Research on the Model Construction and Simulation of the Influence of the Open - door Choice on the Urban Traffic

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Abstract

The State Council issued "on the further strengthening of urban planning and construction of a number of opinions" put forward in principle no longer build a closed area of the policy at the beginning of 2016. In order to explore the optimal opening mode of the community under such a policy and the comprehensive impact of the surrounding roads before and after the opening of the district, we have built a mathematical model of the impact of the internal roads on the urban traffic. In which we selected five evaluation indicators as the evaluation system, and a double-level multi-objective optimization model and a comprehensive evaluation model based on weighted ideal point method are established. Through the genetic algorithm, the least squares method and the OD (origin Destination) demand estimation principle, the open path of the cell is selected and evaluated synthetically. Finally, the computer simulation is carried out by using traffic simulation software, and the reliability of the model is verified. At the end of this paper, an example is given to give the rationalization suggestion of how three types of district should be opened in Yichang City. The type of the community and its surroundings determine whether the community is suitable for opening, the C-type community and the linear community are suitable for opening, and the mesh community is not suitable for opening.

Keywords

Community internal road; open; urban traffic, model; simulation.

1. Introduction

With the rapid development of China's economy, urban traffic problems have become increasingly serious. At the beginning of 2016, the State Council issued the "Several Opinions on Further Strengthening the Management of Urban Planning and Construction", emphasizing that not only "new residential buildings should promote the block system, in principle, no closed-end communities will be built", At the same time, it is required that the completed residential areas and units should be gradually opened. The proposal has caused residents to discuss hot, whether the community can achieve the effect of optimizing the road network structure has become the focus of discussion. According to statistics, in the last 10 years of the last century, Shanghai's closed residential quarters accounted for 83% of the total residential quarters, while the closed districts of Guangdong Province covered more than 70% of urban and rural areas and more than 80% of the population [1-5]. It can be seen in the vast majority of domestic closed community. On-the-spot investigation found that the enclosed residential areas located in the urban areas are generally large in area, traffic mainly depends on the main and secondary roads of the city, and the road system in the enclosed area surrounded by the main and secondary roads is mainly composed of end roads, which leads to the low density of branch roads in the area, affecting the current situation that the main and secondary roads of the city share traffic pressure, i.e. the enclosed residential areas destroy the microcirculation links in the urban traffic system. When the traffic microcirculation system is damaged, only the main and secondary roads are left in the urban network to maintain traffic activities, which will hinder the smooth flow of traffic [6-9]. The closed community not only brings some convenience to the management of the community, but also brings some problems to the urban traffic. It is of great significance to study whether the community is open or not [10, 11].

This paper takes Yichang City's inner community as the analysis object, firstly investigates and counts the types of communities in Yichang City. This paper starts from different types of communities and studies the comprehensive impact of community opening on road traffic. In this paper, we select five evaluation indexes to establish an evaluation system. By establishing a bi-level multi-objective planning model for vehicle traffic, the open road network plan of the residential area is taken as the upper target, and the traffic selection plan of travelers is taken as the lower target. The open road in the residential area is optimized and selected. Combined with the ideal point comprehensive evaluation model, it can judge the influence of the residential area opening on the traffic of surrounding roads. Finally, the traffic simulation software Vissim is used for simulation research to check the rationality of the model. Based on the research example, this paper gives reasonable suggestions on whether the community is open or not.

