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Research on Intelligent Traffic Management Methods for Urban Traffic Congestion

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Abstract:
In recent years, the problem of traffic congestion has become more and more serious as the urban population continues to increase and the number of private cars is also rising. Therefore, there is an urgent need to find methods that can effectively alleviate traffic congestion. Based on this, this paper analyzes and researches the causes of traffic congestion and the existing solutions, and analyzes in detail the three effective solutions to traffic congestion, Telematics, Driver Emotional Adjustment Control and Public Transportation Optimization, and finally puts forward several suggestions in combination with the existing problems of urban transportation system, hoping to provide certain references for the relevant departments.

Keywords: traffic congestion, Internet of Vehicles, public transport optimization, driver behavior control, intelligent transportation systems

1. Introduction

As global urbanization accelerates and people's standard of living improves, the number of people in cities and the number of private vehicles in their possession are also on the rise, and therefore the probability of traffic congestion occurring will also increase significantly. Traffic congestion is a problem that has long plagued the world, especially in cities with large populations and rapid growth. According to the Global Transportation Scorecard 2023 report released by traffic data analytics company INRIX Inc. drivers in New York waste an average of 101 hours a year in traffic jams, ranking first in the world. In addition to the large amount of time consumed, traffic jams bring about a variety of problems such as reduced fuel consumption efficiency, increased pollutant gas emissions and noise levels, deterioration of the driver's psychological state, and increased transportation costs due to transportation delays [1,2,3]. Therefore, there is an urgent need to find effective solutions to alleviate traffic congestion and improve urban traffic management.

Based on this, this paper analyzes the causes of traffic congestion and summarizes the existing several types of solutions, and gives specific examples to analyze the vehicle networking technology, driver emotion regulation control and public transportation optimization three effective solutions to traffic congestion. Finally, the paper analyzes the existing prob-

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lems of urban intelligent traffic management system and puts forward several suggestions, hoping to provide some references for the staff in this field.

2. Causes of traffic congestion

Tanzina Afrin and Nita Yodo categorized traffic congestion into recurrent and non-recurrent congestion [4,5]. The causes of recurrent congestion may be 1. excessive number of vehicles traveling at fixed times, such as congestion caused by high number of travelers in the morning and evening peak hours. 2. improper traffic signal control in the area, such as uncoordinated timing of traffic lights. The causes of non-recurring congestion may be inclement weather such as rain or snow, traffic accidents that make the road unusable, etc. For recurrent congestion, the traditional solution is to build new roads, but due to the limited size of the city, the number of transportation road networks cannot rise indefinitely. Therefore scientific analysis and management of traffic flow is the best method. For infrequent congestion, increasing traffic management and law enforcement to improve drivers' driving standards and legal awareness, and focusing on road condition management such as cleaning up parked vehicles in a timely manner can also play a role in avoiding congestion.

3. Analysis of existing solutions

The current traffic congestion solutions are mainly divided into three categories, 1. the use of the Internet and other technologies to collect road information, through big data analysis to optimize the vehicle navigation routes, so that the vehicle can be based on the road information on the Internet in a timely manner to adjust the route, to avoid entering the congested road, and at the same time, according to the scene of the traffic flow of traffic signals to adjust the traffic signal, in a timely manner, to evacuate the congested vehicles. 2. to strengthen the awareness of road safety drivers. Give positive psychological hints to make it in the driving process to maintain focus and peace. 3. Improve the construction of public transportation, attract more people to choose public transportation, thereby reducing traffic flow to avoid congestion. Next, this paper will give examples from the above three types of solutions, and specific analysis.

3.1 Telematics

Telematics technology is used to optimize vehicle navigation routes through the use of On-Board Units (OBUs), Road Side Units (RSUs), and Telematics platforms. The principle of operation is that, while the vehicle is traveling, the OBU fixed inside the vehicle collects various data information of the vehicle such as speed, acceleration, position, etc. and uploads them to the Telematics platform. The roadside units placed on both sides of the road implement the uploaded road information such as congestion. The Vehicle Networking Platform then plans the best route for the car by summarizing the information from these two places and transmits it back to the vehicle. At the same time, the Vehicle Networking Platform will also control traffic signals when there is too much traffic to reduce the occurrence of traffic congestion. In order to realize this function, Li Xiaodong and Ran Bingbing used the formula Q = k - v to establish a traffic flow model, where Q is the value of traffic flow in units of vehicles /h; k is the density of traffic flow in units of vehicles /km; v is the average speed of the vehicle in units of km/h. Through the establishment of a traffic flow model can be used to achieve the prediction of traffic flow, and through the control of traffic signals to manage it [3].

