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The simulation model on delay time of road accessibility based on intelligent traffic control system

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Abstract
After the Chinese government launched the policy of opening residential, the effects of easing traffic congestion have been widely discussed. In this paper, the impact of the open area on the surrounding road capacity is studied and analyzed quantitatively, and some feasible suggestions are put forward. First of all, we use the road congestion indicators to reflect the road traffic situation. And according to the three indexes to build an evaluation index system that can evaluate the influence of opening residential quarter on the surrounding road capacity. After determining the final evaluation indexes, the analytic hierarchy process is used to determine their standard weights. Second, build a mathematical model of vehicle traffic. The crossing time of vehicles is used to measure the traffic condition. Last but not least, suppose that after opening the residential quarter, there will be more vehicles, with the increase of the number of vehicles, the road saturation will increase, which will lead to the increase of traffic time. In the paper, three typical opening road structures are established to specific analyze the changes of the crossing time of vehicles, and then, use model one and model two to solve it. Opening residential quarter has a certain positive effect on the surrounding road capacity, on the condition of the number of connections between the opening residential quarter and the surrounding roads is not more than two. Otherwise, it will increase road congestion. In spite of a certain positive effect that opening residential quarter brings to the surrounding road capacity, blindly increase the number of opening residential quarter roads, road congestion may be increased.

Keywords Opening residential quarter · Smart traffic control system · Delay time · Road structure · Road capacity

1 Introduction

In February 2016, the State Council China's State Council issued the "opinions" on the promotion of opening residential quarter, which has caused a heated debate. Some people worry about whether or not the opening residential quarter can optimize the road network structure, improve the road capacity, improve the traffic situation and bring definite improvements. On the one hand, some people consider that opening residential quarter can improve the density of road networks, increase road areas, thereby enhancing traffic capacity. On the other hand, the number of vehicles entering and leaving the opening residential quarter will increase, so that road congestion can be caused. The essence of the heated debate focused on the concept of accessibility. In 1959, Hansen proposed the concept of accessibility. Hansen argues that accessibility is a description of the magnitude of the direct attraction of nodes in transportation [1]. In 1970, Hagerstrand combined time geography and accessibility research, through the geographic information system, to build a space-time accessibility model, to explain the spatial distribution of the impact on every individual [2]. In 1987, Goodall pointed out that accessibility represents the distance between two locations, and can not just rely on distance to determine the accessibility [3]. Let's return to the issue of closed residential quarter. In 2000, Landman K analyzed the causes of residential quarters, including fears of crime, a search for a better way of life, a desire for a community consciousness, a quest for like-minded people, and a higher social status Longing and so on are to promote the contin-

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uous development of closed residential quarter. Meanwhile, some drawbacks still exist, such as the contrary to the principle of sustainable development. Karina further pointed out the defects and disadvantages of closed residential quarters, such as the road in the residential quarters have no effect on solving congestion problems, which can greatly reduce the utilization value of District roads, but also makes the road network accessibility decreased [4]. In 2003, Handy and other scholars once again proposed that the broken roads in the connected area could improve the accessibility of urban roads and improve the urban traffic conditions [5]. In 2007, Moore and other scholars believe that optimizing the integration of the district's space environment and the district roads and roads could facilitate the level of travel [6]. Roitman reorganized the research work on the closed residential quarter and analyzed the advantages and disadvantages of the closed residential quarter from the perspective of space, economy, politics and society. It clearly pointed out that the closed area has improved the service and facilities to a certain extent. The utilization rate also makes the environmental quality higher, but also caused the street interruption, broken urban space and the center can be the loss of residence, showing that the existence of a closed area to a certain extent hindered the city traffic [7]. Besides, many scholars have already done a lot of research on these problems and puts forward the corresponding solutions. Cai have carried out intensive research on the influence of access density on the maximum actual traffic capacity of arterial roads [8]. He and other scholars [9] have constructed the actual traffic capacity model to study the influence of different community opening on road traffic, and the model is modified by introducing Lane change coefficient and the mixed intensity coefficient. Vega and Reynolds have presented a modeling framework that combines standard discrete choice models with GIS network analysis for the integrated study of residential location and travel mode decisions [10]. Aktas and Bilec have made a statistical analysis of US residential building [11]. Kammoun thought road networks are characterized by their great dynamics including different entities in interactions, this lead to more complex road traffic management [12]. Guzman has proposed a framework for a dynamic and automatic traffic light control expert system combined with a simulation model, which is composed of six sub models coded in Arena to help analyze the traffic problem [13].

