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Countermeasure Study of Urban Traffic Improvement Based on the Internet of Things

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ABSTRACT In order to reduce the fluctuations of traffic flow and the impacts of traffic flow fluctuations, thereby increasing the level of service of roads and constructing the Internet of Things-based traffic system, based on the various causes of traffic flow fluctuations, the countermeasures were taken, such as the optimization of lanes, the management of intersections, the improvement and perfection of slow-vehicle lanes and bus stops, the timely renewal of traffic signs and marks, the rational arrangements of road operations, and the removal of visual obstacles, etc. The research results showed that these countermeasures could effectively reduce the hidden peril of accidents and improve the road capacity, thereby improving the level of service of roads, which provided a theoretical foundation and basis for road engineering design and traffic management. It can be seen that improving urban traffic through rational management and control measures can effectively improve the level of service of urban traffic.

INDEX TERMS Urban road, traffic flow fluctuation, level of service, countermeasure.

I. INTRODUCTION

Traffic is the position movement of people and objects in space, which is important in any corner of the world. As far as Chinese people concerned, there have been 4 primary events in the livelihood since ancient times, namely clothes, food, houses, and transportation [1]. Transportation is traffic. First of all, the daily lives of people are closely related to transportation and traffic; the fast and convenient means of transportation can greatly expand the range of transportation and activitie. s of people and maximize the utilization of current resources [2]. Transportation leads to communication, communication leads to connection, connection leads to exchange, exchange leads to consumption, and consumption promotes the social production and distribution. The degree of convenience of transportation modes affects the costs of product circulation; meanwhile, it also restricts the flow direction of economic capital [3].

With the growth of urban population and automobiles, the traffic pressure on urban roads is increasing. The development of urban rail transit and the promotion of green transportation still cannot eliminate the trend of increasingly crowded road traffic [4]. The expansion of current roads and the acceleration of trunk roads are all restricted by urban land and require the investment of various capital and human resources, bringing great pressures on local finances. In addition, the process of road reconstruction and engineering causes traffic congestion in a long period of time in the construction area [5]. Through countermeasures such as the local transformation and optimization of traffic management, the traffic efficiency of current roads can be improved given current conditions, thereby reducing the potential safety hazards, avoiding the adverse effects caused by large-scale reconstruction and expansion, and greatly decreasing the capital investment; in terms of newly constructed roads, if the details that are favorable for traffic management are considered, the expected operational effects of the road are easier to be achieved [6].

The Internet of Things (IoT) technology utilizes GPS and other technologies to collect information data in real time. Through the connection of vehicles to different communication networks, the real-time exchange and interaction of information data are achieved; in addition, the collected data are analyzed and processed for intelligent decision-making and control, thereby improving the urban traffic and increasing the road efficiency and road capacity [7]. Factors that affect

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traffic efficiency of roads are various, in which the factor of traffic flow fluctuation is vital. Thus, the analysis of traffic flow fluctuation and the establishment of countermeasures can greatly improve the level of service of urban roads.

