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Study on the Improvement of Traffic Congestion by Community Open

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***Abstract*—The paper establishes a road evaluation system based on congestion degree and vehicle buffering. By analyzing the density of road vehicles, we establish the vehicle traffic model of neighborhood road, and finally get the relationship between the area S of the open area and the suitable open level n.**

Keywords—community open; road access; congestion degree; vehicle buffer volume

I. INTRODUCTION

Recent years, with the continuous progress of the urbanization process, various communities have gradually formed. The State Council issued a number of views on further strengthening the management of urban planning and construction, and put forward the views of closed community in principle. The rapid progress of urbanization has exacerbated the contradiction between urban traffic supply and demand, increasing urban per capita road area is difficult to accommodate the rapid growth of private cars, relatively lagging urban rail transit is difficult to effectively divert urban road transport, lack of forward-looking city Spatial layout planning and urban road planning these four issues have become the biggest obstacle in the process of urbanization[1].

In order to solve this problem ,the government is currently mainly focused on expanding the traffic supply to meet the traffic demand, but Downs' law has done the best summary about that: the construction of new roads reduces travelling time, but at the same time it attracts other roads and other means of traffic transfer, after a period of time will eventually return to the original congestion level[2].And the current urban road area has been unable to continue to increase, in this case how to effectively use the existing urban road transport network and increase the available road area to become a top priority. Open residential area, to provide part of the residential road for the surrounding road diversion becomes a practical way. Therefore, how to quantitatively analyze the impact of community openness on the traffic capacity of the surrounding roads is particularly important.

The past researches mostly focus on the urban traffic signal control[3], road traffic time [4], intersection delay time[5], through the road traffic time research, the road vehicle capacity is quantified. Nowadays, due to the rapid growth of the number of private cars, some researchers have turned to the analysis of the multi-source and multi-sink traffic and vehicle density[6], especially in the large and medium-sized cities[7][8]. In this paper, we consider the impact of vehicle density on the road, combining the congestion of vehicles on the road and the buffering capacity of the community to road vehicles through the opening of the district, which also combining the road evaluation system with the vehicle buffer model to establish a community-cell buffer model.

II. ROAD EVALUATION SYSTEM

A. Basic Assumptions of the Model

1)Assuming that the cells in the model are regular rectangles whose length is **a**, width is **b** (**a** can be equal to **b**);

2)Assuming that the average occupying area of vehicle is the area of a standard parking space;

3)Assuming that the district can only open in the four directions with each direction have only one door open;

4)Assuming that the district traffic around the road is a constant before opening;

5)Assuming that every driver choose the nearest and convenient way to drive;

6) Assuming that the internal road is a cruciform road or a cross-shaped road.

B. Establishment of the Road Evaluation System

On the road evaluation system, there are many factors such as road congestion, the prevailing safety factor, convenient access level and so on. Among these factors, the objective of objectively and intuitively reflecting road traffic capacity is the degree of road congestion. When describing the saturation of traffic on the road, we naturally think of the saturation of the water in the pipeline. If the surrounding area of the road to imagine a through the pipeline, the corresponding, the pipeline will have its saturation. Now think of the vehicle as a flow, given the definition of congestion degree:

Definition 1: The percentage of vehicles on the road to the total area of the road is the occupancy rate of vehicles on this road.

Obviously, the higher the occupancy rate goes, the greater the degree of congestion will achieve.

Which is, congestion degree (J) = number of vehicles on a road (*N*) • Average vehicle floor area (S_c) / total area of surrounding roads (S_r)

$$J = N*S_c/S_r$$

The number of vehicles traveling on the surrounding roads is

$$N = V_f + V_c$$

V_f represents the road fixed vehicle flow, V_c represents the traffic volume of the incoming and outgoing cells, and S_c represents the average occupying area of the vehicle;

In addition, the area of the surrounding area is

$$S_r = (\mathbf{a} + r_1 + r_3)*(\mathbf{b} + r_2 + r_4) - \mathbf{ab}$$

r_1, r_2, r_3, r_4 are the width of the surrounding roads, **a** and **b** are the length and width of the cell respectively.

