# Traffic flow simulation study under large gathering activities based on VISSIM

Xiangcheng Li*

School of Transportation Engineering, Dalian Jiaotong University, Dalian, China, 116028

* Corresponding Author Email: lixiangchengbravo@163.com

**Abstract.** Based on the above background, this paper starts from the theory of traffic flow and the macro-basic diagram, and simulates and researches the traffic congestion problems generated in the period of large-scale gathering activities during festivals. First of all, this paper summarizes the time correlation and spatial correlation of traffic flow, analyses the judgement method and rating index of traffic congestion, and completes the macroscopic basic map; after defining the simulation parameters of each road segment and signal intersection in the road network, it is implemented by using the VISSIM simulation software; finally, it carries out the simulation analysis with the example of the New Year's Eve firework display at the Chaotianmen Gate in Chongqing, and calculates and analyses the traffic flow state of the road network with output data, and then compares the output data with that of the road network. Finally, we use the output data to calculate and analyses the traffic flow status of the road network, compare it with the traffic flow data under the smooth period, judge the congestion characteristics, draw the macroscopic basic map of the road network under each period, simulate the changes of the macroscopic basic map, analyses the impact of traffic congestion on the traffic flow of the road network, calculate the degree of improvement of the traffic status of the network, and put forward the reasonable optimization scheme to provide a decision-making basis for the evacuation of the traffic under the festival and large-scale gathering activities.

**Keywords:** Traffic Flow, Large-scale Gathering Activities, Traffic Congestion, Macro Base Map, VISSIM Simulation.

## 1. Introduction

With the rapid take-off of China's economy in recent years, the domestic per capita motor vehicle ownership has also been steadily increased. According to the data released by the Ministry of Public Security, China's motor vehicle ownership has grown from 96 million in 2003 to 417 million in 2022, of which the number of cars has reached 302 million, an increase of nearly 1,258.3 per cent compared to 2003, and the average annual growth rate of car and motor vehicle ownership has exceeded 10 per cent. In addition, the number of road kilometers and car ownership data published by the National Bureau of Statistics also show [1] that the number of domestic road kilometers has been growing steadily, from 345.7 million kilometers in 2006 to 528.07 million kilometers in 2021, with an average annual growth rate of about 2.86%. This has also led to a gradual increase in the pressure on traffic relief in cities and populated areas in China, especially when a large number of residents move in a certain purposeful manner under certain specific large-scale gathering activities, and traffic congestion seems to have become an inevitable phenomenon. Motor vehicles in bringing people the convenience of life at the same time, the congestion problem also led to traffic demand and road network carrying capacity imbalance, affecting the quality of life of residents and socio-economic development [2-3].

Under the high-speed development of the domestic economy and transport, residents pursue spiritual satisfaction and enjoyment of entertainment, the number of annual domestic travel has increased significantly, and most of them are concentrated in various types of holidays, during such periods, traffic congestion and other types of accidents causing casualties or affecting the normal life of the residents in recent years have also occurred from time to time [4-5]. For example, on New Year's Eve, 31 December 2014, a major stampede occurred in Chen Yi Square on the Bund in Shanghai due to congestion. Although the cause of the accident has not been officially disclosed, the accident caused 36 deaths and 49 injuries. The accident has attracted widespread attention from all sectors of society and relevant state departments. By studying the causes of congestion during specific festivals and simulating the state of the traffic network during special periods, it is possible to understand and prevent congestion during festivals at this stage [6].

At present, with the domestic residents of motor vehicle ownership continues to increase and the desire of residents to travel. In a particular period of time under the large gathering activities, it is difficult to avoid will face more serious congestion problems. This type of congestion will not only affect the experience and mood of the event participants themselves, to a certain extent, but also for the local neighborhood of the residents in their daily lives have a more obvious impact. For the congestion itself, prolonged congestion increases the likelihood of traffic accidents.

In order to avoid more serious congestion and serious accidents caused by congestion under future large-scale gathering activities, this paper understands and analyses the causes and characteristics of congestion in this type of situation from a macro level, as well as the overall impact of the gathering of people in some areas on the road network, which can provide ideas for the realization of the problem of traffic congestion and prevention methods. On the basis of ensuring the efficiency of road commuting, the formation and duration of congestion can be avoided as much as possible, in order to cope with the pressure of traffic commuting under the gradually increasing festivals, and to provide the necessary theoretical support for the handling of traffic flow under the large-scale gathering activities.

