	61

Compared with the Table 8，it can be found that, within the scope of the traffic light interval equally, the parking ability is slightly superior than transportation capacity. When a special situation occurs, such as bad weather, violate the traffic rules of pedestrians crossing the road, traffic violation, accidents and so on, it will make the "red light" continues for a long time, so they may appear serious traffic jam phenomenon.

・3.4.3 Grades of crowding in the Street

Based on the average speed of the vehicles passing through, we can distinguish the grades of crowding. From the formula (4), the average speed is:

$$\begin{aligned}\overline{\boldsymbol{V}} &= \boldsymbol{V} - \frac{\boldsymbol{V}^2}{2\boldsymbol{aT}} - \frac{\boldsymbol{V}}{2\boldsymbol{T}}(\boldsymbol{N}-1)\lambda \\ &= 5.56 - \frac{5.56*5.56}{2*2*65} - \frac{5.56}{2*65}*(31-1)*1 \\ &= 4.158\boldsymbol{m/s} \approx 15\boldsymbol{km/h}\end{aligned}$$

Explaining that the Street lay in the grade（$10 \le 15 < 20$）. If the traffic lies in the severely crowd situation, then average speed $\overline{\boldsymbol{V}} \le 10\boldsymbol{km/h}$，about $2.78\boldsymbol{m/s}$，substituting it into formula（4），we got

$$\begin{aligned}2.78 &= \boldsymbol{V} - \frac{\boldsymbol{V}^2}{2\boldsymbol{aT}} - \frac{\boldsymbol{V}}{2\boldsymbol{T}}(\boldsymbol{N}-1)\lambda \\ &= 5.56 - \frac{5.56*5.56}{2*2*65} - \frac{5.56}{2*65}*(\boldsymbol{N}-1)*1\end{aligned}$$

Calculate the equation above, we can get：

$$\boldsymbol{N} = 63$$

The average speed is

$$\begin{aligned}\overline{\boldsymbol{V}} &= \boldsymbol{V} - \frac{\boldsymbol{V}^2}{2\boldsymbol{aT}} - \frac{\boldsymbol{V}}{2\boldsymbol{T}}(\boldsymbol{N}-1)\lambda \\ &= 5.56 - \frac{5.56*5.56}{2*2*65} - \frac{5.56}{2*65}*(63-1)*1 \\ &= 2.789\boldsymbol{m/s} \approx 10\boldsymbol{km/h}\end{aligned}$$

When there are 63 vehicles on road and duration of green light is 65s. About 32 vehicles wait for the second or third green light, average speed is $10\boldsymbol{km/h}$, road traffic is in severely crowd.

The analysis shows that keeping other traffic situation stay the same, a smooth road is determined by the real access capacity of the intersection. However, a single duration of green light of the intersection also limits it, thus we must timely adjust the duration of traffic light, and then relieve the problem of traffic jams.

Part IV　Popularize the rational model from two sides

・4.1 The Traffic capacity in any section of the road and the grades of crowding

In the previous, we have got the shortest duration of green light

$$T = \frac{V}{2a} + (N-1)\lambda + \frac{OA + (N-1)(l+d)}{V},$$

which means that the traffic capacity of road is N/T.

While the distance between two stop lines $OA = 0$, it explains that N/T is exactly the traffic capacity in a section of road. Then we can get,

$$T = \frac{V}{2a} + (N-1)\lambda + \frac{(N-1)(l+d)}{V} \quad (10)$$

while the data in para.3.4.1 remaining unchangeable, we can get:

$$65 = \frac{5.56}{2*2} + (N-1)*1 + \frac{(N-1)*5}{5.56}$$

While the green light continues $65s$, in a certain section of the road, there is totally $N \approx 34$. From which we can find that at the same scale of time, a certain section allows bigger traffic capacity than the intersection, this accounts that conflict point or obstacle on road will lower the traffic capacity.

・4.2 Grades of crowding for the entire road

Having got the traffic capacity in every intersection and certain section of road, we could get the average speed of vehicles in any location, and then we can get the grade of crowding based on the speed, finally, we can get the grade of the whole road.

For example,

The average speed at every intersection and sectional part of road are $\bar{v}_1, \bar{v}_2, ..., \bar{v}_n$, and give out the grades, respectively, $t_1, t_2, ..., t_n$, so, grade of the entire road is $\frac{t_1 + t_2 + ... + t_n}{n}$.

・Part V　Conclusion and looking ahead

Taking the Luoyu Road in Wuhan City as the research object, we adopt three measures, which are follow-up survey, random searching and questionnaire survey, by comprehensively surveying the traffic′s running condition from “drivers, vehicles and roads”、 " point, line and scale " , to build the rational model.

The result of this item were evidenced are follows:

(1) Taking the intersection as the cutting point of the research, we get the internal

relation between the traffic capacity N/T and the intervals T :

$$T = \frac{V}{2a} + (N-1)\lambda + \frac{OA + (N-1)(l+d)}{V}$$

From the relationship between N/T and T, we can find that the intervals of the traffic light limit the real traffic capacity in the intersection, and the time of traffic light should be adjusted based on the traffic situation.

(2) The formula on the total stopped vehicle number during light duration of traffic for T_r was set up $N_r = \dfrac{T_r + \lambda'\alpha \dfrac{L_{ab}}{l+d} + \dfrac{V\alpha L_{ab}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda' + \dfrac{V}{a'}}$. Moreover, the traffic light time design plan and theoretical foundation in a lane were given

$$\begin{cases} 1 + \dfrac{T_g - \dfrac{V}{2a} - \dfrac{d_a}{V}}{\lambda' + \dfrac{l+d}{V}} \geq \dfrac{T_r + \lambda'\alpha \dfrac{L_{ab}}{l+d} + \dfrac{V\alpha L_{ab}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda + \dfrac{V}{a'}} \\ 1 + \dfrac{T_r - \dfrac{V}{2a} - \dfrac{d_b}{V}}{\lambda' + \dfrac{l+d}{V}} \geq \dfrac{T_g + \lambda'\beta \dfrac{L_{cd}}{l+d} + \dfrac{V\beta L_{cd}}{a'(l+d)} - \dfrac{V}{a'}}{\lambda + \dfrac{V}{a'}} \end{cases}$$

(3) The rational model of grades of the intersection is as follows:

$$\overline{V} = V - \frac{V^2}{2aT} - \frac{V}{2T}(N-1)\lambda$$

While the distance between the two stop lines $OA = 0$, the model could evaluate the grade of any sectional part. So we can find that a smooth road is determined by the real access capacity of the intersection. The computation of this model is simple, easy and practical.

(4) We also calculate the grades of the Street, and conclude that within 65s, the capacity of vehicles is 31, average speed is $15km/h$, from which we can get a situation of traffic jam. While the capacity of vehicles is 63, the average speed is $10km/h$, the it is in a severe crowding,so we have to adjust the cycle of traffic light in such situation.

(5) In addition, we designed a survey for resident trip, and collected the receipt of taxis in the latest three years, to statistic and analysis the taxi's running situation in these three years, we can get such a conclusion that the traffic jam is still a bottleneck of the economics and traffic' development in Wuhan.

This item offers some scientific foundation for Road Traffic Control department of Wuhan to relieve the stress of traffic jam and make more effective measure, meanwhile, This item also offers some convenience for passengers to choose to bypass the congestion of the road, which is worth to be spread.

Of course, with the limits of time, material, means and so on, there still exist lots of details which should be deeper deliberated and explored, such as the relationship among crowding, time, address, type and extent. How to take these into consideration, how to build a more real—reflection model, are still worthy to discuss further.

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