Also, they have put forward the corresponding solutions. Xu and Sun have proposed a traffic signal control method called Green Swirl, and a new route guidance method called Green Drive. Green Swirl controls traffic signals, they also use navigation systems to guide individual drivers along optimal routes [14]. In combination with traffic analysis theory and Bayesian method, Li established an evaluation index to judge the traffic conditions around the enclosed area. Li and Grant have researched the tradable credit scheme—an incentive-based economic measure—in order to address traffic congestion [15,16,30]. Li, Anavatti and Ray have focused on an optimum route search function in the in-vehicle routing guidance system and it could provide dynamic routing advice based on real-time traffic information and traffic conditions, such as congestion and roadwork [17].

In order to analyze the influence of opening residential quarter on the surrounding road, first of all, the road congestion indicators can reflect the road traffic situation and the road congestion index is divided into three sections: Section saturation, intersection saturation and the number of the entrance and exit connections. And according to the three indexes to build a evaluation index system that can evaluate the influence of opening residential quarter on the surrounding road capacity. After determining the final evaluation indexes, the analytic hierarchy process is used to determine their standard weights. Second, build a mathematical model of vehicle traffic. The passage time of vehicles are used to measure the traffic condition. The shorter the passage time, the better the traffic condition is. The passage time of vehicles include: the passage time of a section of a road, the delay time of a section of a road, the delay time of an intersection. And build the relationship between the time indexes and the number of roads in residential quarter and saturation. Last but not least, suppose that after opening the residential quarter, the roads in the residential quarter have advantages to let the driver to choose it. Nevertheless, with the increase of the number of vehicles, the road saturation will increase, which will lead to the increase of traffic time. In the paper, three typical opening road structures are established to specific analyze the changes of the passage time of vehicles, and then, use model one and model two to solve it, and offer some proposals.

2 Problems and research hypothesis

2.1 Break down the problem

In recent years, there are a numerous of researches on the opening residential quarter on road capacity at home and abroad.

In China, it is known to all that suzhou is a city with its long history opening residential block, Xingyu and other scholars have studied searches on the transportation characteristics of suzhou, such as volume of persons and vehicles as well as its relation between land area and floor area, so as to get the relevant parameters and trip prediction model of site traffic, and this study has provided some scientific survey data methods to give reference to opening residential development [18]. Jin and other scholars have analyzed the traffic capacity and delays to vehicles and pedestrians, and assess the impacts of the model parameters [19]. Kang

and other scholars have studied whether the opening of residential quarters can improve the road capacity of the entire city and remit the traffic pressure, which is based on graph theory, density theory and random utility theory [20]. In the foreign countries [21], Lécué and other scholars have presented a new idea that use semantic Web technologies to predict a severity of road traffic congestion. Donato and other scholars have designed traffic identification engine (TIE)'s architecture and functionalities focusing on the evaluation, comparison, and combination of different traffic classification techniques, which can be applied to both live traffic and previously captured traffic traces [22]. Kammoun and Kallel I have proposed an adaptive multiagent system based on the ant colony behavior and the hierarchical fuzzy model to discuss the improvement of the opening residential quarter on surrounding road traffic quality, fluidity and adaptivity [12].

In this paper, in order to analyze the influence of opening residential quarter on surrounding road capacity, we divide this problem into three parts, and we will also analyze each of these problems in turn.

① **Problem1: Select the appropriate evaluation indexes to evaluate the impact of opening residential quarter on the surrounding road capacity**

The influence of the open area on the surrounding road traffic is multifaceted, in order to be able to fully and accurately evaluate the impact of opening residential quarter on the surrounding road capacity, we need to establish a reasonable evaluation index system. In addition, the evaluation indexes need the following principles: comparability principle, coordination principle, independence principle. The opening of the residential quarter is bound to bring two direct results: the increase of the road networks and intersections. Moreover, the road congestion index is divided into a section of a road traffic index and intersection index. Then, according to the road congestion index, we evaluate the impact of opening residential quarter on the surrounding road capacity (Fig. 1).

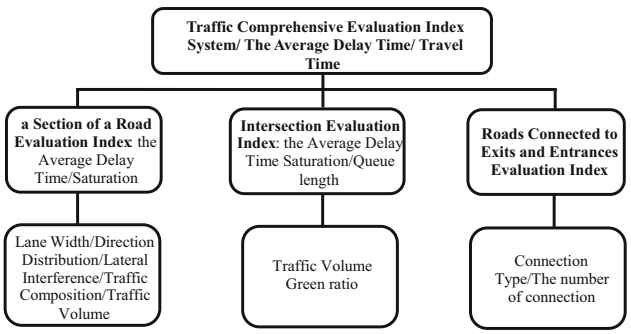

Fig. 1 Evaluation index system

In like manner, when the intersection index is analyzed, the traffic volume, saturation and the average delay time are chosen as the evaluation indexes. We determine the final indicators and the weight of each index through the establishment of the model.