In this paper, we use VISSIM to simulate the road network around the large-scale gathering activities and analyses the characteristics of congestion in this environment by analyzing the changes of Macroscopic Fundamental Diagram (MFD), and at the same time, we provide theoretical support for the Intelligent Transportation System (ITS) to deal with the traffic flow under the festival by certain macroscopic research. Transportation System (ITS) for the traffic network state and prediction of the relevant research to provide solutions and basis.

Urban road network and traffic flow have been paid attention by scholars and research institutions since the beginning of the last century, and the problem of traffic congestion has been widely discussed. In order to describe the causes of traffic congestion, current research is mainly based on the traffic wave theory to analyses the diffusion and propagation process of traffic congestion. Frances [7] evaluated the traffic congestion control strategies in the study area in 2018, and found that the causes of traffic congestion are due to drivers' unregulated driving styles, unregulated road design, and impediments to social and economic development. Qiuxia [8] found that traffic congestion is caused by the unregulated driving styles and unregulated road design, and impeded social and economic development. economic development. Qiuxia [8] in 2019 analyzed the congestion status and congestion characteristics of the road network area based on the acquired traffic congestion index (TPI), which is important for the study of congestion propagation in the road network. At home and abroad, the research on traffic congestion and the causes of traffic congestion lack of corresponding conclusions, and most of the research is still in the stage of simulation research using relevant software. Especially for the holiday period, major scenic spots and activities facing the more serious problem of pedestrian and traffic congestion; for the theory of traffic flow and the driving behavior of the two cars, the lack of a certain scale of road network macro research and analysis.

## 2. The fundamental of data analysis

Traffic flow, i.e., the flow of vehicles (in a broader sense, it can also be composed of pedestrian and vehicular traffic) that is formed by the continuous movement of vehicles on the road. The use of physical and mathematical laws to describe the characteristics of traffic flow can better analyses the various phenomena and characteristics of road traffic and improve the overall efficiency of the road network. The resulting traffic flow theory is also used as the basic theory of traffic engineering, which is widely used in various related fields such as traffic planning, traffic control and road and traffic engineering. Due to the complex road network, the traffic flow will be affected by intersection signals and other lateral cross-influence factors, so it will be intermittent with the change of the road network state. In order to accurately describe the characteristics of traffic flow, traffic flow theory generally uses traffic flow, traffic speed (referred to as "speed") and traffic density of the three parameters to quantitatively describe it, and the resulting data is an important parameter for solving traffic congestion problems [9-10].

With the continuous development of the social economy, the increase in the demand for travelling by residents has led to the problem of traffic congestion gradually becoming a social norm. Some of the problems overlooked in the initial road design have been highlighted as important causes of congestion and imbalance between supply and demand structures. Therefore, the alleviation and management of traffic congestion is still an important issue for each country at this stage.

As the concept of traffic congestion is relatively subjective and abstract, it is difficult to give a reasonable and accepted definition, and there is no uniform standard among countries. The subjectivity of traffic congestion is limited by the differences in different areas, such as in Beijing city, if the vehicle can run for a certain period of time, that is to say, the traffic state is normal; on the other hand, for the relatively low density of traffic in the city or region, if the traffic cannot be driven according to the speed of the normal traffic can be apparent that the traffic is relatively congested.

Internationally, take the United States as an example, in the Highway Capacity Manual compiled by the U.S. Transportation Commission, congested traffic is defined as traffic with speeds lower than 22km/h; and in 35 cities in California, the United States has adopted the Lane Kilometer Duration Index (LKDIF) for periodic traffic congestion. ) for periodic evaluation of the degree of traffic congestion, which is jointly influenced by the length and time of traffic congestion on each specific road section, the evaluation of congestion standards: the average traffic volume and road capacity ratio (ADDT/C) is greater than 9.0 or V/C is greater than 1.0, the traffic is in a congested state.

Domestic mainstream definition of traffic congestion is mainly with reference to the "urban road traffic congestion evaluation index" for the classification of congestion, which is divided into five levels according to the difference in the speed of the traffic flow, and different types of roads with reference to the value of the specific speed will also be different. Generally, the traffic flow without traffic lights more than 250m or make the vehicle failed to drive away from the intersection for three consecutive green lights become traffic congestion.