In addition, Li and Ran Bingbing used Algorithm $D_{ij} = \min \sum_{i=1}^{n} \sum_{j=1}^{n} C_{y} X_{y}$ to select the optimal path for the vehicle's to reach the destination [3]. Where D_{ij} is the shortest path from the starting point i to the ending point j, C_{ij} is the cost required for the path i to j, and X_{ij} is the variable for path selection. By combining the information collected by the on-board unit and the roadside unit, the algorithm will calculate the optimal route for the vehicle that takes into account both short time and low energy consumption, and it will also serve to improve the overall transportation efficiency of urban transportation. Li Xiaodong and Ran Bingbing conducted a simulation experiment by selecting a traffic-intensive area, and they divided the experimental simulation time into peak (7:00 ~ 9:00 and 17:00 ~ 19:00) and off-peak periods, and measured the pollutant gas emissions, fuel consumption, average vehicle speed, average travel time, and traffic accident rate before and after using the Vehicle-to-Go Network. The results are shown in the graphs (Table 1, Table 2, Table 3, Figure 1, Figure 2). From the results, it can be seen that by using Telematics, the traffic flow, average speed of vehicles in the same period of time have increased, and the accident rate, fuel consumption, and pollutant gas emissions have decreased, which shows that Telematics technology can effectively solve traffic congestion.

Table 1. Peak and off-peak vehicle emissions (CO_2, NO_x, etc.)

	CO_2 emissions(g/km)		NO_x emissions(g/km)	
	No Telematics Support	Telematics Support	No Telematics Support	Telematics Support
peak periods	230	190	1.5	1.2
off-peak periods	180	150	1	0.8

Table 2. Peak and off-peak fuel consumption

traffic flow	No Telematics Support	Telematics Support
peak periods/(L/100 km)	8.5	6.7
off-peak periods/(L/100 km)	6	4.8

Table 3. Peak and Off-Peak Traffic Volumes and Average Vehicle Speed

	Traffic flow/(vehicles/hour)		Average vehicle speed/(km/h)	
	No Telematics Support	Telematics Support	No Telematics Support	Telematics Support
peak periods	4000	5000	35	45
off-peak periods	2000	2500	50	60

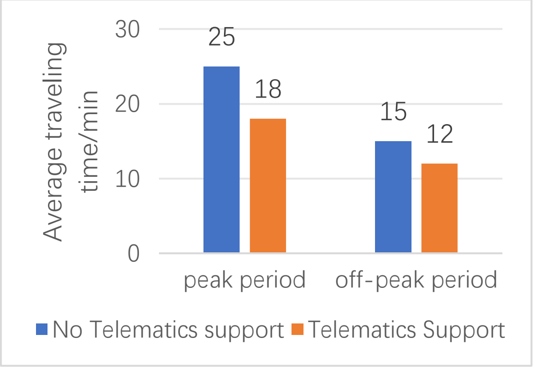

Fig. 1 Average traveling time during peak and off-peak periods

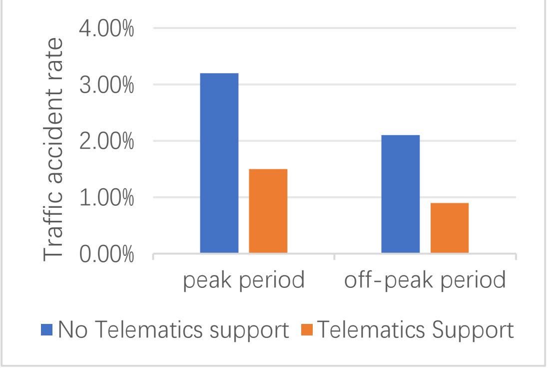

Fig. 2 Peak and Off-peak Traffic Accident Rates

3.2 Driver Emotional Regulation Control

In the driver's daily driving process, negative emotions can be induced by 1. fatigue due to long driving hours, 2. interference with normal driving behaviors such as forced overtaking and lane changing by other drivers, and 3. difficulty in navigating urban roads due to road repairs and imperfect traffic signs. And more and more evidence shows that drivers' negative emotions are also an important cause of traffic accidents [6]. Therefore, regulating and controlling drivers' emotions during driving is an important way to reduce traffic accidents and avoid traffic congestion.