II. LITERATURE REVIEW

Pei *et al.* (2018) proposed a visual analysis system named BVis to analyze the urban traffic that applies large-scale actual sparse public transportation datasets [8]. The BVis system covers 4 modules of bus data visualization: first, the cleansing and mapping of sparse trajectory data; second, the analysis of global traffic conditions and sectional traffic modes; third, the bus station congestion mode analysis of bus station using parking time; and forth, the analysis of the importance of bus stations in complicated public transportation networks. In addition, they proposed an enhanced node importance evaluation algorithm, which comb ines the dynamic features of bus stations, such as station traffic volume and station parking time, etc. The authentic bus wire GPS dataset is used to prove the performances and effectiveness of the system by describing 3 scenarios. Armas *et al.* (2018) studied the level of service of urban traffic in which the multi-objective evolutionary algorithm is combined with the multi-agent traffic simulator MATSim [9]. The evolutionary algorithm searches for the number of private/public transportation users, the capacity of the buses, and the combinations of time intervals between bus departures while minimizing the traffic density and transportation time. Based on the solutions of the evolutionary algorithm, MATSim simulates the movement of 27,000 agents on the traffic network model of Quito. The judge and weight of targets, as well as the generated solutions, are researched and analyzed to obtain the conditions to achieve different levels of service. Tian *et al.* (2018) proposed an improved quantum genetic algorithm (IQGA) to solve the traffic congestion problem in route selection [10]. The IQGA algorithm includes the following contents: (1) A quantum chromosome initialization strategy (QCIS) is proposed to convert and encode the actual traffic conditions, and construct the quantum chromosomes based on the quantum codes of vehicles and roads; (2) A quantum chromosome mapping algorithm (QCMA) is proposed to convert the computational bits of quantum chromosomes into the route selection results of different vehicles; (3) A contemporary optimal solution decision strategy (COSDS) is proposed to judge the current route selection results; (4) A quantum update algorithm (QUA) is proposed to update and iterate the quantum codes of population. Their study carried out 2 experiments: (1) The artificial traffic networks of different scales were designed to compare the IQGA with other algorithms. Experimental results showed that IGQA has better robustness and adaptability. (2) The comparison experiment of the actual urban transportation networks verified the high performances and the real-time performances of IQGA. Liang *et al.* (2018) proposed a dynamic strategy to provide accident information to selected drivers and help the drivers pass around the urban areas [11]. A time-dependent shortest path algorithm is used to generate a subnet in which the vehicle should receive such information. A simulation method based on the extended cell transmission model is used to describe the traffic flow in the urban network, in which the path information and the traffic flow at the downstream road links are well modeled. The simulation results revealed the impacts of certain main parameters of the event-induced congestion dissipation process, such as the ratio of the route change vehicles to the total number of vehicles, the operating time intervals of the proposed strategy, the traffic density in the traffic networks, and the area where the traffic accident information is delivered. This result can be used to improve the current technologies to prevent urban road traffic congestion caused by accidents.

Alfeo *et al.* (2018) proposed a method which utilizes the shame-based urban location data; shame is a biological heuristic mechanism that provides scalar and temporal aggregation of samples [12]. By using the stigmergy, samples that are close to each other are aggregated into a functional structure called a trail. This path summarizes the relevant dynamics in the data and allows them to be matched, providing a measure of their similarity. Moreover, this mechanism can be used to expand specific dynamics. Specifically, the high-density urban areas (hot spots) are identified to analyze their activity over time and show anomalies. In addition, the continuous measurement of dissimilarities with typical activity patterns is provided by matching the activity patterns. Thus, decision makers can use this metric to assess the impacts of policies and change the policies dynamically. Xing *et al.* (2018) introduced the ORNL-PSerc-Alaska (OPA) model to analyze the vulnerability of urban regional transportation networks in order to better describe the network cascade failure caused by random attacks such as traffic accidents [13]. First, a 2-layered network model is constructed to analyze the complex features of regional transportation networks. Second, a cascade fault model is constructed to better describe the process of network cascade faults under random attacks. Finally, by simulating the network fault process, the loopholes of the traffic network are pointed out, which provides a theoretical basis for avoiding network cascade faults under random attacks. Wang *et al.* (2018) proposed a short-term traffic flow prediction framework for urban road networks [14]. The first module contains a set of algorithms for processing traffic flow data; after analysis and recovery, a complete dataset without any anomalous value and a dataset containing pairs of segments that are most similar to each other in terms of their trends are proposed. The second module focuses on long-term and short-term predictions of multiple time steps. Based on the comprehensive understanding of the periodicity and randomness of the traffic flow, the time series is first decomposed into a trend sequence and a residual sequence. After reconstructing the two time series, the training and prediction of the model based on long-term and short-term memory-recurrent neural networks (LSTM-RNN) are performed. Finally, both results are combined to form the final prediction. Model evaluation was performed by using the 2 urban road networks. The results showed that the data processing module can effectively improve the data quality, shorten the training time, and improve the robustness of the model. Ma *et al.* (2018) proposed a new space-time convolution neural network (ST-CNN) model [15]. The Kinect 2.0 is used to construct a traffic police command gesture skeleton (TPCGS) dataset collected from 10 volunteers. Subsequently, the convolution calculations are performed on the positional changes in each bone point to extract the temporal features, analyze the relative positions of the bone points, and extract the spatial features.