② **Problem2: Establish a mathematical model of vehicle traffic to analyze the influence of opening residential quarter on the surrounding road capacity**

The passage time between the two places is the primary factor for the driver to choose the route. In the paper, the crossing time of vehicles are used to measure the traffic condition. The shorter the crossing time, the better the traffic condition is. That is to say, opening residential quarter has a positive effect on the surrounding road capacity. The crossing time of vehicles include: the crossing time of a section of a road, the delay time of a section of a road, the delay time of a intersection. And build the relationship between the time indexes and the number of roads in residential quarter and saturation, to build a mathematical model of vehicle traffic. On the contrary, the condition is actually just the opposite.

③ **Problem3: Based on the model established in problem 2, quantitatively compare the effects of different types of opening residential quarter on the surrounding road capacity**

Suppose that after opening the residential quarter, the roads in the residential quarter have advantages to let the driver to choose it. Nevertheless, with the increase of the number of vehicles, the road saturation will increase, which will lead to the increase of traffic time. In the paper, three typical opening road structures are established to specific analyze the changes of the crossing time of vehicles, and then, use model one and model two to solve it.

2.2 Research hypothesis

① **Hypothesis1**: Assuming that the number of the total vehicle flow unchanged, whether the residential quarter is opened or not.
② **Hypothesis2**: Ignore the impact of pedestrians and non motorized vehicles on road traffic.
③ **Hypothesis3**: Do not consider the start time of motor vehicles, and do not need to stop waiting except for traffic lights.
④ **Hypothesis4**: The delay time function model of T type intersection and cross intersection are the same.
⑤ **Hypothesis5**: Suppose that after opening the residential quarter, the roads in the residential quarter have advantages to let the driver to choose it.
⑥ **Hypothesis6**: Do not consider the passage time of a intersection.

Table 1 Variable description

Variable	Implication	Variable	Implication
c_i	Traffic capacity under the actual conditions	C_1	A section of a road saturation
c_0	Basic road capacity	C_2	Intersection saturation
v_i	Each section of a road peak hour traffic volume	C_3	Roads connected with exits and entrances saturation
T_{ij}	The total transit time of the section of a road "i" to "j"	r_1	The weights of impact a fact section of a road
T_N	The total time of passing through the residential quarter	r_2	The weights of impact a fact section of intersection
T_w	The total time of not passing through the residential quarter	r_3	The weights of impact a fact section of exits and entrances
n	The number of road sections within the traffic scope	f_{cw}	The correction coefficient of the lane width on road capacity
f_{DIR}	Directional distribution of the lane width on road capacity	f_{FRIC}	Transverse interference of the lane width on road capacity
f_{HV}	Traffic composition of the lane width on road capacity	v_i	Each section of a road peak hour traffic volume
n	The number of road sections within the traffic scope	λ_i	Green ratio (effective green time / cycle time)
S_i	Saturation flow rate of lane group (saturation under ideal conditions, generally take 1800 veh/ green hour /ln)	T	The length of signal cycles
t_g	Effective green time	d_i	Capacity of each road

3 Materials and methods

3.1 Data collection

In order to solve the above three problems, we reference to the "Road Capacity Manual", "urban road design code", "urban residential area planning and design code" and other relevant information and norms. And when solve of the third problem, select the length of 2 km of the rectangular residential quarter. In compliance with the specification, It is reasonable to assume that the average speed of the main road around the residential area is 50 km/h, and the speed limit of setting the main road in the residential quarter is 50 km/h. 50 km/h, peripheral road intersection green time is 30 s, the cycle is 60 s. The green time at the exit of the residential quarter is 20 s, the period is 60 s, the green time in the other direction is 40 s, the cycle is 60 s, the peak traffic is 750 (Tables 1, 2, 3, 4, 5, 6, 7).

