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Analysis of Selecting Gated Community as Opening Its Micro-Inter-Road Network

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Abstract

The opening of gated community to expand the micro-road network in the urban traffic system is a hot topic on the urban congestion. To satisfy the demand of opening early choosing case, this paper proposed a comprehensive selecting framework on qualified communities and its appropriate opening time. Firstly, the static influential factors on internal road structure, boundary road structure and traffic flow are qualitatively analyzed. Then, an evaluation opening state index system based on describing accurately traffic flow state is obtained, which takes the opening factors into account at the boundary road network. In this structure, the modified fuzzy C-means (FCM) method calculates the fuzzy entropy weight and range of each opening states index. Finally, the simulation results show that the proposed method is capable of selecting qualified community and the optimum opening time.

Keywords

Opening Gated Community, Opening State Index System, Fuzzy C-Means (FCM) Clustering, Fuzzy Entropy Weight

1. Introduction

Urban gated community creates a boundary separating road system from the open community outside the walls or fences. The boundary walls on the boundary of living quarters from each independent area, and its internal roads are not connected with the main roads of the outside traffic network. It becomes an important topic to optimize the layout of urban road network and to ease the increasingly serious traffic congestion, and meets many problems, such as modification cost, noise pollution, safety, and so on. However, there is little research on how to select qualified gated community and how to optimize the open plan-

ning, which becomes a realistic problem and urgently to be solved, thus motivating the present work. Additional, it is of significance to find the best combination of community to open, which is implemented maximum of urban traffic conditions improved within the limited cost and got efficiently congestion easing, thus becoming objective of the present work.

In order to study the opening state evaluation of the gated communities, it is necessary to analyze the mechanism of the traffic flow congestion at the boundary road networks accurately. The traffic flow of a specific gated living quarter is characterized by unique, experience historical, uncertainty and complexity. Therefore, to address these shortcomings, the historical specific traffic flow data should be studied sufficiently. Washington State Transportation Department [1] released the report that the congestion evaluation degree was defined as the average peak travel time. The latest Highway Capacity Manual (HCM) [2] used the level of service that was defined into six grades to evaluate road performance in the United States. However, it is maybe not appropriate in the urban traffic state in China with specific road network structure. On the other hand the trend entropy theory becomes an important method to study the traffic flow. Shao *et al.* [3] explores the principle and algorithm of entropy-maximizing model (EM model) with gravitational prior probability. Yong *et al.* [4] studies the entropy condition for the Lighthill-Whitham-Richards model of the fractal traffic flows described by local fractional calculus. The traffic flow of a specific gated living quarter is characterized by unique, experience historical, uncertainty and complexity. Therefore, to address these shortcomings, the historical specific traffic flow data should be studies sufficiently. Lozano *et al.* [5] proposed a recognition algorithm for road congestion levels by analyzing real-time traffic flow data based on the K-means clustering analysis algorithm. Sun [6] employed the fuzzy c-means (FMC) cluster analysis and fuzzy synthetic evaluation method to classify urban traffic into six different states classification, but it is difficult to obtain the quantitative evaluation results of traffic state. Antoniou *et al.* [7] proposed an approach for local traffic flow state estimation and prediction based on data-driven computational approaches. Many researches keep warm on the study of the historical specific traffic flow data [8] [9] [10] [11].

In this paper, the overview of framework and process of comprehensive opening evaluation model is first described. Then, the methodology of traffic flow state identification and opening evaluation at the boundary is proposed. Finally, a case study based on a simulated gated community is carried out to demonstrate the performance and applicability of the proposed method.

2. Proposed Framework and Process of Comprehensive Opening Evaluation Model

As shown in **Figure 1**, this paper proposed a comprehensive selecting framework on qualified communities and its appropriate opening time. Firstly, it qualitatively analyzes static influential factors on internal road structure, boundary