In summary, based on the theories of traffic flow fluctuation under the Internet of Things, the relevant fields are researched and analyzed, such as the fluctuation features of the anisotropic traffic flow dynamics models, the dynamic traffic flow network models, the traffic flow fluctuation features at the intersection, the lane-change models, the traffic signal timing, the urban expressway ramp space proportion model, the traffic delay caused by lane reduction, the numerical simulation of traffic accident and interference vehicle flow wave, and the changes in queue length and traffic capacity caused by traffic accidents, etc. In addition, the relevant contents are analyzed, such as the operating mechanism of traffic flow at the entrance ramp connection areas, the effects of mixed large trucks on the stream of traffic on expressways, the traffic capacity and sensitivity of the right-turning traffic signals at the intersections with mixed traffic signals, the effects of traffic accidents on urban road capacity, the driving features and traffic effects of fleets in urban large-scale events, and the aging of dissipating queues, which provides certain references for the engineering designs and traffic management.

III. ANALYSIS OF URBAN TRAFFIC UNDER THE ENVIRONMENT OF THE INTERNET OF THINGS

A. EVALUATION OF URBAN TRAFFIC FLOW

The theory of traffic flow fluctuation is defined as follows: the phenomenon that the interface of 2 different density parts in the stream of traffic propagates through each vehicle is called the fluctuation of traffic flow. The speed at which a vehicle flow fluctuation moves along a road is called the vehicle wave velocity.

The definition of wave velocity is shown in Equation (1):

$$v_w = \frac{x}{t} \tag{1}$$

In the above equation: v_w-wave velocity, x-moving distance of critical area, t-moving time.

Equation (2) is derived from Equation (1), and it is concluded that the wave velocity is obtained by dividing the flow difference with traffic density difference.

$$v_w = \frac{q_1 - q_2}{k_1 - k_2} \tag{2}$$

In the above equation: v_w-wave velocity, the q-moving distance of critical area, k-moving time.

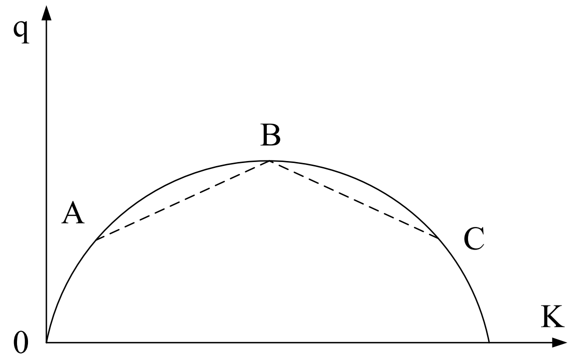

FIGURE 1. The correlation curve of flow-density.

As shown in the flow-density correlation curve, 0 is the traffic state. When the traffic flow increases, from state 0 to state B, the traffic density increases with the flow rate, where B is the maximum flow state and A is the low-density low-flow state. As the traffic density continues to increase, the traffic volume begins to decline, and the traffic efficiency decreases. C is the high-density and low-flow state.

When the traffic flow changes from the low-density and low-flow A-state to the high-density and high-flow B-state, the wave is the queuing wave, and the wave velocity is a positive value (progressive wave); when the traffic flow changes from the B-state to the A-state, the wave is the dissipative wave, and the wave velocity is also a positive value. When the traffic flow changes from the B-state to the C-state, the wave is the queuing wave, and the wave velocity is a negative value (receding wave); when the traffic flow changes from the C-state to the B-state, the wave is the dissipative wave, and the wave velocity is a negative value.