2. Establishing an open analysis model for residential areas

2.1 Establishment of evaluation index system

Based on the analytic hierarchy process (AHP), the target layer is the comprehensive influence of the neighborhood opening on the surrounding road access (O), while the criterion layer mainly includes the influence on the surrounding road network (C1) and the influence on the neighborhood (C2). The decision-making level is shown in figure 1. MATLAB software programming achieves the process of hierarchical analysis. After calculation, the weight of each factor (index) is $w = (0.41, 0.27.0.07, 0.15, 0.10)$

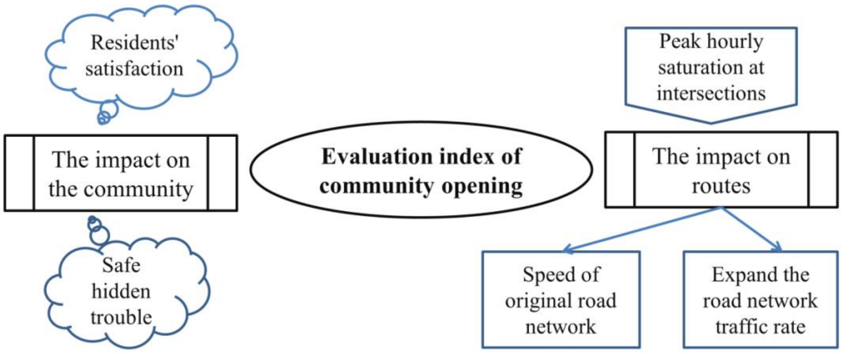

Fig.1 The open evaluation index system of Community

2.2 Two-level multi-objective programming model [12,13]

Bilevel programming can decompose a complex problem into two interacting and influencing layers, and then consider the problem more comprehensively. Whether and to what extent the community is open or not involves the mutual influence between government departments and residents of the community, namely the joint decision-making behavior of the two. Therefore, the bilevel planning is an ideal model to solve whether the community is open or not.

(1) Establishment of upper model [14]

a. Traffic efficiency of the original road network (average impedance)

Let $t(x(a))$ be the average impedance of an original road section, and use BPR function commonly used in academic circles to describe $t(x(a))$:

$$t(x(a)) = \begin{cases} t_{a0}\left[1+\alpha\left(\dfrac{x(a)}{C_0(a)}\right)^{\beta}\right], a \in A \\ t_{a0}\left[1+\alpha\left(\dfrac{x(a)}{\overline{S}(a)C(a)}\right)^{\beta}\right], a \in B \end{cases} \tag{1}$$

The goal of improving the original road network is

$$\min T_1 = \min t_m = \frac{\sum_{a \in A} l(a) \times t(x(a))}{\sum_{a \in A} l(a)} \tag{2}$$

t_{a0} is the travel time required for section a under free flow conditions, in seconds (S)

α is the parameter to be calibrated, and the recommended value in BPR is 2.62

β is the parameter to be calibrated, and the recommended value in BPR is 5.00

$x(a)$ is the traffic flow of section a

$S(a)$ is the saturation of segment a

$\bar{S}(a)$ is the maximum saturation of segment a

$C(a)$ Capacity of microcirculation network after optimization

$C_0(a)$ Capacity of microcirculation network before optimization

b. Traffic Efficiency of Extended Roads (Average Impedance)

Let $t(x(b))$ be the average resistance of an extended road section, and use BPR function commonly used in academic circles to describe $t(x(b))$.

The goal of improving the extended road network is

$$\min T_2 = \min t_m = \frac{\sum_{b \in B} l(b) \times t(x(b))}{\sum_{b \in B} l(b)} \tag{3}$$

c. Intersection saturation

The method to calculate the saturation of intersection is to set the weighted average of saturation of each intersection in the microcirculation area. The weight of each intersection is the ratio of the capacity of the intersection to the capacity of all intersections.

$$M = \sum_{i=1}^{n} \frac{p_i}{q_i} \times \frac{q_i}{\sum_{i=1}^{n} q_i} \tag{4}$$

Then, the optimal model of intersection saturation is:

$$\min T_3 = \min M = \sum_{i=1}^{n} \frac{p_i}{q_i} \times \frac{q_i}{\sum_{i=1}^{n} q_i} \tag{5}$$

Where:

n is the number of sections affected by traffic microcirculation scope;

q_i is the traffic capacity of each road section within the target traffic impact range;

p_i peak hour traffic volume of each road section.

d. Impact of potential safety hazards

As the expansion of roads is carried out in the residential area, it inevitably brings potential safety hazards to residents. If the safety factor of residents will decrease with the optimization of the road network, the scheme will not be easily accepted.