The diagram is as follows:

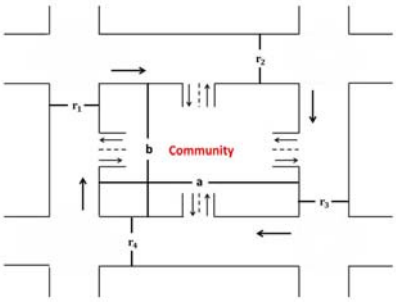

FIGURE I. THE BASIC MODEL OF COMMUNITY

As the degree of openness of the district continues to increase, the congestion degree of the surrounding roads will continue to decrease, but when the congestion degree inside the district is greater than or equal to the congestion degree of the external roads, the community actually has no contribution to alleviate the congestion degree of the external roads, Introducing the definition of congestion rate improvement ratio B:

Definition 2: Changing rate of congestion of external road congestion before and after district opening, that is, congestion improvement ratio = (congestion degree of external road before district opening - congestion degree of external road after district opening) / congestion degree of external road before district opening

$$B = \Delta J / J$$

As the degree of openness of the community is different, the road area available for the community vehicles is different, and the improvement ratio of the congestion rate inside and outside the district is the same, that is, when the density of the vehicles inside and outside the district is the same, the same congestion degree And different levels of congestion improvement. At this point there are

Definition 3: When the density of the vehicle inside and outside the road is same, the corresponding congestion rate improvement ratio is the congestion rate improvement ratio threshold B_0.

III. VEHICLE BUFFER MODEL

A. *Establishment of Vehicle Buffer Model*

(1) For most of the communities, the maximum number of open doors is 4. When the community opens 4 doors, the community has reached its largest buffer for the vehicle. So here gives the definition of the district maximum vehicle buffer:

Definition 4: The maximum vehicle buffer (H) = the area (k*S) / average vehicle floor area (S_c) for the vehicle traffic outside the cell, in the case where the four doors are open, which is

$$H = k*S/S_c$$

S is the total area of the cell, k is the ratio of road area for vehicle traffic to the total area of the community, and S_c is the average vehicle occupying area.

(2) Due to the different level of openness, the actual vehicle buffer volume is different. So the introduction of f_n indicates the vehicle buffering capacity when the neighborhood is open to n doors.

When the district is open 1,2,3,4 doors, the buffer is f_1, f_2, f_3, f_4.

1' Community only open one door, that is, n = 1, because the community does not have the capacity of vehicular traffic, which means it's not open. So there is no buffering effect. The actual vehicle buffer amount of the cell is

$$f_1 = 0$$

2'It opens two doors, that is, n = 2, there are three ways:

2'-1 Open the farthest two doors, as Figure 2'-1 (open the door A and door A') shown below

At this point, because the cell length is a, width is b, the community has two length of a road can be passable, and the total length of the road is 2α. While opening 4 doors, two length is a, two length of b, the total length of the road is 2 (a + b). When two doors are opened, the ratio of road length for vehicular traffic to the total road length in the community is

$$\frac{2a}{2(a+b)}$$

then

$$f_2=\frac{2a}{2(a+b)}H=\frac{a}{a+b}H$$

Similarly,

2'-2 It opens the nearest two doors, as Figure 2'-2 (open the door B and door B') shown below

at this time

$$f_2=\frac{2b}{2(a+b)}H=\frac{b}{a+b}H$$

2'-3 It opens the adjacent two doors, as Figure 2'-3 (open the door A and door B') shown below