The hazards brought by the fluctuation of traffic flow fall into 2 categories, i.e. the generated safety hazards and the reduced road capacity. Both of the categories share a common feature, which is unpredictable. The hazards caused by irrational road route and the damages to road surface and subgrade are fixed at a certain point or a certain range, which is simple and clear. After targeted treatments, they can be completely solved. However, the hazards caused by traffic flow fluctuation are unpredictable, including location, time, and objects. Once the hazard is formed, it is not easy to be solved. Even if it is solved, the next time that the hazard occurs is still unpredictable. Although it is unpredictable, the causes of traffic flow fluctuation can be analyzed, and the harmfulness can be eliminated or reduced by preventive measures.

$$V_L \geq 200Veh/h \tag{3}$$

$$xpord = V_L * \left(\frac{V_0}{N_0}\right) \geq 50000 \tag{4}$$

In the above equation: V_L indicates the amount of traffic heading to the left, V_0 indicates the traffic volume of the opposite lane and N_0 indicates the number of lanes in the

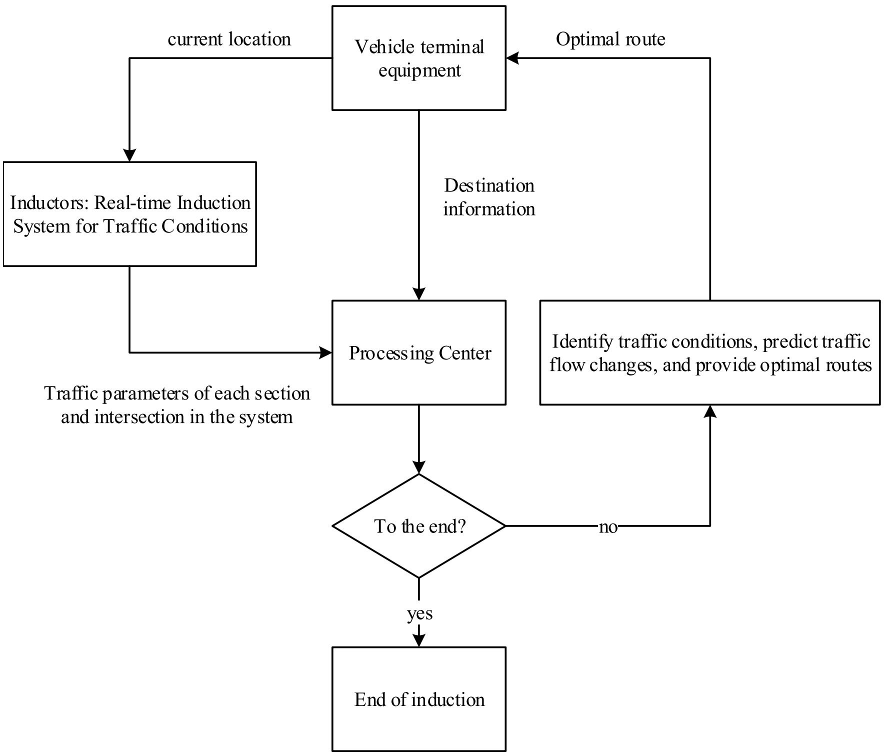

FIGURE 2. Flowchart of traffic guidance.

opposite direction.

$$G_{\min} = \frac{\max\left(W_{\text{east and west}}, W_{\text{north and south}}\right)}{1.2} \tag{5}$$

In the above equation: $G_{\min}$ indicates the lowest time of green light under signal control, and $W_{\text{east and west}}$ $W_{\text{north and south}}$ respectively indicate the width of the road in the east-west direction and the north-south direction.

$$V_e = \frac{V + 0.5H + 0.6L}{n} \tag{6}$$

In the above equation: V_e indicates the amount of traffic volume in the equivalent time period, V indicates the actual traffic volume at the intersection, H indicates the hourly traffic volume of the buses and the trucks, L indicates the hourly traffic volume to the left and n indicates the number of valid lanes per hour through the entrance.

