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Impact of Community Opening on Road Traffic

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Abstract. This paper aims to analyze the effect of open community system on road traffic. Based on the evaluation index system of the impact of community opening on road traffic, a space-time dynamic analysis model of vehicle traffic capacity is established to describe the urban road traffic situation. Firstly, considering the road condition, safety, vehicle type, traffic distribution and other factors, nine indexes for evaluating the impact of community opening on road traffic are established, with the calculation formulas listed. And then through the fuzzy comprehensive evaluation, the comprehensive index for evaluating the road traffic condition is obtained. Secondly, in terms of the road traffic situation, a space-time dynamic analysis model of road traffic capacity is built using mechanism analysis method. This model takes the total space-time resources and the individual space-time consumption of traffic into account. By comparing the influence of the change of the intersections number and the total lanes area on the total space-time resources of urban road facilities before and after the opening of the community, the relationship between the amount of resources and the factors such as traffic density and speed is calculated and analyzed. Finally, various cases are used to analyze the impact of community opening on road traffic under different road network conditions, with the redundant variable assumed as a single variable for quantitative research. The results show that the opening the central community has more positive effect than opening the block community on the same road section. For communities with the same structure, the community opening with larger traffic flow tends to influent more, while the influence of the community with particularly small traffic flow can be neglected.

1. Introduction

With the increase of motor vehicles, urban road congestion has become an inevitable problem in the process of urban development. Urban traffic congestion not only restricts the city's economic development, but also brings a lot of inconvenience to the citizens' travel and normal work. Thus, it has become a social problem faced by every country and city. In order to alleviate the pressure of urban road traffic, some people put forward the proposal of opening the community. By which means, the existing closed housing estates would be took down the walls and make the private roads and garden greening go public. It is of theoretical significance and practical value to analyze and study the influence of community opening to road traffic.

2. Establish a Fuzzy Comprehensive Evaluation Model

In order to study the model of the influence of community opening on road traffic, road factors, human and vehicle safety factors are mainly considered. To establish a comprehensive evaluation system for qualitative and quantitative analysis, the three parameters are set as below:

Road Traffic Effect, Traffic Safety Rate, Motor and Non-Motor Vehicle Isolation Parameters

2.1 Evaluation Model of Road Traffic Effect

According to the systematic principle, scientific principle, comparability principle and practical principles, this paper attempts to establish a comprehensive evaluation index system of road traffic effect as shown in the figure 1.

Road traffic effect
- Main road load degree
- Main road mileage congestion rate / %
- Junction congestion rate / %
- Intersection average delay time / s
- Intersection average vehicle speed / $km * h^{-1}$
- Main roads average saturation
- Intersection average vehicle speed / $km * h^{-1}$
- Branch average saturation
- Branch average vehicle speed / $km * h^{-1}$

Figure 1: Comprehensive evaluation index system of road traffic effect

It is identified: Factor set U is the above nine indexes; Evaluation set V= {V1(very good), V2(good), V3(general), V4(poor), V5(very poor)}. Based on the data, five rank values for each factor are listed; Weight vector A= { 0. 16, 0. 19, 0. 21, 0. 22,0. 1, 0. 03, 0. 03, 0. 03, 0. 03}; Membership function. An evaluation matrix $R = (r_{ij})_{m\times n}$ can then be set up correspondingly.

For the matrix *B* (b_{ik}), because the fuzzy operator is *M(• , ⊕)*, we have

$$b_{ik} = min\{1, \sum_{j=1}^{pi} a_{ij}\, r_{ijk}\}$$

Two evaluation matrices of dimension 5 * 9 before and after community opening can be obtained by calculation, which is

$$R_1 = \begin{pmatrix} Q_{11} & \cdots & Q_{15} \\ \vdots & \ddots & \vdots \\ Q_{91} & \cdots & Q_{95} \end{pmatrix}, \quad R_2 = \begin{pmatrix} R_{11} & \cdots & R_{15} \\ \vdots & \ddots & \vdots \\ R_{91} & \cdots & R_{95} \end{pmatrix}$$