VISSIM (also known as PTV-VISSIM) is a microscopic simulation tool based on driving behavior and time intervals, which can be mainly used to simulate the operation of traffic flow in road networks under various conditions, and it is an effective tool for simulation and evaluation of design schemes and road network planning. For the simulation process of traffic flow, in addition to the 2D state of the road network display, VISSIM simulation software can be more clearly from the 3D level to show the construction of the road network and road network simulation of traffic flow.

VISSIM software can be divided into two parts: traffic simulator and signal state generator, in which the traffic simulator is a microscopic traffic simulation model, including the following model and lane change model; the signal state generator is a signal control software that realizes the logical control of the traffic flow through the program, which belongs to the data detected under a discrete time interval (0.1 to 1 second) in the road network to determine the data of the next simulation second, which can be used to determine the data of the next simulation second, which can be used to determine the data of the next simulation second. to determine the signal state for the next simulation second. The synergy between the two components ensures that the visualization of the traffic state can be generated while the state data of the network traffic (e.g., average speed of traffic, average number of stops, etc.) can be recorded offline after each simulation, and the arithmetic mean of such data can be obtained for multiple simulations.

# 3. Simulation Analysis

## 3.1. The establishment of data computation

Due to the excellence and accuracy of VISSIM in simulating traffic flows on given types of road networks, it is nowadays widely recognized and used in academic and scientific research on traffic flow simulation. The main areas where VISSIM is used can be summarized as follows:

(1) Impact analysis of path guidance and variable message signs;

(2) Analysis of ramp control operations;

(3) Analysis of toll collection facilities;

(4) Capacity analysis and testing of bus priority schemes;

(5) Design, testing, and evaluation of vehicle-inspired signal control.

It should be noted that the VISSIM simulation software is divided into version 4.3 and Student version (version 5.0 and above are this version). In the Student version, the simulation path length is limited to 1km, and the simulation time is limited to 600 simulation seconds, which makes the simulation under the road network affected by the scale and time, and the simulation of some experiments needs to be carried out on the basis of setting up prerequisites.

## 3.2. Indicators for evaluating traffic congestion on inter-district road sections

The recommended standard for traffic congestion in China mainly refers to the "Road Traffic Congestion Evaluation Method" (GA/T 115-2020) issued by the Technical Supervision Committee of the Ministry of Public Security of China in 2020, which was revised and optimized from the "Road Traffic Congestion Evaluation Method" (GA 115-1995), and started to be implemented from 1 October 2020 onwards. This version of the document in addition to the classification of the type of road, but also introduced the intersection traffic congestion by the maximum average delay, the maximum queuing time index evaluation, traffic congestion evaluation of intermediate road sections, such as road intersections and intermediate sections of the traffic congestion evaluation parameters and methods.

The document involves for the relevant congestion terminology is defined as [25]: traffic congestion, that is, due to the demand for vehicle access over the road capacity or by traffic events and other impacts, vehicles are forced to reduce the speed of driving or to stop, and cause the vehicle backlog of more than a certain degree of traffic phenomena; traffic congestion, used to measure the degree of traffic congestion can be divided into I, II, III and IV, respectively, said that severe congestion (red), moderate congestion (orange), mild congestion (yellow) and smooth (green); interval section, that is, the road between the two endpoints on the road with directional road section, which does not contain intersections; intersection average delay, is the average time loss of vehicles in the process of passing through the intersection; queuing length, that is, the length of the vehicle queue from the intersection of the stop line or the queuing start to the queue at the end of the queue; intersection queuing time, that is, intersection queuing time, that is, the vehicle queue from the stop line or queuing start to the end of the queuing between length; intersection queuing time, which is the time spent by queuing vehicles at an intersection from the time they first stop until they pass through the inlet lane stop line; queuing time index, which is the ratio of the vehicle queuing time at a signalized intersection to the signal control period; and queuing overflow, which is a traffic phenomenon in which the queue of vehicles at a downstream intersection spreads to an upstream intersection.

When evaluating the congestion peak based on the time unit of peak period, day, week, month, quarter and year, the high congestion period generally adopts the average value of the most congested 30min during the time period; the daily traffic congestion is taken as the maximum value of the traffic congestion under different time periods of a day; the weekly and monthly traffic congestion is taken as the average value of the daily traffic congestion within the week and the month; and the quarterly and annual traffic congestion is taken as the average value of the daily traffic congestion in the quarterly and yearly traffic congestion is the average of the monthly traffic congestion within the quarter and year. For the evaluation of traffic congestion at intersections with the maximum average vehicle delay, maximum queuing time index, and traffic congestion in inter-area road sections, the average vehicle travelling speed in the road section is generally used as the benchmark.