According to Shouming Qi, Liwei Hu, and Xiaoyang Dai, they analyzed the causes of congestion in Kunyang City, China, which is due to the fact that some of the roads are narrow and there are no motorized and non-motorized segregation strips, so there is a mix of traffic in which motorized and non-motorized vehicles share the lanes [3]. However, this leads to an even greater decrease in traffic speed and produces a vicious cycle of traffic congestion. From the results of the questionnaire on the sources of drivers' negative emotions during traffic jams, it is clear that 43.1% of the participants were worried about time delays caused by congestion, 30.5% of the drivers were dissatisfied with those who were disruptive, 18.6% because of concerns about friction of cars and 7.8% because of noise [3].For the survey of strategies for traffic congestion evacuation they collected the results as shown in Figure 3.

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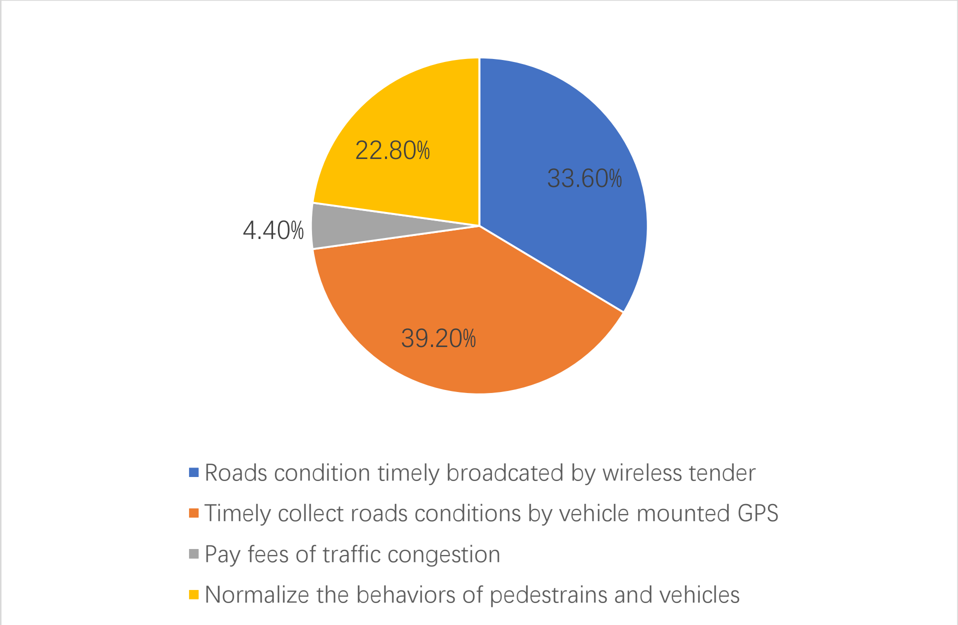

Fig. 3 Investigation results of evacuation tactics of traffic congestion

Based on the results of these two questionnaires, the researchers proposed solutions to alleviate the negative emotions of drivers in traffic jams, from the government's point of view, the specific measures are 1. Improve the driver's sensory comfort, such as improving the landscape on both sides of the road, such as increasing the area of greenery, so that the road is more ornamental. 2. Improve the construction of traffic engineering facilities such as the installation of motorized and non-motorized separator strips, and timely maintenance. 3. Traffic departments to strengthen law enforcement efforts, focusing on the public's learning of traffic laws and regulations, to improve the driver's awareness of safe driving and compliance with traffic laws and regulations consciously.4. Strengthening the cooperation between psychiatrists and traffic management departments, regular psychiatric examination of drivers and psychological guidance, psychiatrists have the right to recommend that the traffic department does not issue or revoke the driver's license of drivers with weaker mental qualities [3]. And from the driver's point of view, there are options to build more comfortable will the space inside the car and to regulate the mood by listening to music or radio when in congested roads [3]. Meanwhile, due to the different gender, age, mental ability and driving habits of different people, the suggestions for different people are also different [3]. For example, women should avoid wearing high heels while driving, while younger drivers should pay more attention to controlling their emotions, responding calmly to road conditions and eliminating nervousness to keep calm and safe driving [3]. In addition Zhang Y et al. proposed to detect the emotional state of the driver and designed a dual channel dual attention graph attention network, called DDGAT, to realize the task of detecting the driver's emotions in real time [6].

3.3 Public transport optimization

Increasing the use of public transportation by the public and reducing the use of private cars is also an effective way to reduce traffic flow and ease urban traffic congestion.