Therefore,

$$B1 = A \bullet R_1 = [\sum_{i=1}^{9} a_i Q_{i1}, \sum_{i=1}^{9} a_i Q_{i2}, \ldots \sum_{i=1}^{9} a_i Q_{i5}]$$

As for Road traffic effect evaluation value W_1

$$W_1 = B_1 \bullet C^T = \left[\frac{b_{11}}{\sum b_{1i}} \; \frac{b_{12}}{\sum b_{1i}} \; \frac{b_{13}}{\sum b_{1i}} \; \frac{b_{14}}{\sum b_{1i}} \; \frac{b_{15}}{\sum b_{1i}}\right] \bullet [90\ 80\ 70\ 60\ 50]^T$$

$$= \frac{\sum_{k=1}^{5}[(100-10k)\sum_{i=1}^{9} a_i Q_{ik}]}{\sum_{i=1;\, j=5}^{i=9;\, j=5} a_i Q_{ij}}$$

Similarly W_2 can be obtained.

By substituting the value of the evaluation indicator before and after community opening, all elements in R1 and R2 can be obtained. The value calculated by the comprehensive evaluation formula will be used to judge the road traffic effect.

2.2 Motor and Non-Motor Vehicle Isolation Parameter

Before the community opening, the roads may have been isolated or non-isolated (motor vehicles, non-motor vehicles), which will be changed after opening. After consulting the data, the isolated parameter will be set to 1 and the non-isolated parameters will be set to 0.8, which is called the Motor and Non-Motor Vehicle Isolation Parameter (M).

2.3 Road Safety Rate

It is believed that the safety factor consists of three indicators which are the number of motor vehicles in the region(O), the number of people(F), and the number of people killed in road traffic accidents in the region(G). So, the safety rate formula is

$$P = \frac{\sqrt{(O \times F)\text{-}G}}{\sqrt{(O \times F)}} \times 100\%$$

2.4 Criteria Equation

To sum up, we can get road traffic effect evaluation value W, road safety rate P and motor and non-motor vehicle isolation parameter M. From these, road capacity (A) is A=W*P*M

Moreover, the comparison of the road traffic before and after community opening can be shown as below:

$$\Delta E = A_2 - A_1 = W_2 \times P_2 \times M_2 - W_1 \times P_1 \times M_1$$

3 Establish a Space-Time Dynamic Analysis Model of Road Traffic Capacity

The opening of the community can give rise to the increase of intersections and lane areas, which will change the total space-time resources of urban roads. The theoretical value of the total traffic resources is calculated by the product of some comprehensive parameters such as road area, road network service time and road capacity.

Total passable resources of space-time traffic flow Ct

A drive of a vehicle occupies a certain road area in space and is recorded as one time. The road area can be provided to other vehicles for use during unit service hours. Therefore, the total passable resources of space-time traffic flow can be obtained as below:

$$C_{总} = S \times T = \mathrm{A} \times D \times T$$

Vehicle individual space-time consumption Ci

Space - time consumption refers to the product of the average dynamic area occupied by individual traffic and the average travel time spent on a trip. Hence, vehicle individual space-time consumption can be calculated as below:

$$C_{个体} = s \times t = \frac{s \times l}{v}$$

Actual total space-time consumption of traffic flow Cf

Based on the concept of space-time consumption and the definition of actual road network capacity, the road conditions and traffic conditions which are inconsistent with the actual road network are corrected. The actual total space-time consumption of traffic flow is as follows:

$$C_{实} = \frac{\mathrm{C}_{总} \times \prod_{i=1}^{5} k_i}{C_{个体}} = \frac{\mathrm{S} \times \mathrm{T} \times \prod_{i=1}^{5} k_i}{\mathrm{s*l/v}}$$

When L=1km, we can get S/k=s

Based on Greenberg Model, $v = v_m \times ln\frac{k_j}{k}$, the formula is obtained as below:

$$C_{实} = \frac{\mathrm{v_m} \times \mathrm{T} \times \prod_{i=1}^{5} k_i}{\mathrm{l}} \times \mathrm{k} \times ln\frac{k_j}{k}$$