$$G_{\max} = \frac{V_{\max}\text{ (east and west, north and south)}}{\text{V}}(T - 3P) \tag{7}$$

In the above equation: $G_{\max}$ indicates the maximum green light passing time under signal control, indicates the one with larger traffic volume in the east-west direction or the north-south direction, V indicates the traffic volume in the actual situation at the intersection, T is the cycle time, and P is the number of phases.

$$d = \frac{G_{\min} - 4}{h} * l \tag{8}$$

In the above equation: d indicates the distance between the parking line and the sensor, $G_{\min}$ indicates the time of the lowest queuing time of green light under the signal control, h indicates the time interval headway when passing the parking line under the saturated stream of traffic, and l indicates the headway spacing during the queuing process.

B. CONTROL OF URBAN TRAFFIC FLOW

Under the Internet of Things, the distribution of vehicles on the road is not uniform. On the one hand, it is caused by the inflow and the diversion; on the other hand, the speed of the vehicle is inconsistent. Reducing the point of entry and the point of diversion is a helpless measure taken when the access branch is too dense and affects the passage of the trunk or the section is saturated for a long time. Other circumstances are not recommended.

Inconsistent driving speeds of the vehicles are the most normal and unchangeable objective fact. The speed of the vehicle is inconsistent. On the one hand, the maneuverability and the load of the vehicle are different; on the other hand, it is caused by the driving habits and technical differences of the drivers [16]. In order to reduce the traffic turbulence caused by the low-speed vehicles hindering the high-speed vehicles and vehicles overtaking each other, different lanes are defined when designing the road cross-sections. According to the outdated specifications, different lanes are divided into "small-vehicle lanes" and "large-vehicle lanes", which presupposes that the driving speed of the large vehicle is lower than that of the small vehicle. With the development of car technology and car types, the division of small and large are

FIGURE 3. Speed limits of urban traffic lanes.

unscientific. The new specifications have revised the different lanes as the ''fast lanes'' and the ''slow lanes'' according to the speed of the vehicles. Due to the large quantity and the best maneuverability of minibusses, on the one-way 3-lane roads, a ''special lane for minibusses'' is divided [17]. Urban development is preferred for public transportation due to a large amount of passenger traffic, and bus lanes are set up (the problem of bus lanes is analyzed separately). This adjustment is more rational; however, many engineering designs have not achieved the expected effects of the differential lanes.

Expressway and first-class highways are designed with high speed and thus the anti-glare facilities are highly valued. The anti-glare problems of the expressways in urban roads have never been neglected; however, the anti-glare problems of the main roads and secondary trunk roads are often not concerned. Opposite to the high beam of the driveway, the vision of the driver is instantaneously or intermittently affected, followed by a sudden deceleration behavior, leading to a clustering wave in the fast lane and changes of lanes of the trailing vehicles, thereby the traffic turbulence and the fluctuations of all lanes will be generated.

The anti-glare panels used on the roads are difficult to meet the urban landscape requirements, and the design of the new styles brings inconvenience to routine maintenance. At present, the central web-layout guardrail is a better method. The height of the column is about 1 m, in addition to the height of the central divider, the overall height of the guardrail is more than 1.3 m. In addition, once the growth of the planted climbing plants flourishes, such as Boston ivy and Rangoon creeper, the anti-glare effects will be better than those of the anti-glare panels, and the landscape can meet the urban requirements, which can also prevent passengers from jaywalking the roads [19]. Such guardrails are low in costs and are convenient for maintenance and repair.

In terms of the secondary trunk roads, branch roads, and other external roads without a central separation zone, there is no condition for installing the anti-glare facilities; thus, even if the vehicle speed is low, the opposite glare still has a certain influence.

It is forbidden to use the high beams in the urban area, which is a mandatory content of education or publicity [20]. The urban roads are illuminated, and the road conditions are clearly visible. Even if there are no streetlights or the streetlights are broken on some roads, the low beam can still meet the sight requirements of speeds below 60 km/h. Drivers with night vision disorders should not drive during nights and choose other modes of transportation.

