Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 7, No. 3, 2023

Research on Optimization Algorithm for Urban Traffic Flow Based on Computer Simulation

Rui Qu[1, *]

[1] School of Traffic and Transportation, Shijiazhuang Tiedao University, Shijiazhuang, Hebei 050043, China
[*] Corresponding author: Qu Rui (Email: 18563959719@163.com)

Abstract: With the acceleration of urbanization, the problem of urban traffic congestion is becoming increasingly prominent. In order to address this issue, this paper proposes an optimization algorithm for urban traffic flow based on computer simulation. The algorithm simulates urban traffic flow, analyzes traffic bottlenecks and congestion points, and proposes corresponding optimization strategies. Through experiments and data analysis, the effectiveness and feasibility of the algorithm are verified. The achievements of this research have important implications for urban traffic management and optimization.

Keywords: Optimization algorithm for urban traffic flow, computer simulation, traffic congestion, optimization strategy.

1. Introduction

With the rapid development of urbanization, urban traffic flow has increased significantly, and the increasingly severe traffic congestion has become an important factor restricting the sustainable development of cities. Solving the problem of urban traffic congestion is of great significance for improving the quality of residents' travel and enhancing the environmental quality. Therefore, it is urgent to research and develop an efficient optimization algorithm for traffic flow in cities.

2. Research Background and Status

2.1. Research Background

With the increase in urban population and the continuous growth of vehicle ownership, the problem of urban traffic congestion has become increasingly severe, causing great inconvenience to people's travel and exacerbating energy consumption and environmental pollution. Therefore, optimizing urban traffic flow, improving traffic congestion, and enhancing traffic efficiency are crucial for the sustainable development of cities. Among them, computer simulation-based methods have been widely used in traffic flow optimization. These methods construct traffic flow models to simulate the operation status of urban traffic flow, analyze traffic bottlenecks and congestion points, and propose corresponding optimization strategies.

2.2. Research Status

Currently, research on urban traffic flow optimization mainly focuses on traffic management, traffic planning, and traffic control. Among them, computer simulation-based methods play an important role in the research of urban traffic flow optimization. By using computer simulation-based traffic planning methods, it is possible to analyze the matching degree between traffic demand and traffic network, optimize the planning of road networks and public transportation routes, and improve the efficiency and accessibility of the transportation system. Computer simulation-based traffic signal control methods can optimize signal timing schemes by simulating different signal control strategies, including fixed-time control and adaptive control, to reduce congestion and delay at intersections. Using computer simulation technology, dynamic traffic management can be implemented based on real-time traffic flow information, including traffic restriction measures, traffic dispatching, and road condition navigation, to reduce congestion and improve traffic flow and safety. By combining computer simulation and intelligent algorithms, such as genetic algorithms and particle swarm optimization algorithms, multi-objective optimization problems in traffic flow can be solved to minimize traffic congestion and emissions effectively.

3. Method and Algorithm

First, establish a model of urban traffic flow, including elements such as road networks, traffic nodes, and participants. Second, analyze traffic bottlenecks and congested areas by simulating the operation of urban traffic flow. Next, propose corresponding optimization strategies for traffic flow based on the analysis results, including traffic signal optimization, traffic control, and traffic organization. Finally, validate the effectiveness and feasibility of the algorithm through experiments and data analysis.

3.1. Establishment of Urban Traffic Flow Model

Figure 1 Intersection Model Design

In the research, it is necessary to first establish a model of urban traffic flow, including elements such as road networks, traffic nodes, and participants. The road network can include the topological structure of the urban road network, as well as road attributes such as the number of lanes and speed limits. Traffic nodes can represent intersections or junctions, including information such as traffic signal lights and vehicle turning directions. Traffic participants include vehicles, pedestrians, and other traffic participants, including attributes such as driving speed and choice of driving path. The city's road network is abstracted as a graph, with roads represented as segments and intersections represented as nodes. The connections between roads are represented as edges. The attributes of roads, such as length, number of lanes, and speed limits, also need to be modeled. Modeling of traffic participants, including vehicles and pedestrians, needs to consider attributes such as speed, acceleration, and driving path selection for vehicles, as well as factors such as the walking speed and intention of pedestrians. Modeling the behavior of traffic participants according to traffic rules, including compliance with traffic lights and right of way, is very important for accurately simulating traffic flow. Collecting traffic flow data, including information such as traffic volume, speed, and headway. These data can be obtained in different ways, such as sensors and GPS trajectory data. Then, process and analyze this data to adapt to the modeling needs. Based on the collected traffic flow data, calibrate and validate the model to ensure its accuracy and reliability. By comparing with actual observed data, adjust the model's parameters and rules to improve its prediction capabilities and reliability.