Let: $v(s)$ be the average speed of section s ;

$v_s(s)$ is the 85% speed on section s ;

$v_d(s)$ is the difference between the 15% speed and the 85% speed on section s ;

$r(s)$ is the accident rate on section s .

The regression model derived from the survey and analysis of urban roads in North America was obtained by reference:

$$r(a) = 0.01802 v_a(a) + 0.01884 v_d(a) - 0.094294 \tag{6}$$

In the actual situation, since it is relatively difficult to measure A in A relatively short time, the vehicle speed on the road is regarded as A normal distribution centering on the speed of 50%, then:

$$r(a) = 0.05876 v_a(a) - 0.094294 \tag{7}$$

Let T_4 be the weighted average of potential safety hazards for optimizing the microcirculatory system in the community:

$$\min T_4 = \frac{\min \sum_{b\in B} l(a)\times r(a)}{\sum_{b\in B} l(a)} = \frac{\min \sum_{b\in B} l(a)\times\left[0.058976 v(a) - 0.094294\right]}{\sum_{b\in B} l(a)}$$

e. Residents' satisfaction:

Residents' satisfaction degree indicates that residents are satisfied with the opening of the community:

$$D = \sum_{i=1}^{k} p_i \tag{8}$$

Where p_i represents the satisfaction of the i residents with the opening of the community.

Establishment of objective function of residents' satisfaction:

$$T_5 = \min D = \sum_{i=1}^{k} p_i \tag{9}$$

Among them, the upper model is a typical multi-objective planning. According to the determined weights, the overall objective of microcirculation system network optimization is the minimum decision impedance, and the objective function is as follows:

The evaluation index	A formula to calculate
Expand the efficiency of the road network （T_1）	$T_1 = \sum_{a\in A} l(a)\times t(x(a))$
The traffic efficiency of the original road network (T_2)	$T_2 = \sum_{b\in B} l(b)\times t(x(b))$
Peak hourly saturation at intersections (T_3)	$T_3 = \sum_{i=1}^{n} \frac{p_i}{q_i}\times\frac{q_i}{\sum_{i=1}^{n} q_i}$
Security implications (T_4)	$T_4 = \frac{\sum_{b\in B} l(a)\times r(a)}{\sum_{b\in B} l(a)}$
Residents' satisfaction (T_5)	$T_5 = \sum_{i=1}^{k} p_i$

The microcirculatory road in the community not only undertakes the function of shunting traffic along arterial roads, but also needs to ensure the function of diverting traffic within the community. The saturation of microcirculatory road network is cited as a constraint condition. Excessive traffic flow on roads leading to residential areas will affect the normal living environment of indigenous residents in the residential areas. Low saturation will lead to waste of road resources, that is, S_1 (a) ≤S (a) ≤S_2 (a); the surrounding environment of the roads generated by the microcirculation system is different. When new roads are built, they will be affected by themselves and the surrounding conditions. The reconstruction ability and level should be limited within a certain limit, that is C_0(a)≤C(a)≤C_1(a); Since the residential area is mainly residential, the car speed should be limited to a certain range, that is the critical speed v<vi for residents' satisfaction.

Objective function and constraint conditions:

$$\begin{cases} \min T_1 \\ \min T_2 \\ \min T_3 \\ \min T_4 \\ \min T_5 \end{cases} \quad s.t \begin{cases} S_1(a) \le S(a) \le S_2(a) \\ C_0(a) \le C(a) \le C_1(a) \\ v < v_i \end{cases} \tag{10}$$

(2) Establishment of the lower level model [15]

If the road network plan of the traffic microcirculatory system in the residential district blindly adds or expands road sections while ignoring the path selection behavior of users in the road network, the traffic condition of the system will deteriorate. Therefore, the lower level model builds the user balance model. After the upper model optimizes the decision-making scheme of whether to build a new road section. The traffic microcirculation system is designed to meet the user selection principle of WARDROP balance [3, 7, 10].