IV. COUNTERMEASURES OF URBAN TRAFFIC IMPROVEMENT BASED ON THE ENVIRONMENT OF THE INTERNET OF THINGS

Once the road traffic is affected by traffic flow fluctuations, timely and effective methods should be adopted for alleviation. The characteristics and features of each road in each city are different, but the main steps are roughly the same: the diversion and guidance, the incentive elimination, and the dispersion and recovery. Regardless of the causes, in terms of the road sections whose traffic efficiencies are sharply reduced

FIGURE 4. Joint roads of urban roads.

FIGURE 5. Central web-layout guardrails of urban trunk roads.

by traffic flow fluctuations, if the input flow is not controlled, not only the traffic flow fluctuations cannot be alleviated but also the impacts and time of traffic flow fluctuations are increased. Therefore, appropriate measures to reduce traffic flow are necessary.

Adjusting the timing of the intersection at the upstream of the road section is the most direct measure of traffic flow reduction. The vehicle entering the road section is reduced, and the transit time of the intersecting road is increased, on the one hand, the pressure on the congested road section is relieved; on the other hand, the traffic efficiency of the intersecting road is increased, and the vehicle is detoured.

At present, many driving navigation systems have the road condition reporting functions, and the drivers can plan an unobstructed route in advance or avoid the congested road sections in time. Drivers who are not accustomed to or do not need to use the navigation systems in China still make up for the majority; thus, the traditional road instructions are still necessary. Through the surveillance videos, the traffic command center judges that the congestion elimination time is long, and the road conditions (urban expressways and trunk roads) are reflected on the information boards of the upstream road sections, prompting the vehicles to drive away from the bypasses; in addition, temporary notices are also

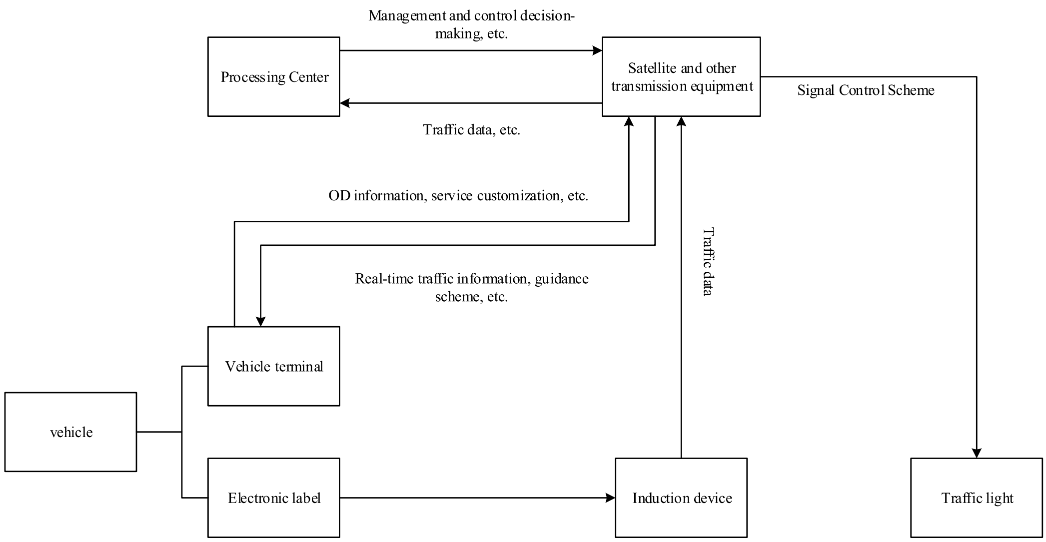

FIGURE 6. **System chart of the Internet of Things.**

placed at the upstream intersections (the secondary trunk roads and the lower-leveled roads) to prompt the vehicles to detour at the intersection. In addition to broadcasting traffic messages in the morning and the evening, the radio stations in the area must also insert traffic accidents and propose roundabouts.