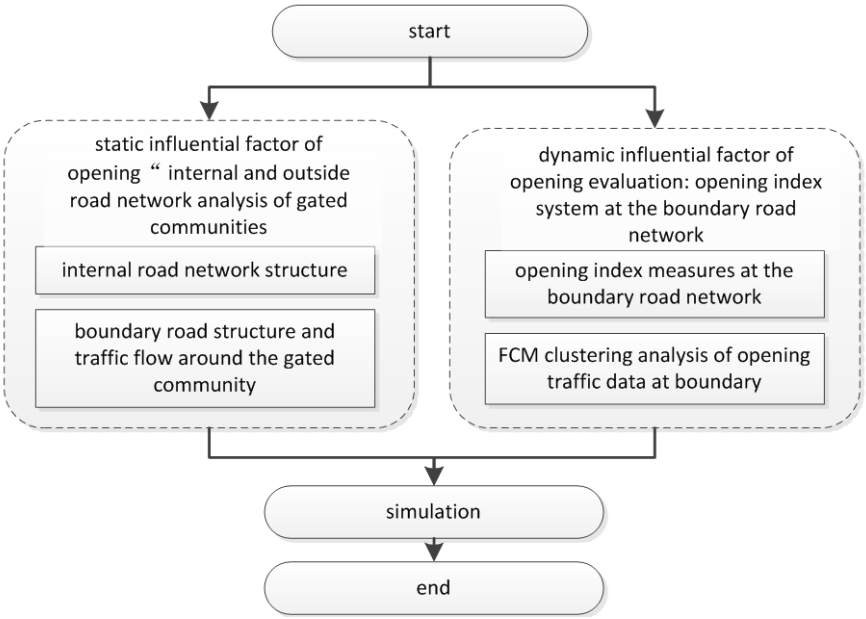


Figure 1. Framework and process of comprehensive opening evaluation model.

road structure and traffic flow. Then, the evaluation opening index system based on describe accurately traffic flow state at the boundary road network is obtained.

3. Static Influential Factor of Opening: Internal and Outside Road Network Analysis of Gated Communities

3.1. Internal Road Network Structures

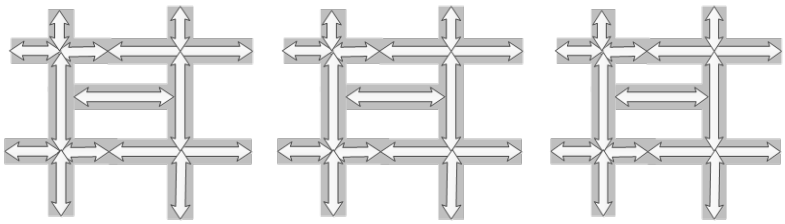
Three typical internal road network types in urban of Shanghai, as shown in Figure 2, are adopted as the study object, which are square type, grid type, and inter-loop type networks, respectively.

The road networks are compared between the three types network by evaluating notes, density, traffic accessibility and traffic reliability, and results are shown in Table 1. Here the area is defined as a 2 and three service levels (A is the good, B is middle and the C is low) are divided.

1) Linear type: linear type network, as shown in Figure 2(a), is typical with a curve or a polyline road through the entire network, which formed two gates naturally at the two sides. Then, the two entrances are respectively located in different directions of the community, in which the residential houses are connected to the outside main road through the inter group roads. As opening this type network, two nodes are added at the road networks. The density of this type is the smallest among the three forms because the only linear road cuts the network on left and right sides. Therefore, at the same scale, this type network exhibits limited coverage and minimal accessibility. Since there are only two gates and the main roads are highly traffic-oriented, there are no other routes to be alternative. Therefore, the reliability of internal road network is also low level.

Table 1. Comparison and analysis of three typical types' networks.

No	Types	note	density	accessibility	reliability	Qualified level for open
1	linear	+2	1/a	C	C	C
2	grid type	+5	2/a	B	B	B
3	Inter-loop	+8	3/a	A	A	A



(a) (b) (c)

Figure 2. Three typical types of internal road structures in gated communities. (a) linear type; (b) grid type; (c) inter-loop.

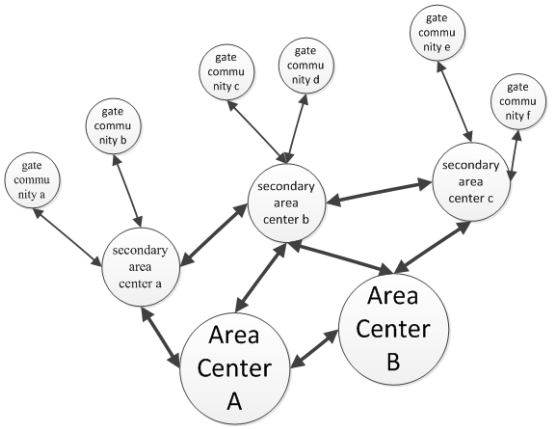
2) Grid type. Grid type, as shown in **Figure 2(b)**, is typical with cross-shaped road through the entire network, which is a deformation of linear type. If opening this type network, fives notes are add at the network. The density of this type is 2/a, which is larger than that of linear type. Traffic accessibility also increases in response to road coverage's increasing. But the main road also has low traffic transfer function even if it is improved comparing with the linear type, and the reliable increases with increasing the gate.

3) Inter-loop types: inter-loop type, as shown in **Figure 2(c)**, is evolved to alleviate the traffic problem at crossroads. The cross is changed to a loop, and inter group roads connect to radiation instead of loop itself. As opening this type network, it adds eight notes at the network, and the density becomes 3/a. The density and accessibility are higher than that of above two types. Because the inner loop is not only the role of coordinating and transferring, but also can evacuate traffic flow as much as radioactivity. Therefore its traffic reliability is higher than that of above two types.