The lower model is as follows:

$$\begin{cases} \min \sum_{a\in AUB(y)} \int_0^{x(a)} t_a(x)dx \\ \sum_{k=1}^{l(r,s)} f_k^{rs} = q_{rs}, r,s=1,2...,n \\ x(a) = \sum_{r=1}^{n}\sum_{s=1}^{n}\sum_{k=1}^{L(r,s)} f_k^{rs}\delta_{ak}^{rs}, a\in A\cup B \\ f_k^{rs} \ge 0, r,s=1,2...,n, k=1,2,...,L(r,s) \end{cases} \tag{11}$$

In the above plan: $x(a), a\in A\cup B$ Satisfy lower level planning； $(q_{rs})_{n\times n}$ is traffic demand, q_{rs} is the traffic flow from the intersection point r to the intersection point s; $L(r,s)$ is the number of paths between OD and (r,s) ; f_k^{rs} is the traffic flow of route k between OD and (r,s) .

The upper model obtained microcirculation optimization plan, including reconstruction and road construction plan. According to the optimization scheme obtained from the previous model, the lower model (equilibrium distribution model) distributes traffic to microcirculatory sections, and after traffic flow distribution, traffic flow, traffic time, saturation and other distribution data of each section are obtained. These data are brought into the upper model for solution. The parameters of the new microcirculatory road network optimization scheme are obtained, and the constraint conditions established by the upper layer model are used for judgment. After repeated iteration, the optimal solution of the upper layer model and the lower layer model is finally obtained.

In order to solve the above two-level multi-objective programming, the ideal point method is used to evaluate the model, which can be solved by genetic algorithm [8].

2.3 Ideal point method model [16-19]

Assuming that the ideal points solved are respectively $(x_1, y_1, z_1, g_1, k_1)$, the influence on surrounding roads can be judged by comparing the distance from the ideal point before and after the opening of the community.

The distance between the first five indicators of the community opening and the ideal point is:

$$d_1 = \sqrt{w_1(x_2-x_1)^2 + (y_2-y_1)^2 + (z_2-z_1)^2 + (g_2-g_1)^2 + (k_2-k_1)^2}$$

The distance from the ideal point after the community opening is

$$d_2 = \sqrt{w_1(x_3-x_1)^2 + (y_3-y_1)^2 + (z_3-z_1)^2 + (g_3-g_1)^2 + (k_3-k_1)^2}$$

By comparing the relative sizes of d_1, d_2, we can judge the relative influence on surrounding roads before and after opening

3. The example analysis

According to the investigation and statistics of the residential areas in Yichang city, we have classified the closed residential areas into three types, namely, linear residential areas, mesh residential areas and C-type residential areas. The top-down road maps of the three types of residential areas are shown below. According to these three types of cells, the established model and genetic algorithm are used to select the optimal open route, and the ideal point method is used to judge whether the selected three types of cells should be open. Finally, the traffic simulation software Vissim is used for computer simulation to verify the rationality of the model.

In order to facilitate calculation and use traffic simulation software to carry out computer simulation tests, the three types of residential areas are respectively represented by fixed road maps, as shown in the following figure:

Fig.2 The route map of the linear community

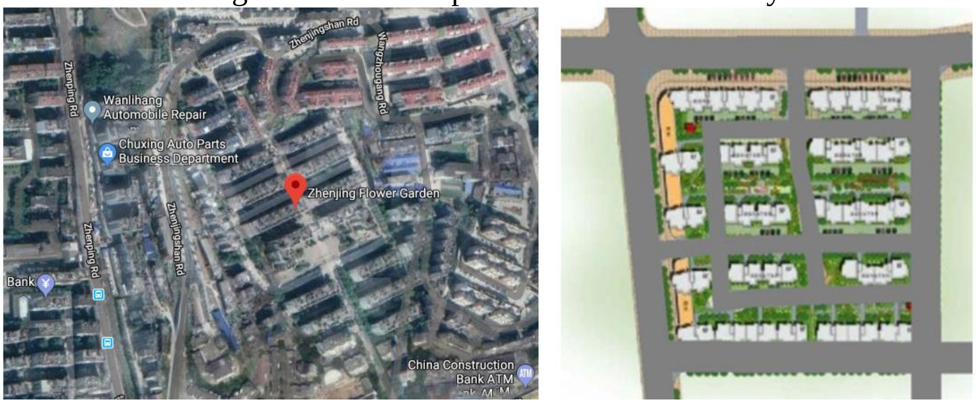

Fig.3 The route map of the mesh community

Fig.4 The route map of the type of C community

In order to better reference the survey data of each district to the established model, the three districts are divided into four sections, namely, section 1, section 2, section 3 and section 4 as shown in the following figure.

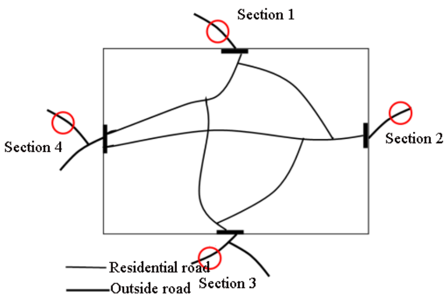

Fig.5 Four sections of the road map of the three types of community

3.1 Data collection and preprocessing

The collected data include the traffic flow around the community, the saturation degree of surrounding sections, the length of surrounding sections, the free flow speed of surrounding sections and the traffic capacity of surrounding sections.

(1) Traffic

Average the traffic flow data of different sections and get the following table:

Table.1 Traffic data for different sections

traffic	Agricultural village	Zhenjiang Flower Garden	Dongfnag Flower Garden
Section 1	787.77	931.91	850.81
Section 2	656.60	813.94	782.71
Section 3	608.67	837.96	782.15
Section 4	778.47	849.96	683.65

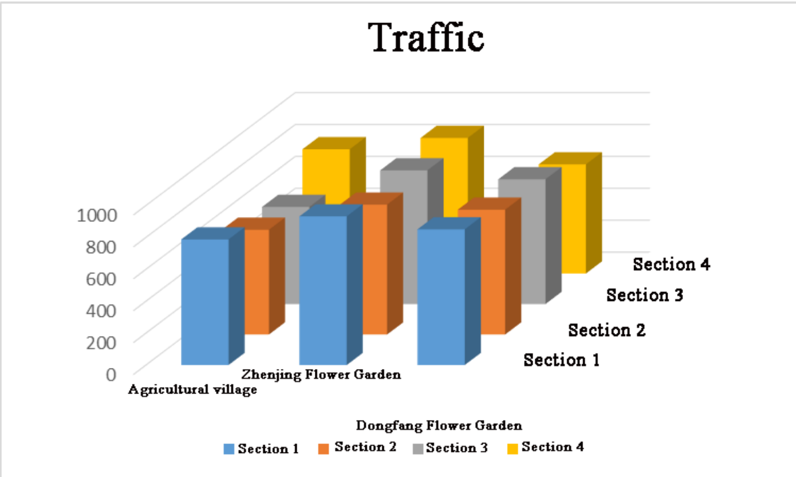

Fig.6 Flow chart of traffic flow on different sections

As can be seen from the above figure, from a macro point of view, the traffic flow of Zhenjing Flower Garden is the largest, and that of Agricultural village is the smallest. From a microscopic point of view, the traffic volume of different sections of Zhenjing Flower Garden is also the largest, with the traffic volume of one section being the largest, the traffic volume of two sections being the smallest, the traffic volume of one section being the largest in Dongfang Flower Garden, the traffic volume of four sections being the smallest, the traffic volume of one section being the largest in linear residential areas, and the traffic volume of three sections being the smallest. Overall, the traffic volume of section one in different types of residential road networks is the largest.