at this time

$$f_2=\frac{a+b}{4(a+b)}H=\frac{1}{4}H$$

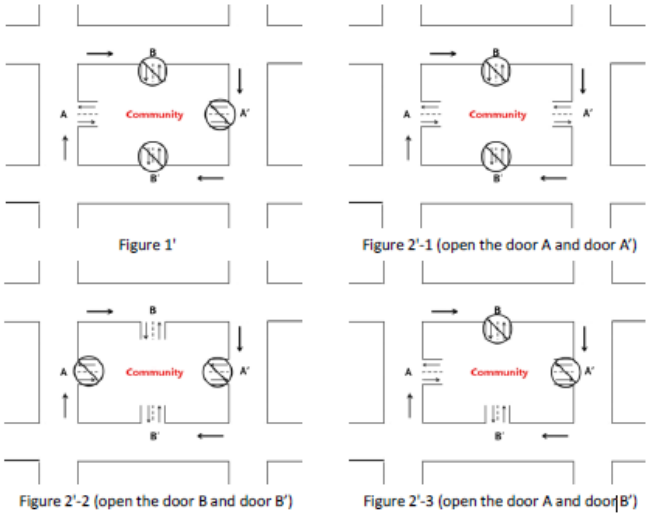

Figure 1'
Figure 2'-1 (open the door A and door A')
Figure 2'-2 (open the door B and door B')
Figure 2'-3 (open the door A and door B')

FIGURE II. FIGURE 1'—FIGURE 2'-3

3 ' Community open three doors, that is, n = 3, there are two ways:

3'-1 It opens the two furthest doors and an adjacent door, as Figure 3'-1 (open the door A , door A' and door B') shown below

at this time

$$f_3=\frac{2a+b}{2(a+b)}H$$

H is the maximum vehicle buffer volume;

3'-2 Open the nearest two doors and an adjacent door, as Figure 3'-2 (open the door B , door B' and door A') shown below

at this time

$$f_3=\frac{2b+a}{2(a+b)}H$$

4' All four doors are open, that is, n = 4, as Figure 4' shown below

at this time

$$f_4=H$$

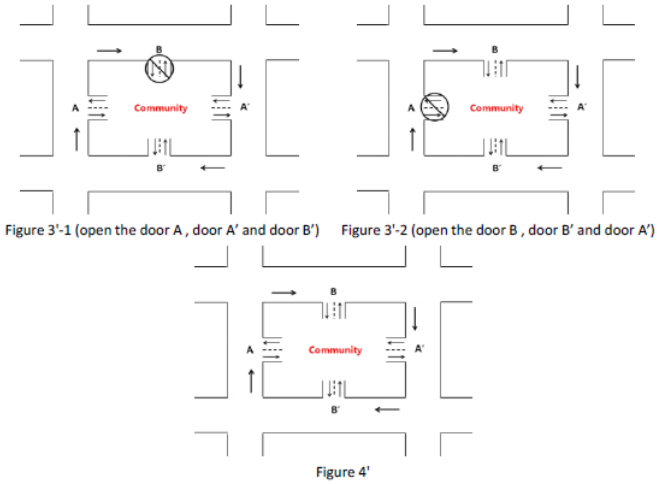

Figure 3'-1 (open the door A , door A' and door B')
Figure 3'-2 (open the door B , door B' and door A')
Figure 4'

FIGURE III. FIGURE 3'-1—FIGURE 4'

Therefore, in the different open degree, the vehicle buffer is

$$f_n=\begin{cases} 0 & ,n=1 \\ \frac{2a}{2(a+b)}H=\frac{a}{a+b}H & ,n=2\ (\text{open the door A and door A'}) \\ \frac{2a}{2(a+b)}H=\frac{a}{a+b}H & ,n=2\ (\text{open the door B and door B'}) \\ \frac{a+b}{4(a+b)}H=\frac{1}{4}H & ,n=2\ (\text{open the door A and door B'}) \\ \frac{2a+b}{2(a+b)}H & ,n=3\ (\text{open the door A,door A' and door B'}) \\ \frac{2b+a}{2(a+b)}H & ,n=3\ (\text{open the door B ,door B' and door A'}) \\ H & ,n=4 \end{cases}$$

B. *Application and Solution of the Model*

Eleni l's studies [9] show that it is possible to construct an accurate predictor that will use past information on traffic and statistical characteristics of patterns in order to predict the pattern in the next step. Back in the Vehicle traffic model, the district vehicle buffer amount f_n is the variable V_c above. When V_c take a negative value, it shows the flow into the cell within the vehicle, this part of the vehicle is the amount of parking for external vehicles, which can be used to quantitatively simulate the change of the congestion degree of the surrounding roads in different areas before and after the opening of different style of communities.

