

Influence of Tidal Lane on Traffic Flow Based on Network Flow Sensitivity

Youyi Ge, Xing Zhao*, Hao Lin, Jinghao Liu, Bailiang Zhou*

School of Civil Engineering and Communications, Hehai University, Nanjing 210000

Abstract: Based on the theory of urban traffic network flow, this paper studies the influence of the setting of urban tidal lane on the traffic distribution in the regional road network. According to the influence mechanism of tidal lane's setting on road network facilities, the sensitivity of road network traffic flow after tidal lane's setting to free travel time, road section capacity and OD travel demand is studied and analyzed, and the sensitivity equation of tidal lane's input variables in the equilibrium network to road section traffic flow is established, thus analyzing the influence of tidal lane's setting on road network traffic flow. By analyzing the changes of road flow on the road network before and after the setting up of tidal lane, an effective analytical method is provided for analyzing the impact of the setting up of tidal lane on the road network.

Keywords: Traffic Engineering; Tidal Lane; Sensitivity; Equilibrium Network; Road Sections; Urban Road Network

Introduction

With China's rapid economic growth and rapid development of urban construction, the number of vehicles in cities is increasing day by day, and the traffic pressure continues to increase. Modern transportation is affected by urban layout planning, residents' living and working habits, traffic policy guidance, traffic control measures, etc. All kinds of traffic problems are gradually highlighted. Tidal traffic is the representative of many traffic problems, that is, one-way surge in traffic flow occurs at specific times, such as rush hour and holiday rush hour. Tidal traffic problems mainly occur in the cities with centralized urban areas. Its formation is bound up with the trend of grouping in the current urban development structure, the single function of city grouping, and the strong attraction of city center to surrounding groups. Under the overall situation of China's current urban planning, tidal traffic seems to be an inevitable result, which makes a large number of labor force stranded in rush hours and has a great impact on the normal production and development of the city. Take different traffic management measures, such as re-dividing the number of lanes in two directions within a specified time, limiting the types of vehicles entering within a specified time period, and limiting the driving direction of vehicles within a specified time period. At present, many domestic and foreign cities such as Shanghai, Beijing, Guangzhou, Nanjing, Zhuhai and Los Angeles have adopted the method of setting up tidal lane to improve tidal traffic. Many scholars at home and abroad have also studied and analyzed the feasibility of tidal lane from the aspects of traffic flow characteristics, traffic organization and decision-making methods in tidal lane, and have achieved many results. Document^[1-2] establishes a mathematical model of network flow according to the principle of urban traffic network flow. Literature^[3] has studied the algorithm and sensitivity analysis of the traffic network flow model with elastic demand. Literature^[4-5] studies the complex selection behavior of random users in multi-mode traffic networks. Document^[6] analyzed the influence of different types of influencing factors on road traffic flow characteristics by using the method of detection data. The document^[7] analyzes the causes and characteristics of tidal traffic, systematically analyzes the operation process of tidal lane, and gives the solution method of the adjustment model for

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the best switching time of tidal lane. Document^[8] analyzed the applicable scope and selection of setting scheme of tidal lane through simulation. From the perspective of tidal traffic congestion diffusion network, the paper^[9] studies the design method of optimal variable lane setting scheme in the network. It can be seen that tidal lane's technology has been deeply studied, and most of the problems can be effectively solved through these technologies. However, it cannot be ignored that the setting of road sections in tidal lane as part of the urban road network should consider the impact of the setting of tidal lane on the traffic flow of the road network. Therefore, from the perspective of the urban road network, this study further considers the impact of the setting of tidal lane on the traffic flow of the road network. Through analyzing the influence mechanism of tidal lane on road network traffic flow, an analytical relationship between tidal lane and road network traffic flow is proposed.

1. Analysis on the mechanism of tidal lane's influence on road network traffic flow

The setting of tidal lane is to reasonably allocate the existing urban road resources and realize the purpose of improving the overall service level of the urban road network on the basis of not transforming the original road network structure. After setting up in tidal lane, the road attribute and user travel demand of the urban road network will change. The change of attribute and demand will cause the setting up of tidal lane to affect the road network in the region. This study further analyzes the impact of tidal lane's setting on the road network by using the influence mechanism of three basic parameters of free flow travel time, traffic capacity and OD demand of each road section on the road network after the setting of tidal lane.