(2) Capacity before optimization

The traffic capacity data of different sections were counted, and the following table was obtained:

Table.2 The traffic capacity data of different sections

Capacity before optimization	Agricultural village	Zhenjinag Flower Garden	Dongfang Flower Garden
Section 1	997.06	990.51	987.53
Section 2	1014.6	984.13	977.27
Section 3	982.06	926.43	1043.6
Section 4	1028.8	1039.49	978.92

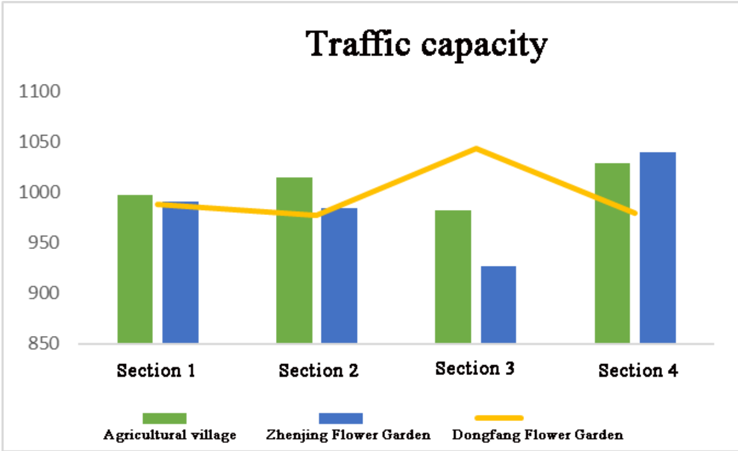

Fig.7 Comparison of traffic capacity of different sections

It can be seen from the above figure that the free flow speed of section 3 in dongfang garden is the highest and that of section 2 is the lowest.The free flow speed of section 4 is the highest and that of section 3 is the lowest.The free flow speed of section four in agbank community is the highest, while section three is relatively low.

(3) The length of the road

The length data of different sections were counted and the following table was obtained:

Table.3 Length of data on different sections

Length	Agricultural village	Zhenjiang Flower Garden	Dongfnag Flower Garden
Section 1	0.27	0.25	0.25
Section 2	0.25	0.26	0.25
Section 3	0.26	0.26	0.25
Section 4	0.24	0.27	0.26

3.2 The optimal open route of the three types of residential areas

According to the characteristics of different communities, the genetic algorithm is used to select the optimal open route (marked in red as the open road of the community) for the three typical communities surveyed in Yichang city according to the established model as follows:

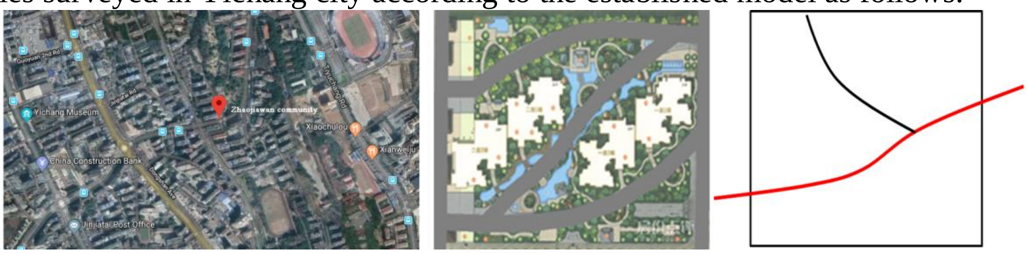

Fig.8 The route map of the linear community and the optimal route open chart

Fig.9 The route map of the mesh community and the optimal route open chart

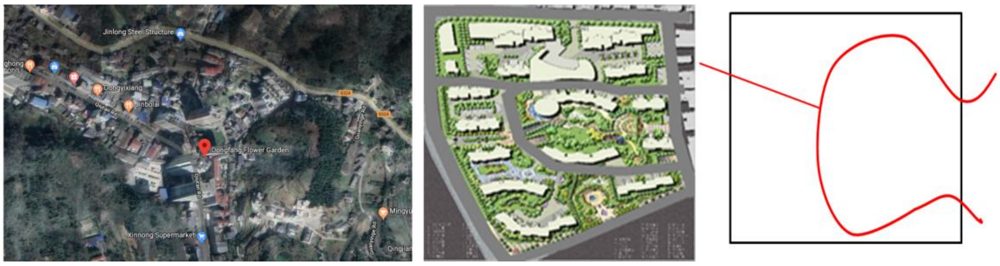

Fig.10 The route map of the type of C community and fixed route open chart

3.3 Comprehensive evaluation index

Table.4 Comprehensive evaluation form of the type C community

	Original road impedsance	Extended path impedance	Saturation	Safe hidden trouble	Residents' satisfaction
Before the opening	5.72	0.00	3.38	2.58	6.00
Ideal point	4.83	1.10	3.34	2.57	5.60
After opening	5.34	1.71	3.41	2.60	6.10

As shown in table 4, for a bank community, the distance between the ideal point and the open community is 0.48, and the distance between the ideal point and the open community is 0.82.Because the closer the distance from the ideal point is, the better the degree of synergy between each index is. However, the distance between the index and the ideal point is larger before opening than after opening

Table.5 Comprehensive evaluation form of the linear community

	Original road impedsance	Extended path impedance	Saturation	Safe hidden trouble	Residents' satisfaction
Before the opening	4.67	0	4.86	2.50	6.40
Ideal point	3.38	0.72	4.73	1.80	5.50
After opening	4.41	2.72	4.77	2.47	5.71

As shown in table 5, for zhenjinghuayuan, the distance from the ideal point to the community after opening is 1.26 according to the formula, and the distance from the ideal point to the community before opening is 0.99, so it is not open.

Table.6 Comprehensive evaluation form of the mesh community

	Original road impedsance	Extended path impedance	Saturation	Safe hidden trouble	Residents' satisfaction
Before the opening	5.23	0.00	4.35	3.49	5.30
Ideal point	4.16	1.07	4.20	3.47	4.90
After opening	4.66	1.11	4.32	3.51	5.00

Similarly, as shown in table 6, for Dongfang garden, the distance between the community and the ideal point after its opening is 0.32, and the distance between the community and the ideal point before its opening is 0.89, so it chooses to open.

3.4 Traffic simulation based on Vissim software

First, the floor plans of the three cells above are imported into Vissim as background images. Match the original scale to the map scale. According to the road on the map, use the software to draw the road in the corresponding position.

Through the previous calculation, the Vissim software was used for computer simulation, and the vehicle operation parameters were set by relevant data. In the road network before and after the opening of the continuous increase in unit time through vehicles. By comparing the traffic flow when the road network is blocked, it is found that the traffic flow in unit time when the block occurs in the community is larger than that in unit time when the community is closed. The specific results are as follows.

Fig.11 Traffic flow simulation chart

Table.7 The changes of traffic flow for different types of community open

Community	Passing vehicles at unit time before opening	After opening the unit time passes the vehicle	Whether open
Agricultural village	36	63	Yes
Zhenjing Flower Garden	33	29	No
Dongfang Flower Garden	38	45	Yes

The simulation results are basically consistent with the results of the ideal point method, so the accuracy of the model is verified.

4. Proposal on community opening

This paper selected the five evaluation indexes to establish the evaluation system, using bi-level multi-objective programming model of vehicles, with the aim to the upper village road network open plan, with the aim to lower traveler travel transportation options, open to inside the village road for optimization selection, combined with the ideal point comprehensive evaluation model is set up, calculate village open before and after opening and the ideal point distance, then open the impact on the surrounding traffic.The type of the community and its surrounding conditions determine whether the community is suitable for opening. In our selected research example, if it is a mesh community, it is not suitable for opening, because the surrounding roads will be more crowded after opening than before.If it is a c-block or a linear block, it is suitable for opening.