3.2 Nomenclatures

3.3 Modeling foundation and solution

3.3.1 Model one

The surrounding road traffic states of opening residential quarter conclude: A section of a road traffic states and intersection traffic states. The two basic traffic factors are considered to analyze a section of a road traffic states: Road traffic volumes "Q", section length "S". Also, the passage time of a section of a road, the delay time of a section of a road, the delay time of a intersection are traffic factors. The increasing of the passage time of a section of a road and the decreasing of travel speed are the most direct expressions of congestion. Thus, the evaluation of urban road traffic state can be taken into account in terms of traveling time, traveling speed and delaying rate. In this paper, we choose the road travel time as the main evaluation indicator.

Road traffic state is quantified by saturation, we choose the sections of road, intersections and entrances and exits to analyze, and we use the weights of each of influence indexes to calculate the comprehensive traffic state of sections of road saturation.

$$\frac{v}{c} = r_1 C_1 + r_2 C_2 + r_3 C_3 \tag{1}$$

① A section of a road saturation is used to quantify each of indexes

Build the following model,

$$C_1 = \sum_{i=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} c_i} \tag{2}$$

$$c_i = c_0 \times f_{cw} \times f_{DIR} \times f_{FRIC} \times f_{HV} \tag{3}$$

Table 2 The correction coefficient of the lane width on road capacity

Lane width	Correction coefficient
6	0.52
7	0.56
8	0.84
9	1.00
10	1.16
11	1.32
12-15	1.48

Table 3 Directional distribution of the lane width on road capacity

Directional distribution (%)	Correction coefficient
50/50	1.00
55/45	0.97
60/40	0.94
65/35	0.91
70/30	0.88

Table 4 Transverse interference of the lane width on road capacity

Transverse interference level	Correction coefficient
1	0.91
2	0.83
3	0.74
4	0.65
5	0.57

② Intersection saturation is used to quantify each of indexes

$$C_2 = \sum_{i=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} c_i} \tag{4}$$

$$c_i = S_i \times \lambda_i \tag{5}$$

By means of fuzzy evaluation model, unify a section of road saturation, intersection saturation, roads connected with exits and entrances connect saturation, to reflect the impact on road traffic.

③ Influence of entrance and exit on road traffic is used to quantify each of indexes

After opening the residential quarter, the number of the roads that connected with residential quarter's exits and entrances will impact on road traffic, meanwhile, with the change of the level of roads, the impact index will be changed. In the paper, the following three types of connections are selected, and assign the corresponding value.

A Residential quarter's exits and entrances are connected to branch roads, and its value is "N".

Table 5 Two lane highway service level classification table

Service level	Saturation (v/c)
1	0.14
2	1.40
3	0.64
4	1.00

B Residential quarter's exits and entrances are directly connected to the city secondary main roads, and its value is "2 N".

C Residential quarter's exits and entrances are directly connected to the city main roads, and its value is "3 N".

There into," N" means the number of residential quarter's entrances and exits.

④ The selection of evaluating criterion

The primary indicators of comprehensive evaluation system consist of the impact of intersection, section and entrance and exit on road capacity. Correspond to the primary indicators collection ($x = \{x_1, x_2, x_3\}$). Meanwhile, determine the saturation of evaluating collection ($z = \{z_1, z_2, z_3, z_4, z_5\}$), corresponding to the five levels of evaluation: no congestion, low congestion, general congestion, moderate congestion and high congestion. Then, we use the analytic hierarchy process to analyze the proportion of the primary the primary indicators collection in the comprehensive evaluation system. Also, we consult road capacity manual and get the relationship between two lane highway service level and saturation.

⑤ Determine the evaluation index weight vector

First of all, construct the judgment matrix, we choose AHP method to compare the relative importance of all factors [17], and every time only two factors are compared, the judgment matrix structured is as follows, there into, a_{ij} is the element of judgment matrix A, indicates the importance of relative a_i to a_j:

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}. \tag{6}$$

Then, through the data investigation and subjective grading method, we get the importance of all the primary evaluation factors in comprehensive evaluations, that is to say, we score the influence of all evaluation factors on comprehensive evaluation index. And the scores are as follows.

And, to obtain the relative importance of the two factors, we define the factor a_{ij}:

$$a_{ij} = \frac{p_i}{p_j} \tag{7}$$

Table 6 The definition and description of 1–9 scale

Scale	Definition
1	Two factors that have the same importance when compared to the two factor
3	A factor is slightly important than the other factor when compared to the two factor
5	A factor is obviously important than the other factor when compared to the two factor
7	A factor is strongly important than the other factor when compared to the two factor.
9	A factor is extremely important than the other factor when compared to the two factor
2, 4, 6, 8	The median of the two adjacent judgments
Reciprocal	If the result of the comparison of factor "i" and "j" is "a_{ij}", then the result of the comparison of factor "i" and "j" is "a_{ij}=1/a_{ij}"