1.1 Free flow travel time in tidal lane section

Free-flow speed is an important index for analyzing traffic flow characteristics and traffic capacity of road sections and determining service quality of road sections. In the U.S. road capacity manual, free flow speed refers to the average speed of a given traffic facility under low traffic conditions. At this moment, the driver is driving at the desired speed and is not affected by control delays. There are three main factors affecting free-flow travel time: (1) Road conditions: including lane width, shoulder width, road nature, sight distance, longitudinal slope, etc. (2) Traffic conditions: including vehicle composition, lateral interference, traffic management, etc. (3) Environmental conditions: including weather conditions, land use conditions on both sides of the road, etc. The influence of the setting of tidal lane on the free-flow speed of tidal lane section is mainly reflected in the change of the width of one-way lanes. The existing research^[6] shows that the free-flow speed increases with the increase of the width of the road surface, and shows an approximate linear relationship.

1.2 Capacity of tidal lane section

Tidal lane refers to increasing the number of lanes reasonably in some sections of the urban road network in heavy traffic directions and decreasing the number of lanes correspondingly in light traffic directions.

After the tidal lane was set up, the traffic capacity of the section changed, resulting in a change in the service level on the road network in tidal lane section and a certain range around, and a decrease in the time impedance on some of the routes. In the flexible demand traffic network flow problem, the demand of each OD pair is affected by the network service level, and the reduction of time impedance may cause the release of previously inhibited travel demand.

2. Sensitivity equation of network flow based on traffic equilibrium theory

2.1 Traffic network flow sensitivity problem description

Traditional traffic allocation is to find the optimal allocation of demand on the traffic network according to the path selection mechanism of network users on the premise of knowing the spatial distribution of traffic demand. It is a traffic mode in an equilibrium state. However, traffic is a dynamic process and will be affected by various factors. When planning the transportation network system, in the long run, it is necessary to capture the impact of population migration or land use change on the planning scheme. In the short term, it is necessary to analyze the impact of recent road system renovation and road expansion on the spatial distribution of urban road network traffic. From the point

of view of optimization, such problems can finally be attributed to sensitivity analysis. In the network flow theory, sensitivity problem refers to the problem of analyzing the degree of influence of external variables on internal variables by controlling the changes of input “external variables” such as free flow time, OD demand, link capacity, etc., and solving with traffic equilibrium model to obtain “internal variables” such as link flow, travel time, etc.

The setting up of tidal lane has not changed the original structure of urban road network, but only redistributes the number of directional lanes on some sections. At the same time, the setting of road sections in tidal lane has a direct impact on the road section properties and travel demand of the urban road network. Therefore, it is feasible and effective to analyze the impact of the setting of tidal lane on the traffic flow of the road network based on the network flow sensitivity theory.

2.2 Sensitivity equation for balancing traffic flow of sections on network flows

It reflects the sensitive relationship between the traffic flow of the balanced traffic network section and each input variable under the condition of setting up tidal lane. In this problem, we assume that when the road network system approaches or reaches the equilibrium state, there are multiple shortest paths between OD node pairs, i.e. multiple shortest paths with equal travel time. There is a set of used paths between each node pair. If a new path with shorter travel time is found. Then the elements in this path set become the next shortest path. According to the shortest path selection principle, the transfer of users on the next shortest path to the shortest path will reduce the travel time of all users between the OD node pairs. In order to effectively obtain the path solution of the equilibrium network, two transformations are adopted in the network equilibrium flow model, and constraints are introduced into the objective function.

The UE allocation model needs to be carried out in strict accordance with the four-stage traffic allocation method in the actual application process, and a large number of repetitive calculation processes need to be carried out when studying the formulation of the traffic management control scheme. However, when using the traffic flow sensitivity method to analyze the traffic management and control scheme, only the calculation results of the sensitivity equation need to be loaded into the original road network results. Therefore, the sensitivity method reduces the repetitive calculation process and is easier to be accepted by traffic planners than using UE model to calculate the allocation results in the traffic allocation process.

3. Conclusion

From the point of view of traffic flow in urban road network, this paper analyzes the influence of the setting of tidal lane on traffic flow in each section of urban road network by using the sensitivity of network flow under urban balanced network traffic distribution. Based on the influence mechanism of tidal lane on road network traffic flow, the influence equation of road network traffic flow is established, and the results obtained by sensitivity analysis are compared with the results obtained by cross-traffic distribution software in the calculation example, which proves its high feasibility. This study can make the setting and operation of tidal lane more comprehensive and reasonable, and can also provide a practical theoretical tool for urban traffic planners to make setting decisions in tidal lane.

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