The relationship between the degree of congestion and the amount of vehicle buffering is as follows:

$$J=\frac{(V_f-f_n)S_c}{S_r}$$

Then

$$J=\begin{cases} \dfrac{V_f \cdot S_c}{S_r} & ,\ n=1 \\ \dfrac{(V_f-\frac{a}{a+b}H)S_c}{S_r} & ,n=2\ (\text{open the door A and door A'}) \\ \dfrac{(V_f-\frac{b}{a+b}H)S_c}{S_r} & ,n=2\ (\text{open the door B and door B'}) \\ \dfrac{(V_f-\frac{1}{4}H)S_c}{S_r} & ,\ n=2\ (\text{open the door A and door B'}) \\ \dfrac{(V_f-\frac{2a+b}{2(a+b)}H)S_c}{S_r} & ,n=3\ (\text{open the door A,door A' and door B'}) \\ \dfrac{(V_f-\frac{2b+a}{2(a+b)}H)S_c}{S_r} & ,n=3\ (\text{open the door B ,door B' and door A'}) \\ \dfrac{(V_f-H)S_c}{S_r} & ,\ n=4 \end{cases}$$

In addition, due to the limited number of vehicles in the surrounding roads, the size of the actual vehicle load on the road will determine the maximum number of households suitable for living in the most crowded period of the road, that is, the morning and evening peak hours and the actual Traffic conditions, so that:

Definition 5: The maximum number of vehicles that can be accommodated in the road per unit time is the vehicle carrying capacity of the roadside;

Area road vehicle load capacity of the road around h = road area (S_r) / the average occupying area of vehicle (S_c)

$$h=S_r/S_c$$

Tian Qiong(2010) proposed a morning commuting equilibrium model that incorporates traffic congestion based on fundamental traffic flow diagram to deal with the morning traffic peak[10].In this paper, we assume that all the people who need to work leave the community in the morning rush hours(morning rush hours is defined as 8: 00-9: 00 a.m.), then the community outflow of traffic V_c should meet

$$V_c \le h - V_f$$

H is the vehicle carrying capacity of the surrounding roads, V_f is the traffic volume of the surrounding roads.

C. *Case Study*

The size of the area will directly determine the size of the area of the road, so as to determine the size of the internal road vehicle volume. According to the area of the plot to divide the community into small, medium and large three categories, we assume that the width of each road around the community is consistent, that is, $r_1=r_2=r_3=r_4$, and all the cells are square cells. The area of small-sized community is 129,600(360*360) m^2, the area of the medium-sized community is 176,400(420*420) m^2, and the area of the large-sized community is about 211,600 (460*460) m^2. Where the number of open doors is 2, and the opening of the two adjacent doors only allows the vehicle to pass through (because the reverse will return to the previous position, which is no practical significance), so the number of opening door as 2-1, When opening two non-adjacent doors, the number of open doors is counted as 2-2. Assuming that the average occupying area of vehicle(S_c) is the area of a standard parking space. Applicated the road assessment system and vehicle access model, there are

1. Small-sized community

(V_f=2000/h, k=0.15, a=360 m, S_c=18.75 m^2,r=7.5 m)