Table 7 The score of the influence

	Intersection	A section of a road	Road connected with exits and entrances
Score (Pi)	9	7	6

The relative importance degree matrix:

$$A = \begin{bmatrix} 1 & 1.286 & 1.500 \\ 0.778 & 1 & 0.667 \\ 0.667 & 0.857 & 1 \end{bmatrix} \tag{8}$$

⑥ **Compute weight vectors**

To begin with, let the feature vector of matrix "A" as "$|A - \lambda I| = 0$", and "I" means unit matrix, then we can get the eigenvalue λ_i $(i, 2, 3 \cdots n)$ and the maximum eigenvalue is $\lambda_{\max}$, the corresponding of $\lambda_{\max}$ normalized feature vectors is $Y = (y_1, y_2, y_3, \ldots, y_n)^T$, $y_i o$ $(i = 1, 2, \ldots, n)$ is the objective weight of factor "c_i". And it also corresponds to the eigenvector of the maximum eigenvalue of the judgment matrix that indicates the relative importance degree of the factors.

Calculate the n square root of the product of each row elements of the judgment matrix A:

$$\bar{W}_I = \left(\prod_{j=1}^{n} a_{ij} \right)^{\frac{1}{2}} \quad (i = 1, 2, \ldots, n) \tag{9}$$

Normalization and normalization of vector:

$$W_i = \frac{\bar{W}_I}{\sum_{I=1}^{N} \bar{W}_I} \tag{10}$$

$W = (W_1, W_2, \ldots, W_n)^T$ is the eigenvector of the maximum eigenvalue.

And then we get greatest eigenvalue:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(A \times W)_i}{n \times W_i}. \tag{11}$$

3.3.2 Model two

Because the passage time from the starting point to the destination are the total of the passage time of the road section, the delay time of the road section and the delay time of the intersection. So we establish the following formula, and we assume the passage time of the road section is "T_{ij}":

$$T_{ij} = \frac{S_{ij}}{V_{ij}} + t_{ij} + n_j \tag{12}$$

Thereinto,"t_{ij}" is a function the delay time of the road section, S_{ij} is the distance of "ij", "V_{ij}" is the vehicle speed.

Also, we build that:

$$t_{ij} = \delta \times \left(\frac{V_{ij}}{C_{ij}} \right) \gamma \times \frac{S_{ij}}{V_{ij}} \tag{13}$$

And $\delta = 0.15$, $\gamma = 4$.

What's more, we assume that the average delay time of the intersection as "n_J", and the influencing factors include the road saturation and the length of the cross lipstick light signal. After consulting the relevant information, the relationship between the three is as follows:

$$n_j = \frac{0.5T\left(1 - \frac{t_g}{T}\right)}{1 - \frac{V_{ij}}{C_{ij}} \times \frac{t_g}{T}} \tag{14}$$

put the T and t_g into the formula (12), and we can get the overall evaluation model:

$$T_{ij} = \frac{S_{ij}}{V_{ij}} + \delta \times \left(\frac{V_{ij}}{C_{ij}} \right) \gamma \times \frac{S_{ij}}{V_{ij}} + \frac{0.5T\left(1 - \frac{t_g}{T}\right)}{1 - \frac{V_{ij}}{C_{ij}} \times \frac{t_g}{T}}. \tag{15}$$

3.3.3 Model three

We reference to the "urban road design code", "urban residential area planning and design code" and other relevant information and norms. And when solve of the third problem, select the length of 2 km of the rectangular residential quarter. In compliance with the specification, it is reasonable to assume that the average speed of the main road around the residential area is 50 km/h, and the speed limit of setting the main road in the residential quarter is 50 km/h. 50 km/h, peripheral road intersection green time is 30 s, the cycle is 60 s. The green time at the exit of the residential quarter is 20 s, the period is 60 s, the green time in the other direction

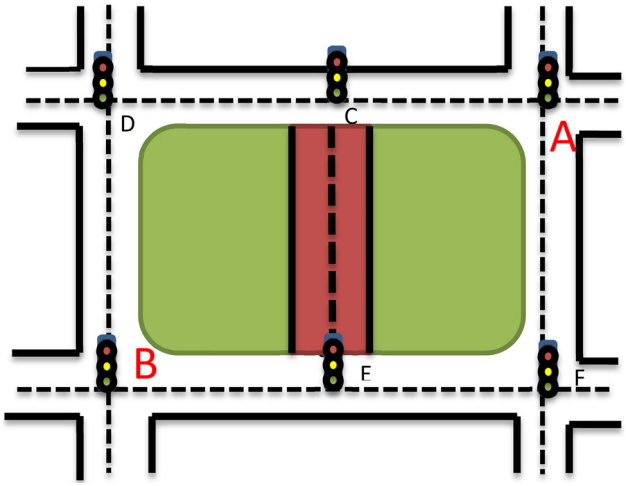

Fig. 2 The first case

is 40 s, the cycle is 60 s, the peak traffic is 750. And we use the model one and model two to solve the problem3.