In view of the above calculation and analysis, this paper gives reasonable Suggestions on the opening of the community

a. According to the road network environment outside the community, choose whether to open to the community

Considering that the opening of the community will have a certain impact on the road sections around the community, it mainly includes the five evaluation indexes determined in the first question, namely, the original road impedance, the extended road impedance, the hourly saturation of the road intersection, the safety risks inside and outside the community, and the satisfaction of the residents.

As the purpose of opening residential areas is to open up the " capillaries" of the city and form a complete road network, thus improving the accessibility of roads. Since road impedance and peak hour saturation at intersections are both indicators for evaluating road accessibility and smoothness, they are selected as indicators for whether to open residential areas.

b. According to the internal structure of the community, choose whether to open to the community

Some communities are relatively large and closed, which affects the accessibility of urban traffic to a certain extent. Such communities are suitable for opening. For example, the straight-line road network and c-type road network selected in the second question are examples.

Some small areas, even if open cannot improve urban traffic, but because of the transformation of small areas and spend a lot of money, not only cause waste, and break the balance of the community, affect the lives of residents.

Some are semi-closed, with a relatively complete internal traffic system, but not completely open to the outside world. Such a community can consider re-opening part to adjust the smoothness of the urban traffic system. For example, in the netted community selected in the second question, only part of the road is open.

c. According to the comparison of security degree before and after the opening of the community, whether the community is open or not is selected

Gated communities have been inherited from ancient China to the present. Part of the reason is that gated communities make people feel more secure, and gated communities are indeed more secure than open ones in most cases.Open community, strangers can enter at will, vehicles can enter and exit freely, these for the safety of life and property of residents bring hidden dangers, but in closed community these hidden dangers can be effectively avoided.

Therefore, if the opening of the community can increase the relevant security measures in the community, and before the opening of people to give some guarantee of security, can consider opening.

Here are some tips for post-opening security measures:

(1) Set up traffic lights. After the district opens, the traffic flow increases, the traffic accident increases, causes the resident's sense of security to reduce greatly. Therefore, when the community is open, traffic lights should be set up at the gate of the community and the intersection around the community, which is conducive to residents' travel and can effectively reduce urban congestion.

(2) Set up roadblocks. Setting up roadblocks is conducive to slowing down the speed of vehicles, giving vehicles a buffer time, so as to reduce the occurrence of vehicle accidents and protect the lives of residents.

(3) Put warning signs. The installation of warning signs will give a reminder to passing drivers and pedestrians, and effectively improve the alertness of drivers and pedestrians.

d. According to the residents' feedback, choose whether the community is open or not

The community should provide the residents with a comfortable living environment, so whether the community is open or not should take into account whether the residents live comfortably and satisfactorily. On the one hand, opening the community can make it more convenient for residents to travel, and save time for residents to travel, but on the other hand, the passage of vehicles will have a certain degree of noise, air pollution to the community, strangers will make residents feel uncomfortable and other reasons.

Considering the impact of the above open community on residents, residents should weigh the pros and cons. If most of them agree, they can consider more open community to bring more convenience to people.

5. Conclusion

Aiming at the factors that have great influence on urban traffic after the road opening of the community, this paper establishes a double-layer multi-objective planning model, and quantitatively analyzes the choice of different types of road opening of the community and the influence on urban traffic before and after the road opening of the community. Its focus is to solve the traffic congestion at the same time, the least impact on the lives of residents and the environment. Multi-objective collaborative optimization method was used to analyze the optimization objective, and WARDROP balance principle was adopted for flow allocation. Genetic algorithm was used to solve the problem, so as to determine the road opening mode inside the community and its comprehensive impact on urban traffic. Finally, traffic simulation software is used to verify the accuracy of the model.

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