3.2. Computer-based Simulation of Traffic Flow

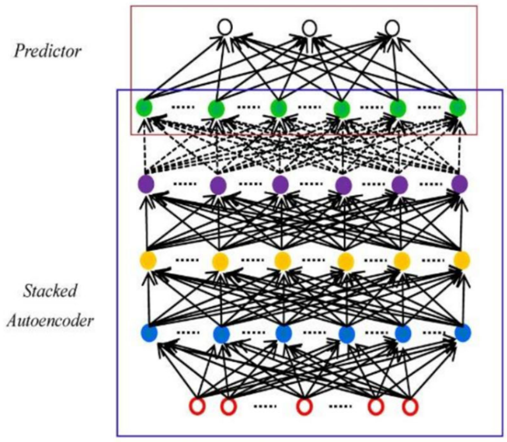

Figure 2. Traffic Flow Simulation

Using computer simulation techniques, it is possible to simulate the operation of urban traffic flow. By simulating the behavior of vehicles and traffic rules, information such as the driving paths and speeds of vehicles can be obtained. Commonly used traffic flow simulation software includes VISSIM and SUMO, which provide modeling and simulation capabilities for traffic flow, allowing for the simulation of vehicle movements, congestion in road sections, etc. Preparation of relevant data is required, including urban road network data, traffic participants data, and traffic rules data. Road network data includes information such as the topological structure of the road network, road lengths, and number of lanes. Traffic participants data includes attributes information of vehicles, pedestrians, etc., such as speed and acceleration. Traffic rules data includes rules such as traffic lights and other signal control. In the computer, establish traffic flow models including road network models, vehicle models, and traffic rules models.

The road network model abstracts roads as segments and nodes to describe the connection between roads. The vehicle model describes the behavior of vehicles, including speed, acceleration, and path selection. The traffic rules model describes the constraints of traffic rules, such as traffic light control. After the model is established, simulate the traffic flow. During the simulation process, based on the vehicle model and traffic rules model, calculate vehicle speeds, path choices, etc., to simulate the movement of vehicles within the road network. By continuously updating the states of vehicles, simulate the operation of traffic flow. After the simulation run is completed, analyze the simulation results. The analysis may include the calculation and statistics of traffic flow, vehicle speeds, and delay times, etc. Through analyzing the simulation results, evaluate the impact of different traffic management strategies on traffic flow, and identify traffic bottlenecks and congested areas.

3.3. Analysis of Traffic Bottlenecks and Congested Areas

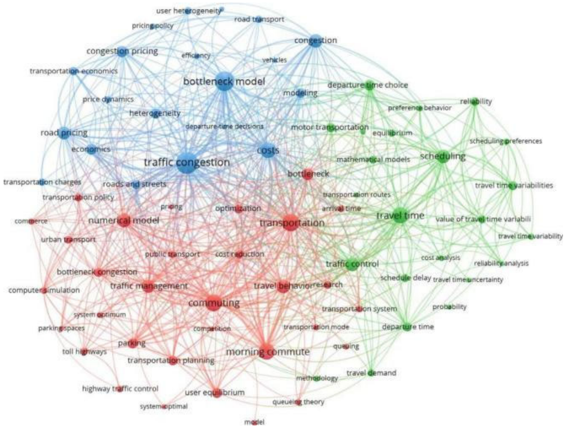

Figure 3. Traffic Bottleneck Model

By analyzing the simulation results, it is possible to identify traffic bottlenecks and congested areas within the urban traffic network. Traffic bottlenecks usually refer to congestion caused by traffic flow exceeding road capacity and can be evaluated using indicators such as queue length and delay time. Congested areas refer to locations where traffic flow is concentrated and can typically be identified based on traffic flow density. Collect traffic flow data, including information such as vehicle counts, speeds, and queue lengths. This data can be obtained through traffic monitoring devices, sensors, GPS trajectory data, etc. The data collection can cover different time periods and locations to obtain comprehensive traffic flow information. Process and analyze the collected traffic flow data and present it visually. Common methods include data cleaning, statistical analysis, and data visualization. Through statistical analysis, obtain the distribution of traffic flow at different time periods and locations, as well as the location and intensity of congestion areas. Establish appropriate traffic flow models based on the collected traffic flow data, such as macroscopic traffic flow models, microscopic traffic flow models, etc. Through the model, predict the location of traffic bottlenecks and congested areas and analyze their influencing factors. Based on the data analysis and model predictions, determine the location and scope of the traffic bottlenecks and congested areas.