For the traffic flow that has entered the road sections, proper guidance can also improve traffic efficiency. Traffic flow fluctuations on the road sections do not necessarily cover all lanes, and the fluctuations of different lanes are different. If there is still one or more lanes are clear to pass, the traffic flow can be directed to pass through this lane. Traffic lights on the expressways and traffic trunk roads can be set in reference to the traffic lights of tunnels to predict the downstream roadway lane conditions; a group of traffic lights should be set every 500∼1000 m to make the vehicles gradually merge into the unobstructed lanes [21]. Eliminating the predisposing factors is the most effective way to end the traffic flow fluctuation hazards. The monitoring videos of the expressways and important urban trunk roads are relatively densely distributed, and the road conditions are relatively timely obtained [22]. When the traffic flow is too large but the traffic congestion is not yet reached, the traffic police squadron will be notified to let the polices direct the traffic; also, the road custody unit will be notified to let the emergency team dispatch in time for the fastest removal of roadblocks and treatments of damages.

At a certain moment, the special situation on the road surface causes large fluctuations in the traffic flow. The road surface works, such as watering, spraying, and cleaning, should be immediately stopped after receiving the notice from the traffic command center and the staff members should quickly deviate, which can avoid the superposition of fluctuation effects [23]. The works can be resumed after the fluctuation has been slowed down, which will not affect the daily work tasks.

Road reconstruction and expansion, the new construction of pedestrian overpass tunnel, and subway construction will inevitably cause traffic flow fluctuations. The construction undertakers must arrange one or more traffic commanders to regularly inspect the bypass road sections or control road sections, monitor the road conditions 24 hours a day, and clear roadblocks and direct the traffic in time. The construction of the subway station of the Nanhai Square section of Nanhai Avenue is taken as an example; in the construction project, the lanes were rebuilt, and the 2-way 10-lane road was compressed into the 2-way 6-lane road. During the peak hours of the traffic flow, 2 traffic commanders were on the scene, and the running lane of the road section was reduced but the traffic capacity was not greatly affected.

After the influencing factors of traffic flow fluctuations are eliminated, it takes time to recover the traffic order; thus, it is necessary to implement the diversion measures. Traffic lights at downstream intersections should increase the proportion of release phase time, including left and right turns, to accelerate the evacuation of stranded vehicles. After the traffic order of the road section is restored, the traffic lights at the upstream and downstream intersections are restored, and the traffic in the whole road section is restored [24], [25]. The rest of the flow reduction measures are also withdrawn, including that the lane traffic lights are turned green and the temporary signboards at the upper intersections are removed; in addition, the electronic information screen and the radio stations should all report that the traffic is smooth again so that the vehicles do not make unnecessary trips that may increase the traffic pressure on the surrounding roads [26].

V. CONCLUSIONS

There are many factors that affect the traffic safety and traffic efficiency of urban roads. The fluctuation of traffic flow is closely related to the service level of urban roads, and it has become more obvious with the increase of traffic volume [27]. Based on the Internet of Things, the lane speed limit is optimized, the roads and overpasses are expanded to avoid the physical separations, the road condition signs and information boards are simplified, the web-layout guardrails are set, the stagnant water problems are solved, the traffic facilities along the slow lanes are improved, the intersection signal control and lane matching are optimized, the bus routes are optimized, the bus stations are improved, and other countermeasures are taken [28]. However, the fluctuation of traffic flow caused by road work is inevitable, and it is always a technical problem to reduce the working time. The reduction in time consumption of preventive maintenance of the same road surfaces, road maintenance, and other works require the technical requirements to be advanced in further. The central web-layout guardrails have good anti-glare effects, but the height is limited. For the concave vertical curves, especially at the positions of overpass approaches, the problems of glare still cannot be solved since the design of the guardrail to a few meters in height is not realistic. The above difficulties need to be further studied in the future, and the factors causing fluctuations in urban traffic flow have also increased with the development of society, transportation, and car manufacture. Thus, the study of urban traffic flow fluctuation should be continued, and its characteristics and solutions need to be further analyzed and explored.

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