① **The first case: Only one road in the residential quarter connected with the surrounding roads**

As the Fig. 2 shows, suppose the vehicle travels from A to B. And we use to model one to analyze the surrounding roads, roads in residential quarter, intersections, entrances and exits road capacity.

The surrounding roads:

$$c_1 = c_0 \times f_{cw} \times f_{DIR} \times f_{FRIC} \times f_{HV} = 1547 \tag{16}$$

$$V_1 = 750 \tag{17}$$

Roads in residential quarter:

$$c_2 = c_0 \times f_{cw} \times f_{DIR} \times f_{FRIC} \times f_{HV} = 515.84 \tag{18}$$

$$V_2 = 350 \tag{19}$$

Crossroads: $c_1 = S_i \times \lambda_i = 900$ (Green ratio $\lambda_i = 30/60$, $\lambda_i = 1800$).

Three-way intersection $c_1 = S_i \times \lambda_i = 600$ (Green ratio $\lambda_i = 20/60$, $\lambda_i = 1200$).

(1) Before opening the residential quarter, the section of a road traffic saturation:

$$c_1 = \sum_{i=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} c_i} = \left(\frac{750}{1547} + \frac{750}{1547}\right) \times \frac{1547}{1547 \times 2} = 0.48481 \tag{20}$$

Intersection saturation:

$$c_1 = \sum_{i=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} c_i} = 1.3216 \tag{21}$$

Next we test the impact of entrances and exits of the residential quarter on road capacity.

Calculate the saturation before opening residential quarter $\frac{v}{c}$:

$$c_3 = \frac{1}{3}, \frac{v}{c} = r_1 C_1 + r_2 C_2 + r_3 C_3 = 0.4296 \times C_1 + 0.2839 \times C_2 + 0.2864 \times C_3 \tag{22}$$

Into the data:

$$\frac{v}{c} = 0.8715 \tag{23}$$

(2) After opening the residential quarter, in intersections, according to the principle of distribution, we distribute the traffic volume in accordance with road traffic capacity, and he principle of distribution is defined as the formula:

$$v_i = v \times \frac{d_i}{\sum_{i=1}^{n} d_i} \tag{24}$$

We can separately calculate the traffic saturation within and outside the residential quarter.

In the residential quarter,

Traffic volume:

$$v_i = v \times \frac{d_i}{\sum_{i=1}^{n} d_i} = 331 \tag{25}$$

A section of a road saturation:

$$C_1 = \sum_{i=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} C_i} = 0.3244 \tag{26}$$

Intersection saturation:

$$C_2 = \sum_{i=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} C_i} = 0.8745 \tag{27}$$

Roads connected with exits and entrances saturation:

$$C_3 = \frac{1}{6} \tag{28}$$

So, the road saturation in the residential quarter:

$$\frac{v}{c} = r_1 C_1 + r_2 C_2 + r_3 C_3 = 0.4296 \times C_1 + 0.2839 \times C_2 + 0.2864 \times C_3 = 0.3014 \tag{29}$$

Outside the residential,

Traffic volume:

$$v_i = v \times \frac{d_i}{\sum_{i=1}^{n} d_i} = 419 \tag{30}$$

A section of road saturation:

$$C_1 = \sum_{t=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} c_i} = 0.3778 \tag{31}$$

Intersection saturation:

$$C_2 = \sum_{t=1}^{n} \frac{v_i}{c_i} \times \frac{c_i}{\sum_{i=1}^{n} c_i} = 1.638 \tag{32}$$

Roads connected with exits and entrances saturation:

$$C_3 = \frac{1}{6} \tag{33}$$

So, the road saturation outside the residential quarter:

$$\frac{v}{c} = r_1 C_1 + r_2 C_2 + r_3 C_3 = 0.4296 \times C_1 + 0.2839 \times C_2 + 0.2864 \times C_3 = 0.6751 \tag{34}$$