When evaluating the traffic congestion under each intersection, the two main indicators involved are maximum average vehicle delay and maximum queuing time. The maximum average vehicle delay is determined by manual survey methods such as the sample method, license plate method and intelligent traffic measurement equipment. When the sample method, license plate method and other manual investigation methods are selected, it should be ensured that the minimum vehicle sample of each inlet road is more than 30 vehicles; if the traffic flow of the inlet road is less, it should be ensured that the continuous sampling time is more than 5 times the length of the signal cycle, and the calculation method is as follows:

$$\overline{D}_{\max} = \max\left\{\overline{d}_1, \overline{d}_2, \cdots, \overline{d}_i, \cdots, \overline{d}_n\right\} \tag{1}$$

Where$\overline{D}_{max}$ denotes the maximum average vehicle delay in seconds (s); $\bar{d}_i$is the average vehicle delay in seconds (s) at the ith inlet lane during the time period; and n is the number of inlet lanes.

The maximum queuing time is mainly measured by manual survey method, in the evaluation time interval, continuous observation of vehicles in the inlet road in and out of the state, record in each time the vehicle queuing to reach the maximum queuing time at the intersection of the vehicle at the end of the queue, the maximum queuing time of the maximum value of the time interval recorded; if you take the method of the investigation of the record of the intelligent traffic equipment, and at the same time record the inlet road If the method of intelligent traffic equipment record survey is adopted, the vehicle queuing time of each inlet road is recorded at the same time and its maximum value is taken as the maximum queuing time of the intersection; when choosing the sample for evaluation, the faulty or scrapped vehicles as well as the accidental vehicles should be ignored voluntarily, and its maximum queuing time index is calculated as follows:

$$QTI_{\max} = \max\left(QTI_i\right) = \max\left(\frac{T_i}{C}\right) \tag{2}$$

Where $QTI_{max}$ denotes the maximum queuing time index; $QTI_i$ is the queuing time index of the ith inlet lane in the time period; $T_i$ denotes the queuing time of the ith inlet lane in the time period in seconds (s); and C is the average control period of the signals, which is taken as the average signal duration of the first three cycles of the cycle in which the vehicle is located when it passes through the stop line, in seconds (s).

When evaluating traffic congestion on the scale of an inter-segment road section, it is necessary to take into account the changes in the average travel speed of vehicles on the road section. The sample size required to determine the speed will be affected by the number of lanes in the interval road section, generally speaking, the sample size of vehicles should be greater than 10 times the total number of lanes in the interval road section. If the interval section has a speed limit value, should be in accordance with the actual road vehicles under the normal speed limit value shall prevail; and when the interval section of the road without a clear speed limit provision, need to be determined in accordance with relevant laws and regulations. In addition, attention should also be paid to the diversity of the survey sample, and the data of all ordinary vehicles should be recorded, but special vehicles such as police cars, sprinklers, ambulances and so on should be ignored, and their average travelling speeds are calculated as follows:

$$\bar{v} = \frac{nL}{\sum_{i=1}^{n} t_i} \tag{3}$$

where $\bar{v}$ is the average travelling speed of the vehicle in the interval section in kilometres per hour (km/h); L is the length of the interval section (excluding road intersections) in kilometers (km);

$t_i$ denotes the time for vehicle i to pass through the interval section in hours (h); and n is the number of vehicles measured in the experimental record.

The evaluation of traffic congestion under the scale of roads and road networks is mainly carried out with reference to the journey time ratios given in 7.2.2, 7.2.3 and 8.2 of GB/T 33171-2016, and the larger the ratio is to symbolize that the traffic situation of the road and road network is worse, which is calculated as follows:

$$TTI_{kj} = \frac{\overline{t_{kj}}}{t_j^f}, \overline{t_{kj}} = \frac{l_j}{v_{kj}} = \frac{\sum_{j=1}^{n} t_{kj}}{n} \tag{4}$$

Where $TTI_{kj}$ is the travel time ratio of road j under time period k; $\bar{t}_{kj}$ denotes the average time consumed to pass through road j during time period k; $t_j^f$ is the time consumed to pass through road j under the free-flow condition (TTI=1); and n denotes the number of vehicles travelling on the road and in the road network.