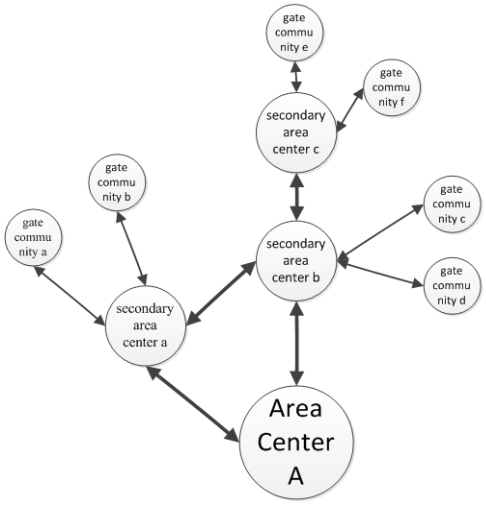
As above summary, the inter-loop type has the highest density and multi-directional structure as comparing the three typical internal road networks. Therefore, based on the effect of the opening internal roads on the surrounding road capacity, the inter-loop type is most qualified to open, and the grid type is second choice and the linear type is last one.

3.2. Boundary Road Structure and Traffic Flow around the Gated Community

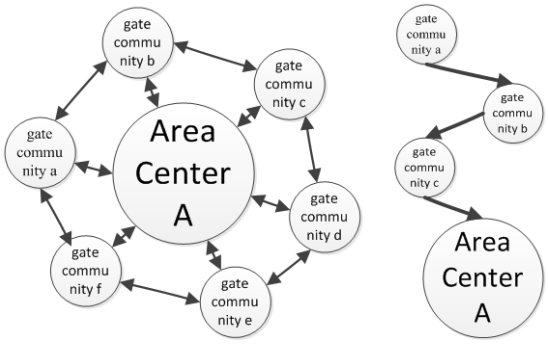
The traffic flow at the boundary of gate community is connected closely to its location, road level, structure and density. Considering outer road structure and traffic flow, we construct four typical type outer road networks, which are grid type, tree type, loop type and linear type. As shown in **Figure 3**, it is visual effect



(a)



(b)



(c) (d)

Figure 3. Visualization of boundary road structure and traffic flow. (a) Grid type; (b) tree type; (c) loop type; (d) linear type.

of road structure and traffic flow, in which the color depth of the arrows represents the visualization of the traffic flow.

1) Loop type (**Figure 3(a)**): the relationship between communities and social center (area center, secondary area center) is very close, so there is large traffic flow around it. Therefore, the opening of the loop type can play a role in gather-

ing the surrounding branches, which improves the traffic conditions.

2) Grid and tree types (**Figure 3(b)** and **Figure 3(c)**): these two types locate at urban center with large traffic flow and complicated surrounding road network. So, it is also qualified to open bring with good effect.

3) Linear type (**Figure 3(d)**): this type network, such as a community around a highway with a typical simple structure, exhibits large traffic flow and low density. Its opening only servers as a vehicle diversion. Additional, because linear type has low density and road numbers, all traffic flows are aggregated on few main roads. The intersection at the entrance and exit is extremely eased to cause congestion and vehicle queuing at arterial roads, thus bring with negative impact on traffic capacity.

4. Dynamic Influential Factor of Opening Evaluation: Opening Index System at the Boundary Road Network

4.1. Opening Index Measurements at the Boundary Road Network

1) Volume Road Q_r means the total number of vehicles running on a certain road during a certain time period:

$$Q_r = \sum_{i=1}^{m} Q_{s_i} \tag{1}$$

where Q_{si} is the number of vehicles running in the ith section during the time period and m is the number of sections on the road.

2) Road network average speed V_m refers to the average speed of all vehicles running in the road network during a certain time period. It can be denoted as:

$$V_{rn} = \frac{\sum_{i=1}^{n} V_{r_i} \cdot Q_{r_i}}{Q} \tag{2}$$

3) Road network load degree g_{rn} is the ratio of the actual number of vehicles running in the network at a certain time and the number of vehicles accommodated in the network under the maximum capacity. It can be estimated by the road load degree:

$$g_{rn} = \sum_{i=1}^{n} w_r(i) \cdot g_{r_i} \tag{3}$$

where n is the number of roads in the network. $W_r(i)$ is the weight of the ith road in the given network and g_{ri} is the load degree of the ith road.