Into the model two, we can get the road traffic time outside the residential quarter:

$$T_1 = \frac{4}{50} \times 3600 + 0.15 \times (0.8715)^4 \times \frac{4}{50} \times 3600 + \frac{0.5 \times 60\left(1 - \frac{30}{60}\right)}{1 - 0.8715 \times \frac{30}{60}} = 339.5\,(s) \tag{35}$$

Similarly, we can get the passage time that reach the end through the surrounding road of residential quarter T_{N_1}, and the passage time that reach the end through the residential quarter T_{W_1}.

$$T_{N_1} = 333.00\,(s)\,, \quad T_{W_1} = 337.81\,(s) \tag{36}$$

Through the comparative analysis of the three passage time, we can make a conclusion that the opening of the residential quarter will improve the efficiency of the surrounding roads and the efficiency of the roads in the residential quarter, that is to say, the opening of the residential quarter can ease the traffic pressure.

② **The second case: Two roads in the residential quarter connected with the surrounding roads**

As the Fig. 3 shows, use the model one, we can get the saturation of surrounding roads is 0.2167, and the saturation of roads in the residential quarter is 0.5008, after opening the residential quarter. Into the model two, we can get :

$$T_{N_2} = 342.80\,(s)\,, \quad T_{W_2} = 340.83\,(s) \tag{37}$$

Through the comparative analysis of the three passage time, we can make a conclusion: When there are two road in the residential quarter connected with the surrounding roads,

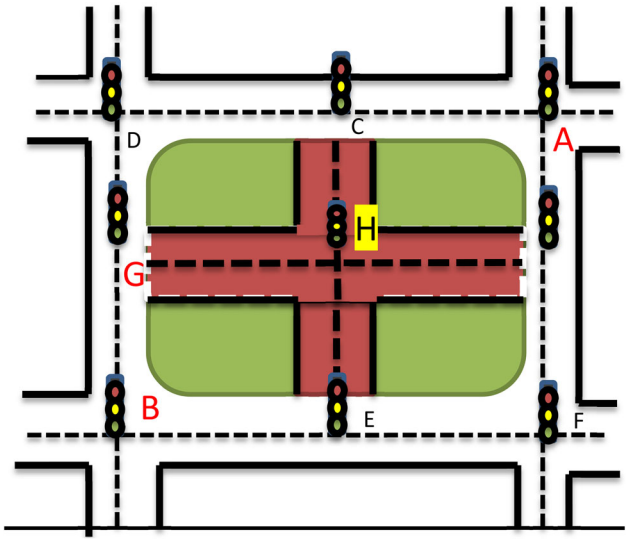

Fig. 3 The second case

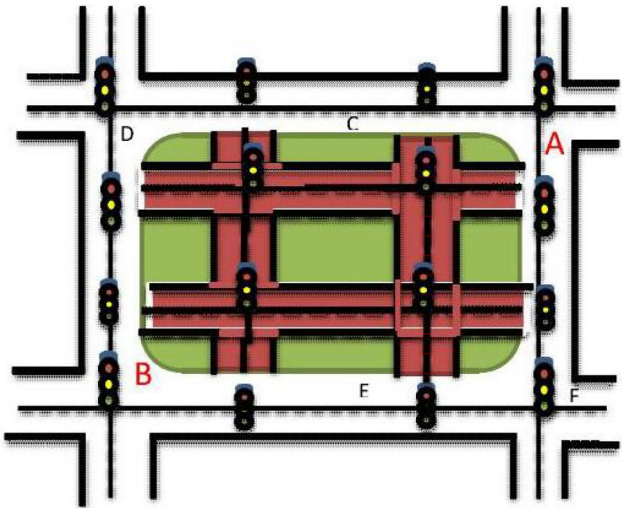

Fig. 4 The third case

the passage time is increased when compared with the first case. But this case can also ease the traffic pressure.

③ **The third case: Four roads in the residential quarter connected with the surrounding road**

As the Fig. 4 shows, similarly, use the model one, we can get the saturation of surrounding roads is 0.1524, and the saturation of roads in the residential quarter is 0.4513, after opening the residential quarter. Into the model two, we can get:

$$T_{N_3} = 371.06\,(s)\,, \quad T_{W_3} = 366.37\,(s) \tag{38}$$

Through the comparative analysis of the three passage time, we can make the conclusion: the passage time is much greater than the time before opening the residential quar-

ter, this case cannot ease the traffic pressure, instead, it will increase the passage time.