The modified function of road category, lane location, average route frequency and road network service time is added to further improve the actual value. Among these,

$$\prod_{i=1}^{4} k_i = (P_a + \frac{M_{1s}M_{2s}\overline{N}_s}{M_{1a}M_{2a}\overline{N}_a} \bullet P_s + \frac{M_{1l}M_{2l}\overline{N}_l}{M_{1a}M_{2a}\overline{N}_a} \bullet P_l) \bullet 0.945 \bullet [1 - \frac{S(c)}{\overline{c}}] \bullet \overline{\theta}$$

4 Case Study on the Influence of Community Opening on Road Traffic

In order to quantitatively compare the influence of each type of cell before and after opening on road traffic, the control variate method is used to discuss the cell structure and the traffic flow around the cell respectively, and then substituted the numerical value into the space-time dynamic analysis model of road traffic capacity.

$\Delta C_1 = C_{实2}$-$C_{实1}$ =680.877(Central community on ordinary roads)

$\Delta C_2 = C_{实3} - C_{实1}$ =544.166(Block community on ordinary roads)

$\Delta C'_1 = C'_{实2} - C'_{实1}$ =923.448(Central community on busy roads)

$\Delta C'_2 = C'_{实4} - C'_{实3}$ =6.558(Central community on suburban roads)

the following conclusions is got:

(1) Since it takes costs to keep traffic in order, 500 is set as a reference value. $\Delta C > 500$ indicates that it is worth opening the cell, while $\Delta C'_2 < 10$ indicates that it is not worth opening community.

(2) In the same section, $\Delta C_1 > \Delta C_2$ shows that the opening to the central community has more positive effect than the block community. In the case of the same community structure, $\Delta C'_1 > \Delta C'_2$ shows that the community opening with larger traffic flow has greater influence.

(3) $\Delta C_1 > 0$, $\Delta C_2 > 0$, $\Delta C'_1 > 0$ and $\Delta C'_2 > 0$ show that opening community normally have a positive impact on road traffic.

5 Summary

Comparing the actual total space-time consumption of traffic flow before and after the opening of the community is compared, it can be noted that the increase of C_f after opening indicates that the opening has a positive effect on the road traffic effect under known data. Therefore, road traffic effect evaluation value W will increase, but the increase in human flow and vehicle flow will reduce the road safety rate P. According to the fuzzy comprehensive evaluation model, A=W*P*M, the change of road capacity a is not linear, so it is necessary to analyze all factors in a comprehensive way. As a result, a series of measures can be introduced to make A reach its maximum after opening community.

Based on the results of the model analysis, it is advised that: (1) When $\Delta C > 500$, we need to open the community. (2) In the same situation, it's preferred to open the central community. (3) In order to raise the road safety rate, traffic signs such as traffic lights and road signs shall be set up at the intersections where the community is open, and sidewalks shall be added to separate people and vehicles.

References

[1]. Liang Jun, W. Jiang & X.H. Li, An improvement on fuzzy comprehensive evaluation method and its use in urban traffic planning[J], Journal of Traffic and Transportation Engineering, 2002,2(4), p.1671-1637

[2]. Yong Hua Liu. Research and application of vehicle capacity model in urban road network [D]. Kunming University of Science and Technology, 2004

[3]. Huang Shi Ling. Transport science [M]. Beijing: China communication press, 1988, p.285-295

[4]. Peng Fang, R.Y.Yang, H.J.Xiao&Y.M.He. Mathematical modeling method [M]. Beijing: Science Press, 2012, p.190-194

[5]. Zou Zhijun & D.Y. Yang, Preliminary Study on Dynamic Traffic Microsimulation[J], Journal of Tongji University, 1996,27(3), p.305-308

[6]. Dong Zhen Pu. Mathematical modeling method and practice [M]. Beijing: National Defence Industry Press, 2006, p.131-137

[7]. Zhou Xizhao, C.Q.Liu & P.K.Yang. Space - time resources and traffic space capacity of urban road network during peak hours[J], Journal of Tongji University, 1996,24(4), p.392-397