3.3.1 Bus route optimization

Buses have the advantages of being safer than personal transportation, more energy-efficient, and able to adapt to increasing travel demand with smaller cost growth [7]. However, with the continuous construction of the subway, the gradual formation of the city's underground transportation network, coupled with the popularity of shared bicycle and Internet taxi, the shortcomings of traditional buses become more and more obvious, such as fixed lines and slower speed. In addition to the general problems of traditional buses are 1. Bus stops are set unreasonably, too many stops in some areas cause buses to stop constantly affecting the efficiency of the work, and too few stops make passengers need to walk a long distance to reach their destinations, which makes the travel is not convenient enough [8].2. Buses are delayed a high percentage of the time, due to the lack of dedicated lanes for buses in the city, the mixture of buses and private cars will reduce the efficiency of bus operation. The lack of dedicated bus lanes in the city and the mixing of buses and private cars reduces the operational efficiency of buses and increases the number of bus delays [8].3. Bus routes are set up in an irrational way, with many duplicated routes, which makes it inconvenient to transfer to other buses [9].

In order to solve the above problems, the most important thing is to optimize the bus traveling line and station location. Qin Minheng proposes to optimize the routes from the perspective of analyzing the passenger flow pattern: 1. Analyze the existing bus routes before adjustment, summarize the advantages and disadvantages of the routes, and derive the distribution pattern of the passenger flow [9].2. Conduct public opinion surveys through the media, telephone networks, and other channels, and collect the passenger's suggestions as a reference for modifying the routes, and conduct a return visit to check the optimization after optimizing the routes [9].3. The use of computer simulation of road operation status to simulate traffic flow changes and reference to the GIS geographic information platform as a reference for the design of bus routes to exclude subjectivity, so as to make the design of routes and stops more reasonable [9].

In addition, tourist attractions can be added to the bus routes as optimization directions.Sriprateep K, Pitakaso R and Khonjun S used Hybrid Reinforcement Learning-Variable Neighborhood Strat-egy Adaptive Search (H-RL-VaNSAS) algorithm to optimize bus routes [10]. Taking Mueng Ubon Ratchathani and Warinchamrab cities in Ubon Ratchathani province area as an example, the algorithm simulation incorporates the tourist attractions such as temples, restaurants, museums, salons and spas, cultural and historical monuments in the vicinity of the bus routes to design the high quality bus routes that are safe, resilient, accessible, and have short total distance traveled [10]. This not only attracts more people to public transportation to generate income for the city, but also eases the traffic flow in the city and reduces traffic congestion.

Planning bus routes using passenger data collected by cabs is also one of the optimization methods. Song Y, Jin Y and Li D used the GPS system of cabs to collect the spatial and temporal distribution data of cab trajectories and passenger journeys, based on which they analyzed the passenger demand and identified potential bus stops, and then applied a link growth probability model to optimize the existing bus routes. Weiquan South Station in Shaanxi Province was used for model validation, which led to the identification of 153 potential stops and 2726 qualified solutions [11].

In addition to optimizing bus routes, the quality of bus service can also be improved to attract more people to use public transportation, specific measures include: 1.Introducing an intelligent bus scheduling system, through data analysis to optimize bus routes, improve bus punctuality, while analyzing the historical data according to the changes in passenger flow dynamically adjust the number of buses and intervals, increase the number of trips to reduce the passenger's waiting time during peak periods. 2.Adding an e-ticketing system, which reduces the time required for passengers to purchase tickets while the system also collects user travel data to help the company find customer demand to optimize service quality [12].

Customized buses are also one of the new forms of bus development in the future. Customized bus imitates the operation mode of Internet taxi, customers in the online platform to release travel demand such as origin, destination, acceptable maximum walking distance and maximum acceptable travel time. The bus company gathers many travel demands into a few orders and consolidate demand and plan departure times and routes for customized buses. Compared to traditional buses, customized buses integrate the needs of customers to make it more convenient. Compared to cabs, customized buses have the advantage of high capacity and a large number of customers with the same needs [13].

3.3.2 Optimization of urban underground rail construction

Generally speaking, the main problem of urban underground transportation engineering is that the construction is not perfect, the number of subway is insufficient resulting in the inability to share more passenger traffic, and play an effective role in alleviating surface traffic congestion. Optimization programs are 1. The government should speed up the construction of the subway, and to ensure the quality, timely inspection and maintenance of the line, to ensure the safety of passengers travel [8].2. For the construction of new lines can be used in other cities of the subway line planning experience, and with the local traffic flow, geographic environment and other factors combined to make the construction of the subway is more reasonable and convenient [8]. 3. Increase the linkage between the subway and the underground commercial street to realize the win-win situation of increasing the number of people applying to the subway and increasing the passenger flow in the underground commercial area, so as to achieve the purpose of alleviating the traffic congestion on the ground and generating income for the city at the same time.