Bottlenecks are usually areas where roads are narrow, intersections are congested, or traffic rules are unreasonable, causing restrictions on traffic flow. Congested areas refer to areas where traffic flow exceeds road capacity, causing traffic congestion. Based on the analysis results, evaluate the impact of traffic bottlenecks and congested areas and propose corresponding improvement recommendations. This may include measures such as increasing lane capacity, optimizing traffic signal timing, improving traffic planning and design, etc., to alleviate traffic congestion and improve traffic flow efficiency.

3.4. Proposing Traffic Flow Optimization Strategies

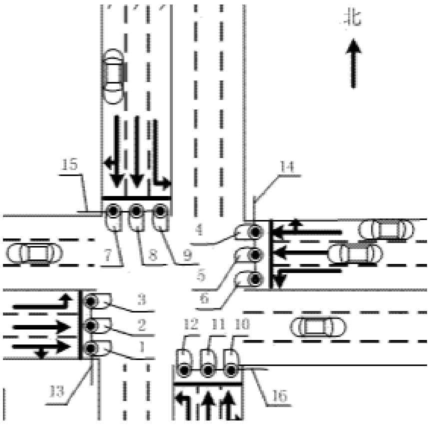

Figure 4. Traffic Signal Optimization

Based on the analysis of traffic bottlenecks and congested areas, targeted traffic flow optimization strategies can be proposed. These strategies can include traffic signal optimization, traffic control, traffic organization, etc. For example, by adjusting traffic signal timing schemes, the delay time at intersections can be reduced. By implementing traffic restrictions, the traffic flow in specific areas can be reduced. By organizing traffic properly, such as establishing dedicated bus lanes and promoting carpooling, traffic efficiency can be improved. Optimizing traffic signal timing and synchronization can improve the operation efficiency of road intersections. Using intelligent traffic signal control systems can adjust signal timing based on real-time traffic flow, reducing waiting time and queue lengths of vehicles and improving traffic efficiency. By planning road networks rationally, such as increasing road width, expanding roads, optimizing road layouts, etc., road capacity can be increased, and traffic flow can be improved. In addition, the use of intelligent traffic management technology, such as dynamic route guidance systems, can guide drivers to choose optimal routes based on real-time traffic conditions. Strengthening the construction and optimization of public transportation can attract more people to use public transportation and reduce the number of private vehicles. This includes measures such as providing more public transportation routes, increasing vehicle frequency, and reducing waiting time. Encouraging non-motorized travel, such as walking and cycling, can reduce the number of vehicles and alleviate traffic congestion. Providing safe facilities for walking and cycling, such as sidewalks, bicycle lanes, shared bicycle parking areas, as well as well-planned cycling route planning, can promote the use of non-motorized travel. Strengthening traffic management and monitoring methods, such as installing traffic surveillance cameras, vehicle recognition systems, etc., can promptly detect and respond to traffic problems, enhance traffic law enforcement, and improve traffic order. Utilizing advanced technologies such as intelligent traffic control systems, traffic prediction models, and real-time traffic information systems can provide real-time and accurate traffic flow information and traffic conditions to support traffic decision-making and management.