### 3.3. Analysis of simulation results

Since each section of the road network belongs to the topological structure model, for the establishment of the road structure in the road network, it is necessary to consider the reasonable length of the road, the number of lanes and the width of each lane; in the three-dimensional direction, it is possible to set the height and thickness of the road, to complete the simulation of overpasses, viaducts and other special roads. Under the signal interval of a traffic intersection, VISSIM can be used to set the light pattern of the signal and the presence time of each light pattern in each signal cycle. In addition to the traditional red-green-yellow, the light patterns can be set to red-red/yellow-green-yellow, red-green, red-red/yellow-green flashing-green-yellow, etc. After selecting the light type, the cycle and phase of the signal can be set, and the phase of the signal needs to be reasonably designed according to the traffic flow of each road section. Between two adjacent intersections, it is necessary to calculate the running time of the traffic flow in the intervening road section, and set a reasonable phase difference between the two signal models to ensure that the vehicles entering from the green light at the upstream intersection can meet the green light at the downstream intersection just in time. After completing the road network modelling, vehicle paths should be set up between road intersections, and the decision-making of vehicle paths can determine the proportion of vehicles turning into roads in each direction. Vehicle behavior models in VISSIM include the following model and the changing model, and the following behavior of vehicles is divided into two kinds: Wiedemann99 and Wiedemann74. Generally speaking, the following model is commonly used in single-lane roads, while the lane-changing model is used in multi-lane roads. After the relevant layouts of the road network are completed, specific road sections can be selected as vehicle inputs. The amount of vehicle input generally depends on the actual traffic flow of the simulated road network, or the theoretical traffic flow of the network obtained by mathematical calculations based on the relationship between the length of the network and the average length of vehicles in a certain proportion.

VISSIM-based simulation is more convenient and less costly than the field study of traffic flow in the road network. After importing the relevant road network map, VISSIM can reasonably simulate the traffic flow situation and related data of the road network, and the closer the various parameters are to the actual value, the more accurate the simulation results are. Generally speaking, the intersections with signals in the main urban area can be divided into two categories: intersections of main roads and arterial roads, and intersections of arterial roads and branch roads. In order to make the simulation close to the reality while ensuring the operational efficiency and accuracy of traffic flow in the road network, the study defines the main road as a four-lane road and the branch road as a two-lane road. Their respective intersection states are shown in Figure 2. In the elevated area, since the road has the height of Z-axis in 3D space, the elevated road in the road network should be avoided to conflict with the traffic flow in the normal road, so it should be given a certain amount of Z-axis offset and 3D thickness. In the study, in order to facilitate the control of the road network, the height of the elevated road is defined as 6 m, and the thickness is 0.4 m. The roundabout in the road is a special kind of traffic node, which is a kind of planar road crossing form. The application of roundabouts can reduce traffic conflict points without the need for signals and viaducts. Generally speaking, a roundabout in a road network needs to contain four entrances and exits, a circular driveway and a center road in three parts, and traffic entering and exiting the roundabout generally needs to yield to the traffic in the roundabout. Figure 1 is the road simulation for non-holiday and Figure 2 is the road simulation for holiday, the image we depicted by simulating the actual road condition is shown below.