3.3.3 Bike sharing optimization

Bicycle-sharing travel is a low-emission, sustainable transportation mode with high flexibility and good travel experience [14]. However, sometimes the indiscriminate parking of shared bicycles due to the lack of management can also lead to road narrowing, thus causing traffic congestion.

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In order to solve this problem, Lv Chang et al. pointed out that the BikeSharingSystem (BSS) in the city is characterized by a large scale, a large number of stations, and non-unique warehouses. They analyzed that there will be an imbalance in the number of shared bikes between sites in the normal use of shared bikes. If the number of bicycles at a site is too small, it will affect the user's travel experience, while the number of bicycles is too large, which will cause indiscriminate parking and traffic congestion, and at the same time, the storage of too many shared bicycles will increase the inventory cost. Therefore, transportation vehicles are needed to constantly balance the number of shared bicycles between sites. However, due to the lack of scientific management and planning, and the limited load capacity of the transportation vehicle, it needs to be transported back and forth between the sites several times, which will cause unnecessary consumption [15]. Therefore, Lv Chang et al. proposed a supply-demand chunking strategy to form a collection of sites that can be self-sufficient by pairing sites with a low number of bicycles and oversaturated sites with each other. After that, a two-layer taboo search algorithm is used to enhance the information exchange among the site collections, which facilitates the scientific scheduling of transportation vehicles. After the standard case test, the algorithm can obtain an optimal solution within 100s of Cpu consumption in analyzing the problem of balancing the number of shared bicycles with less than 150 sites, and at the same time, it uses up to 5 fewer transportation vehicles, which reduces the cost of the transportation operation and also reduces the cost of inventory of bicycles for more than 80% [15].

4. Existing Problems and Suggestions for Urban Intelligent Transportation Management

With the continuous development of science and technology, intelligent traffic management system using vehicle networking, big data and other technologies will step by step replace the traditional human management system. However, Huang Fubin and Du Xin found that there are certain problems in the current intelligent traffic management, 1. There is no in-depth communication and cooperation between the enterprises and government departments that study intelligent traffic management technology, which makes some new technologies not used effectively [16]. 2. The lack of a systematic resource integration platform makes the data resources collected by different intelligent management modes independent of each other, and can not be interoperated and used [16]. 3. departments and enterprises have information differences and technical barriers that hinder the research and development of intelligent traffic management system [16].Since the development of intelligent transportation depends on the deep integration of new technologies such as vehicle networking, big data and data information sharing. Therefore, in order to better build the intelligent transportation management system, government departments should strengthen cooperation with various enterprises and actively apply advanced technologies [16]. In addition, relevant government departments should establish a resource integration platform and unify the collected data and information, so that the collected data can be used interchangeably and break the information barriers between departments. At the same time, the government should increase the capital investment in the construction and maintenance of intelligent transportation systems, and cooperate with universities and research institutes to absorb high-end technical personnel. In this way, the construction of intelligent transportation management system can be better.

5. Summary

This paper firstly analyzes the causes of traffic congestion, the main causes of regular congestion are large traffic volume and unreasonable traffic management during fixed hours, while the causes of infrequent congestion are bad weather, traffic accidents and so on. After that, this paper discusses the existing three types of solutions and gives specific examples for analysis and research. 1. Telematics technology collects information about cars and roads, and after summarizing and organizing on the telematics platform, it optimizes the travel route for cars to avoid entering congested roads, and at the same time, optimizes traffic control such as traffic light timing to evacuate the traffic flow to avoid congestion. According to the research, Telematics can effectively reduce the rate of traffic accidents, fuel consumption, pollutant gas emissions and increase traffic flow and the average speed of vehicles. 2. For the driver's emotional regulation and control, increase the road beautification efforts, improve the construction of traffic engineering facilities, timely psychological counseling for drivers and give appropriate advice and other measures can reduce the driver's negative emotions, in addition to improve the driver's awareness of safe driving, effectively reduce the occurrence of traffic accidents and ease traffic congestion. 3. In the optimization of public transportation, the optimization of bus routes can be integrated into the tourist attractions, or use the spatial and temporal distribution of passenger trips obtained from cab data to optimize station locations. Besides the construction of the subway can be increased with the underground commercial street linkage. Also The optimization of the shared bike system can be managed by grouping each shared bike storage site using a chunking strategy of shared bike supply and demand, This reduces the amount of traffic consumed by transporters needed to balance the number of shared bikes between each station. Finally, this paper analyzes the development of urban intelligent transportation management system, and finds that the government needs to strengthen cooperation with enterprises, establish official traffic data management platform, realize data sharing, and break information barriers in order to better build urban intelligent transportation system. It is hoped that the above research and suggestions can provide certain references for relevant staff.

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