TABLE I. SMALL-SIZED COMMUNITY(S=129600(360·360) M^2)

n	f_n	J	B	$S_{in}(m^2)$	$S_{out}(m^2)$	B_0	ΔB
1	0.00	3.47	0.00	0	10800	0.00	0.00
2-1	259.20	3.02	0.13	4860	10800	0.31	0.18
2-2	518.40	2.57	0.26	9720	10800	0.47	0.21
3	777.60	2.12	0.39	14580	10800	0.57	0.19
4	1036.80	1.67	0.52	19440	10800	0.64	0.12

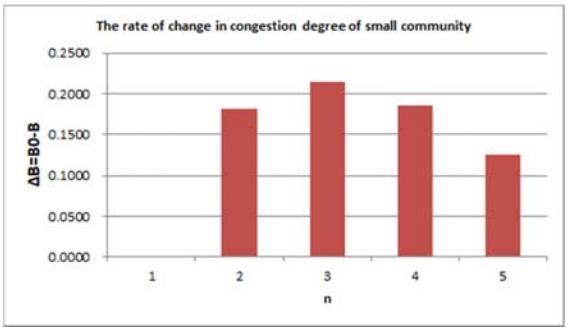

FIGURE IV. SMALL-SIZED COMMUNITY

2. Medium-sized community

(V_f=2000/h, k=0.15, a=420 m, S_c=18.75m^2, r=7.5m)

TABLE II. MEDIUM-SIZED COMMUNITY IS 176400(420·420) M^2

n	f_n	J	B	$S_{in}(m^2)$	$S_{out}(m^2)$	B_0	ΔB
1	0.00	2.98	0.00	0	12600	0.00	0.00
2-1	352.80	2.80	0.18	6615	12600	0.34	0.17
2-2	705.60	1.93	0.35	13230	12600	0.51	0.16
3	1058.40	1.40	0.53	19845	12600	0.61	0.08
4	1411.20	0.88	0.71	26460	12600	0.68	-0.03

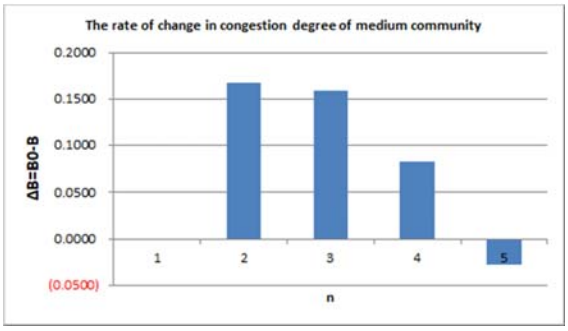

FIGURE V. MEDIUM-SIZED COMMUNITY

3. Large-scale community

(V_f=2000/h, k=0.15, a=460 m, S_c=18.75m^2, r=7.5 m)

TABLE III. LARGE-SIZED COMMUNITY 211600 (460·460) M^2

n	f_n	J	B	$S_{in}(m^2)$	$S_{out}(m^2)$	B_0	ΔB
1	0.00	2.72	0.00	0	13800	0.00	0.00
2-1	423.20	2.68	0.21	7935	13800	0.37	0.15
2-2	846.40	1.57	0.42	15870	13800	0.53	0.11
3	1269.60	0.99	0.63	23805	13800	0.63	0.00
4	1692.80	0.42	0.85	31740	13800	0.70	-0.15

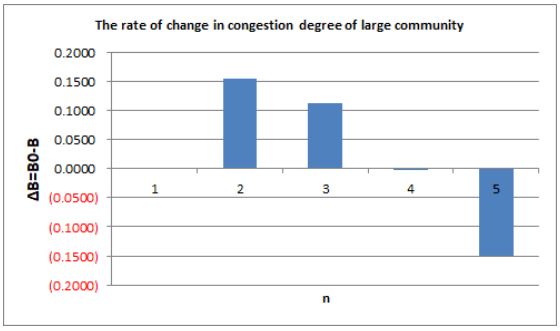

FIGURE VI. LARGE-SCALE COMMUNITY

D. Chart Analysis

1) When the model reaches the dynamic equilibrium, it performs as external road traffic density is equal to the density of vehicles within the community. Due to the difference in the area between the inside and the outside of the district, the corresponding increase in the ratio of congestion at the same internal and external road density is not the same. When $\mathbf{\Delta B > 0}$, the external vehicle has been the trend of continuing to flow into the district; when $\mathbf{\Delta B < 0}$, buffers of vehicles within the community has reached saturation, which means the outside vehicles can't go into the community so that there is no improvement to continue opening.