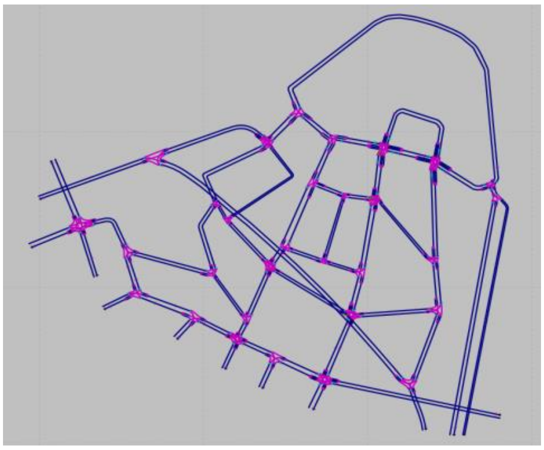

**Figure 1.** Simulation of roads on non-holiday days

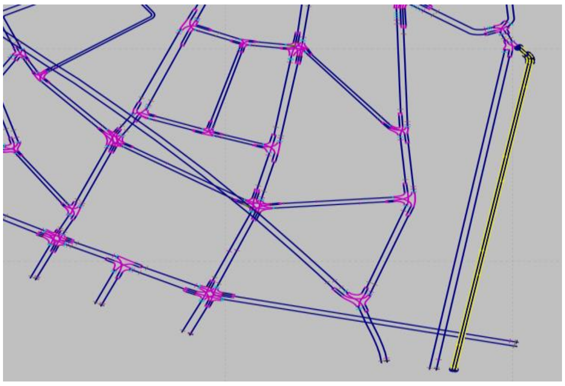

**Figure 2.** Road simulation for holidays

We optimize the average speed of the traffic flow and compare it with the average speed of the traffic flow in the smooth period and the congested period of the gathering activities, and it can be found that, after adopting the optimization scheme, the average speed of the traffic flow in the road network has a more obvious enhancement compared with the average speed of the congested period of the gathering activities, and the enhancement range is around 10km/h; meanwhile, in the two scenarios, completely adopting the bus to transport the passengers has a greater enhancement range of the average speed of the traffic flow in the road network, and the value of the average speed of the traffic flow in the network is more close to that of the average speed of the traffic flow in the smooth period after the traffic flow is stabilized by the simulation, as shown in Figure 3.

The variation of the travel time ratio in the road network after we take the optimisation scheme is shown in Figure 4. After the simulated traffic is stabilised on the road network, the values of the travel time ratio of the traffic on the road network after taking the two schemes have the same value, which is in the range of about 1.4 to 1.7. In most periods of the simulation, the travel time ratio stays below 1.6, and the traffic in the road network basically stays smooth, which is a more obvious improvement compared to the travel time ratio (1.8 to 2.0) and traffic congestion (moderate congestion) under the congested period of the aggregated activities, which makes the traffic congestion of the road network closer to the value of the smooth period.