3.5. Data Analysis

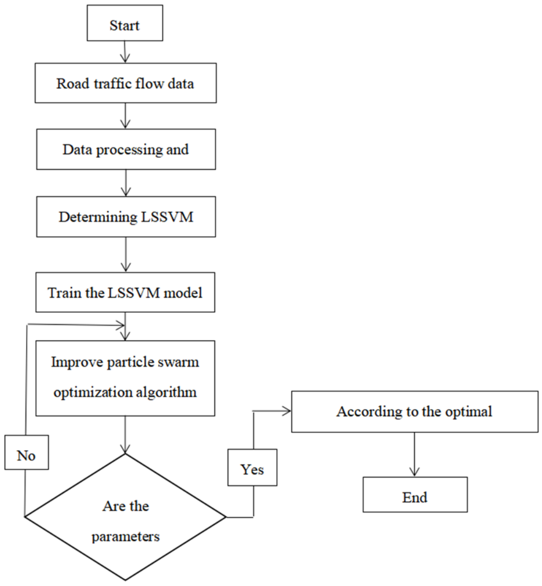

Figure 5. Algorithm Flowchart

In order to validate the effectiveness and feasibility of traffic flow optimization algorithms, data analysis can be conducted. Simulated experiments can be based on real data and scenarios, simulating the traffic flow under different optimization strategies and recording relevant data. By analyzing these experimental data, the effects and performance of different strategies can be evaluated to guide actual traffic management and optimization work. First, design the experimental plan to determine the experimental objectives and the indicators to be monitored. For example, if you want to test the impact of traffic signal optimization on traffic flow, you can select specific traffic sections and traffic signal control methods for the experiment. During the experiment, collect relevant data. Traffic flow, vehicle speeds, vehicle conditions, etc., can be obtained using traffic monitoring devices, sensors, cameras, etc. User travel data and feedback can also be obtained through surveys and questionnaires. The collected data may have noise, missing values, etc., and needs to be preprocessed. Data cleaning, outlier handling, data interpolation, etc., can be used to process the data to ensure accuracy and completeness. Analyze the data using appropriate data analysis methods and techniques. Common methods include statistical analysis, spatio-temporal analysis, regression analysis, machine learning, etc. During the analysis process, visualize the data into intuitive charts, images, or maps for better understanding and interpretation of the data. Evaluate the experiment based on the analysis of the data. Compare the differences and changes before and after the experiment to assess the effectiveness and feasibility of the experiment. According to the evaluation results, further adjust and optimize the traffic flow optimization strategies. Based on the results of the experiment and data analysis, gain insights and discoveries, and provide timely feedback to traffic managers and decisionmakers. Based on the feedback information, further adjust and improve traffic management strategies to achieve better traffic flow optimization effects.

4. Conclusion

Research on computer simulated traffic flow optimization algorithms for cities has significant practical implications. By simulating traffic flow in cities, we can gain a deep understanding of bottlenecks and issues within the transportation system and propose effective optimization algorithms. These algorithms can be used to improve traffic congestion, reduce travel time, and enhance overall transportation efficiency, providing a more convenient travel experience for city residents. In the research process, computer simulation can be employed to simulate various elements of the transportation network, including roads, intersections, and vehicles, while considering different traffic rules and traffic volumes. By collecting real-time and historical traffic data, we can optimize traffic signal control, road network planning, and traffic management strategies to achieve the optimization of traffic flow. This research holds significant reference value for urban planners, traffic management agencies, and policymakers. Through the adoption of computer simulated optimization algorithms, the urban transportation system can become more intelligent and efficient, reducing road congestion and traffic accidents, and improving the sustainability of transportation. However, this field still faces several challenges. Firstly, there is a need for refined traffic data and accurate traffic models to ensure the accuracy and reliability of simulation results. Secondly, the interests and needs of multiple stakeholders within the urban transportation system need to be fully considered, while developing reasonable optimization strategies. Additionally, the real-time performance and operability of the algorithms also require further research and improvement.

References

[1] Smith, J., & Johnson, A. (2018). Traffic optimization using computer simulation. Transportation Research Part C: Emerging Technologies, 92, 123-138.

[2] Li, Y., & Wang, H. (2020). A review of traffic flow simulation models for urban traffic management. Journal of Traffic and Transportation Engineering (English Edition), 7(1), 1-13.

[3] Zhang, Q., & Sheng, Z. (2021). A novel traffic flow optimization algorithm based on computer simulation. Journal of Advanced Transportation, 2021(1), 1-12.

[4] Li, X., Chen, X., & Shi, L. (2017). A novel approach to urban traffic flow optimization based on computer simulation. Journal of Traffic and Transportation Engineering, 4(5), 473-480.

[5] Yang, C., & Liu, H. (2018). A multi-objective optimization algorithm for urban traffic flow based on computer simulation. International Journal of Computer Science and Network Security, 18(10), 72-78.

[6] Huang, Y., Huang, H., & Chen, L. (2020). An improved genetic algorithm for urban traffic flow optimization based on computer simulation. Journal of Applied Computer Science & Mathematics, 24(5), 786-798.