2) In addition, the number of opening doors will also directly affect the congestion improvement ratio, we can draw from the figure: small area open four doors to achieve the best results to improve; medium-sized open three doors to achieve the improvement of the door Good; large district open two doors to achieve the best results to improve. At the same time, when opening two doors, the traffic benefits of opening two doors on the opposite side are higher than those of opening two doors on the border. If a cell is suitable for opening two doors and its area is relatively small, it is suitable for opening two doors on the opposite side.

The opening of the community will change the pattern of urban planning, and will bring great changes to the road traffic network. Through the establishment of the model and the analysis of the example, we conclude the relation between the area **S** of the open area and the most suitable open door number **n** and the standard threshold of the classification of the size type of the community, as follows:

TABLE IV. CLASSIFICATION OF THE SIZE TYPE OF THE COMMUNITY

Community type	critical area（m^2）	n
small	168018.01	4
medium	210864.64	3
large Ⅰ	286011.04	2
large Ⅱ	458329.00	2

Specially, when the community area is 210864.64 ＜S ≤ 286011.04(m^2), the community type is large-scale Ⅰ community, the number of opening gate should be 2.When the community area is 286011.04＜S≤458329.00(m^2), the community type is large-scale Ⅱ community, the number of opening gate should be 2.When the community area is S>458329.00(m^2), the community type is super-scale community, according to the model, there is no necessity to open this community.

IV. CONCLUSION AND PROSPECT

Based on the existing road space and the road access status, this paper established the vehicle traffic model on account of the maximization of road space utilization by analyzing the road traffic effect that may be generated by community open. It makes reasonable planning on the existing road and community situation in order to achieve the effective use of road space resources, which will provide guiding references for the growing number of regional community open in the future.

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REFERENCES

[1] LIU Zhiyan, YUE Xiaoyan, ZHAO Rui. The Cause of Urban Traffic Congestion and Countermeasures in China. Urban Studies. 2011(11):90-96.

[2] LIU Xiao. A Literature Review on the Study of Urban Traffic Congestion. Economic Research Guide. 2010(4):102-103.

[3] Webster F V. Traffic signal settings[R].Road Research Laboratory Technical Paper No.39,HMSO,London,1958.

[4] Nagel K, Schreckenberg M. A cellular automaton model for freeway traffic[J].Journal of Physics I France,1992,2(12):2221-2229.

[5] GUAN Yicheng, YAN Tingxiao, GONG Changhui. The Influence of Open Community to Traffic. Logistics Engineering and Management. 2017(1):85-86.

[6] Wang Qian, Zhou Ruoyu, Li Jiahao. Evaluation of opening community based on the multi-source and multi-sink maximum flow model. Shanxi Architecture. 2016(33):28-29.

[7] WANG Dan, MAO Ziyang, WU Mengda. The Influence of Opening the Gated Communities. Mathematical Modeling and Its Applications. 2016(4):34-40.

[8] LI Yue, LI Yong, WANG Qing, et al. A Study on the Influence of Community Opening on Road Traffic. Journal of Xichang College·Natural Science Edition. 2017(1):19-23.

[9] Eleni I. Vlahogianni. Prediction of non-recurrent short-term traffic patterns using genetically optimized probabilistic neural networks.Operational Research.2007,7(2):171-184.

[10] Tian Qiong, Yang Hai, Huang Haijun. Novel travel cost functions based on morning peak commuting equilibrium. Operations Research Letters.2010(3):195-200.