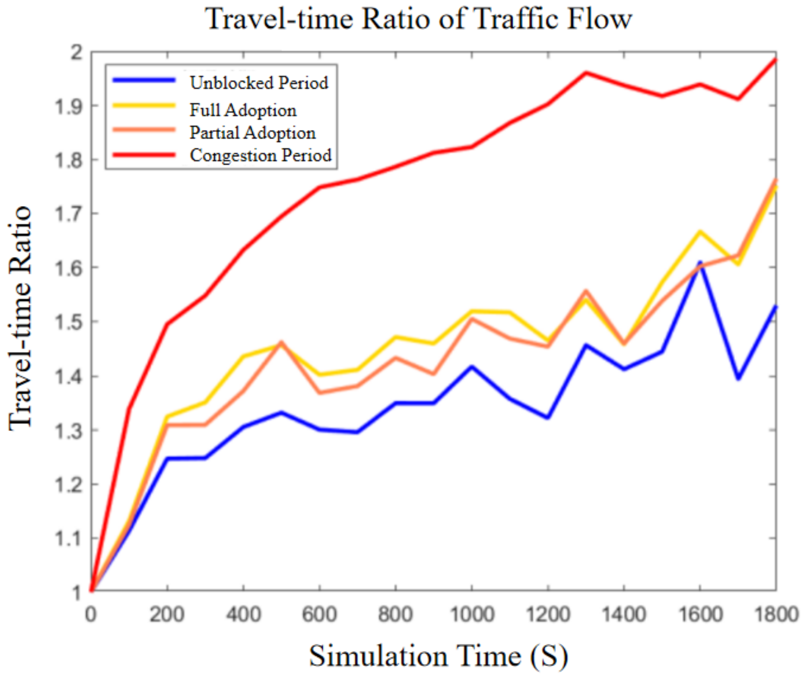


**Figure 3.** Average speed of traffic on the network after adoption of the optimization scheme

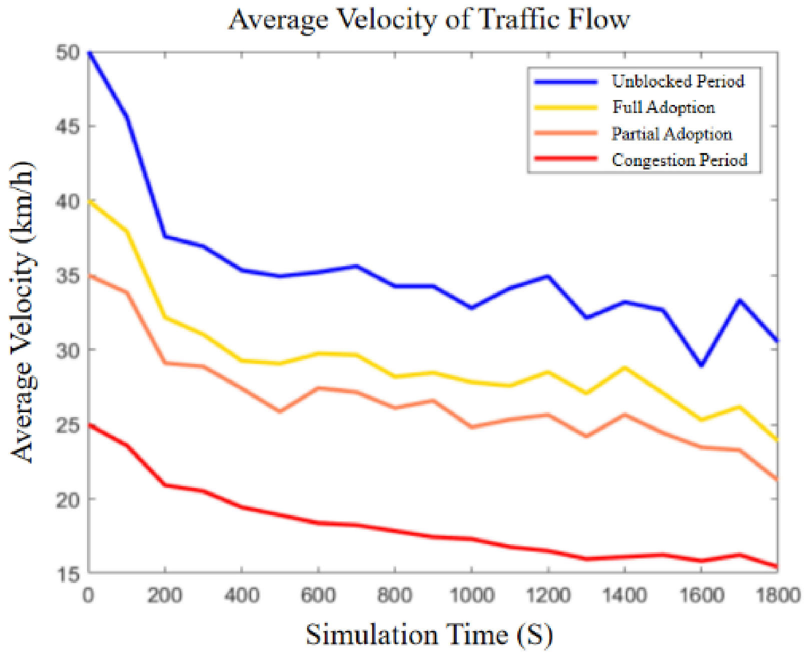


**Figure 4.** Journey time ratios of traffic flows on the network after the adoption of the optimization scheme

## 4. Conclusions

With the increasing number of motor vehicles in China and the growing desire of residents to travel, the congestion problem generated during specific festivals or events has become an unavoidable phenomenon. Therefore, this paper takes large gathering activities as the background, builds a simulation model based on VISSIM simulation software, understands and analyses the characteristics of traffic flow and the formation of traffic congestion under the occasions of festivals where people gather, observes the changes of MFD diagrams compared to normal conditions at the same time, and carries out a case study based on the example of the New Year's Eve fireworks display at Chaotianmen in Chongqing, to provide certain ideas and measures for the study of evacuating traffic congestion.

The simulation experiments conducted in this paper only focus on gathering activity locations with only one-way traffic input, and only the surge of traffic and the change of traffic path decision in the road network are investigated, ignoring the impact of the objective and purely human flow changes. Future research can choose more diversified gathering activity locations, and should consider the changes in pedestrian flow and the possibility of activity for lane occupancy, and introduce the real-time data of the road network to increase the reliability and reasonableness of the simulation study. In future research, signal chaining and machine learning can be introduced to find the optimal signal timing scheme for the road network under different traffic and pedestrian flow changes.

## References

[1] National Bureau of Statistics. China Statistical Yearbook [M], Beijing: China Statistics Press, 2021.

[2] Liu Jie, Nie Xiangbo. Research on the status quo of traffic congestion management in some cities of China and analysis of countermeasures[J]. Times Automobile, 2023, (13): 181-183.

[3] Wei Jingnan. Analysis on the Degree of Traffic Congestion and Influencing Factors in China's Cities--Based on the Perspective of Road Traffic Supply and Demand Balance [J]. Journal of Liaoning University of Technology (Social Science Edition), 2023, 25(02): 36-40.

[4] HUANG Cuixiang, ZHANG Wei, XU Di. Impact of bicycle sharing on traffic congestion in major cities in China [J]. Transport Systems Engineering and Information, 2023, 23(02): 300-306.

[5] WEI Jingnan, SAN Yongjuan. Has urban depopulation eased traffic congestion? --Taking 35 major cities in China as an example [J]. Journal of Northwest Normal University (Natural Science Edition), 2022, 58(06): 54-60.

[6] Cheng Dongxiang. Urban transport and low carbon development [M]. Nanjing Southeast University Press:, 202112.214.

[7] Frances Agyapong, Thomas Kolawole Ojo.Managing traffic congestion in the Accra Central Market Ghana[J].JournalofU1ban Management,2018,7(2)184-18.

[8] Quxia SunYixin Sun,Lu SunQing Li,JianliZhao,Yu Zhang,Hao He.Rese arch on traffic congestion characteristics of city business circles based on TPI data:The case of Qingdao China[J].Physic a A Statistical Mechanics and it Applications,2019534(C)1234-1236.

[9] Zhao Guo. Research on urban traffic congestion management countermeasures [D]. South China University of Technology, 2021.

[10] Zhong Zeging. Research on urban traffic congestion [D]. Xinjiang Agricultural University, 2020.