4 Results and conclusions

4.1 Results

4.1.1 The results of model one

By establishing the model one, the road congestion index is divided into three sections: Section saturation, intersection saturation and the impact of the entrance and exit on the road capacity. After determining the final evaluation indexes, the analytic hierarchy process is used to determine their standard weights:

The weights of impact a fact section of a road $r_1 = 0.4296$

The weights of impact a fact section of intersection $r_2 = 0.2839$

The weights of impact a fact section of exits and entrances $r_3 = 0.2864$.

4.1.2 The results of model two

To research the impact of the opening residential quarter on the surrounding road capacity, the standard of passage time to measure the degree of smoothness of vehicular traffic, the passage time of vehicles include: the passage time of a section of a road, the delay time of a section of a road, the delay time of an intersection. By building the model of the passage time of a section of a road:

$$T_{ij} = \frac{S_{ij}}{V_{ij}} + \delta \times \left(\frac{V_{ij}}{C_{ij}}\right)\gamma \times \frac{S_{ij}}{V_{ij}} + \frac{0.5T\left(1 - \frac{t_g}{T}\right)}{1 - \frac{V_{ij}}{C_{ij}} \times \frac{t_g}{T}} \quad (39)$$

To evaluate the influence of opening residential quarter on the surrounding road capacity.

4.1.3 The results of model three

Through three cases: (1) Only one road in the residential quarter connected with the surrounding roads. (2) Two roads in the residential quarter connected with the surrounding roads. (3) Four roads in the residential quarter connected with the surrounding roads, and we draw a conclusion that the opening of the residential quarter will have a certain benefit to the surrounding roads capacity, but the number of the roads in the residential quarter connected with the surrounding roads cannot be more than 2. Otherwise, it will increase the road congestion.

4.2 Suggestions

Blindly opening the residential quarter and blindly increasing the number of residential quarter roads cannot ease the surrounding road traffic pressure, but will increase road congestion, we must use other feasible measures. In the paper, we put forward several feasible.

Suggestions:

① Reasonably set the vehicle speed around the residential quarter and the vehicle speed in the residential quarter. Also, large cars are into prohibited the residential quarter.

② The pedestrian bridge can be set in exits and entrances of the opening residential quarter to reduce the transverse interference.

③ Appropriate increase the road width [23].

④ Urban road network density is too sparse, which is one of the fundamental reasons for urban congestion. Establish a principle making the road net denser. Setting multiple-lane can enhance the road capacity [24].

⑤ Intersection traffic light signal as an important factor in the management of the traffic network, intelligent traffic lights is the most optimistic direction of development to reduce congestion [25]. After opening the residential quarter, traffic lights are increased, if we use a new intelligent traffic light control system [26], which can automatic adjust the length of traffic signal according to the traffic flow, to improve the efficiency of road traffic [27].

⑥ Setting the intelligent traffic signal system with automatic intelligent navigation function can effective solve the problem of unbalanced traffic flow. When the front road congestion, the intelligent traffic signal system can automatic guide vehicles to another road. According to the prompt of the intelligent traffic signal system, vehicles can get round the congested road to save time.

4.3 Conclusions

Through the establishment of models and the analysis of the use of programming methods, we can draw a conclusion: opening residential quarter has a certain positive effect on the surrounding road capacity, on the condition of the number of connections between the opening residential quarter and the surrounding roads are not more than two. Otherwise, it will increase road congestion. That is to say, blindly increase the number of opening residential quarter roads, road congestion may be increased. The construction of the opening residential quarter will have a great impact on the surrounding road and even the entire urban road network traffic conditions, leading to local and even overall situation road network traffic unbalance between supply and demand, which will decline the level of road service. In order to better implement the opening residential quarter mode, better ways must to be found

to improve it. For instance, impose speed restrict, meanwhile prohibit large cars into the residential quarter. Also, the pedestrian bridge can be set in exits and entrances of the opening residential quarter to reduce the transverse interference. Particularly, the intelligent traffic control system is the most promising direction to reduce congestion. In recent years, researchers have shown great interest to use techniques and methodologies from artificial intelligence. Kammoun and other scholars allow to intelligently solving complex problems related to the transportation systems [12]. In the future, a set of intelligent management mode will be set up to deal with the impact of opening residential quarter on the surrounding road.

Of course, there's still room for perfection. In the future, dynamic game will be taken into the direction of improvement. After the policy of opening residential quarter, the participant can be regarded as a player. This process can be regarded as an infinite turn of the similar bargaining game in the dynamic game model. In 1984, Shaked and Sutton proposed a more appropriate evolutionary game theory [28]. Stackelberg [29] proposed a duopoly dynamic model in which leader took the lead, followed by follower.

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