4) Boundary road network journey time delay JTD_m is the rate of journey time delayed when the actual road network average speed is lower than the free-flow speed of the network caused by the interaction between vehicles or other factors. It can be defined as follows:

$$JTD_{rn} = \frac{\frac{L}{V_{rn}} - \frac{L}{V_f}}{\frac{L}{V_f}} = \frac{V_f}{V_{rn}} - 1 \tag{4}$$

where L is the total length of the network and V_f is the free-flow speed of the road.

4.2. FCM Clustering Analysis of Opening Traffic Data at Boundary

In this paper, the fuzzy C-means (FCM) clustering algorithm is used to solve the threshold values of different traffic and opening states. Opening data and traffic flow at boundary is a continuous randomly and process, so it is necessary to build a clustering model to distinguish opening state from others.

The modified FCM method calculates the fuzzy range of each index. The input data defines as:

$$x_i = \{x_{i1}, x_{i2}, \ldots, x_{in}\}, i = 1, 2, \ldots, m, \tag{5}$$

where m is the sample data number and n is the number index number. The solution steps are as follows:

[1] Initialization parameters. In this paper, the opening state data is classified into six different states: close (A), ready close (B), inform close (C), inform open (D), ready open (E) and open (F). Set the clusters number c = 6, the iterative stopping threshold $\varepsilon = 10^{-6}$ and the exponential weight t = 2.5. Choose the initial cluster centers $K_0^{(0)}$, $K_1^{(0)}, \ldots, K_c^{(0)}$, randomly from the x_i. Set the iteration number r = 0. x_{ij} is the *jth* sample, K_i is the *ith* cluster center and n is the number of evaluation indices.

[2] Compute or update the membership matrix $U_{(r)}$. Set

$$d_{ij} = \left\| x_j - K_i \right\| = \sqrt{\sum_{l=1}^{n} \left(x_{jl} - K_{il} \right)^2},$$

the distance between the *ith* cluster center K_i and *jth* sample. The matrix $U_{(r)}$ can be expressed by the following.

$$U_{ij}^{(r)} = \begin{cases} \left\{ \sum_{k=1}^{c} \left(\frac{d_{ij}^{(r)}}{d_{kj}^{(r)}} \right)^{\frac{2}{(t-1)}} \right\}^{-1}, d_{ij}^{(r)} > 0 \\ 1, \ d_{ij}^{(r)} = 0, and \ \ i \neq j, \\ 0, \ d_{ij}^{(r)} = 0, and \ \ i = j \end{cases}. \tag{6}$$

where $U_{ij}^{(r)}$ is the membership degree of the *jth* sample belonging to the *ith* cluster.

[3] Update the new cluster centers $K_i^{(r+1)}$ as follows:

$$K_i^{(r+1)} = \frac{\sum_{j=1}^{m} 1 \left(u_{ij}^r \right)^t x_j}{\sum_{j=1}^{m} 1 \left(u_{ij}^r \right)^t}, i = 1, 2, 3 \ldots n \tag{7}$$

[4] Set $\Delta = \left\| K^{(r+1)} - K^{(r)} \right\|$. If $\Delta < \varepsilon$, algorithm finish, and outputs the membership matrix U and the clustering center K. If $\Delta \geq \varepsilon$, $r = r + 1 \rightarrow [Step 2]$

5. Simulations

Based on the framework of the comprehensive opening evaluation model, we choose a typical simulation case to study. The simulation gated community as shown in Figure 4, is selected with inner loop type network and outer loop type road system, which is expressed in Section 3. It covers a total area of 3900 square meters, in which a total construction area has 13,000 square meters and a greening rate is 42%. It is mainly constructed high-rise buildings and slab-type apartment.

The sample case is characterized by loop type boundary structure. It located at the key center of Shanghai urban, surrounded with advantageous trading. As shown in Figure 4, Dapuqiao business zone locates at 200 m from the west, Huaihai road locates at 300 m from the north, and a new shopping mall locates in the east. It also has a primary school, a medical school of a top university, various small business building, shops and many other facilities in a kilometer circle.

The internal road network is typical loop types and the main road is two-way single lane, as shown in Figure 4. The surrounding living quarters constructed mainly more than 20 years and internal networks are limited for huge vehicles. In addition, width road, completely split flow of people and vehicles, good view and other various advantages promoted it to be an opening community.

As to the more important boundary road network system, it blocks center area road networks in the daily urban traffic. As shown in Figure 4, it is a well-shaped road network. The east is Madang road, the north is Jiangguo east road, the west is Danshui road and the south is urban main road Xujiahui road.

The key south and north viaducts locate at 100 m from the southwest along the Xujiahui road. As examining the historical data in the morning and evening traffic peaks, the gated community blocks the urban traffic flow seriously. In this study, we evaluate the opening threshold value to determine the optimum time to open the gated and relieve the congestion.

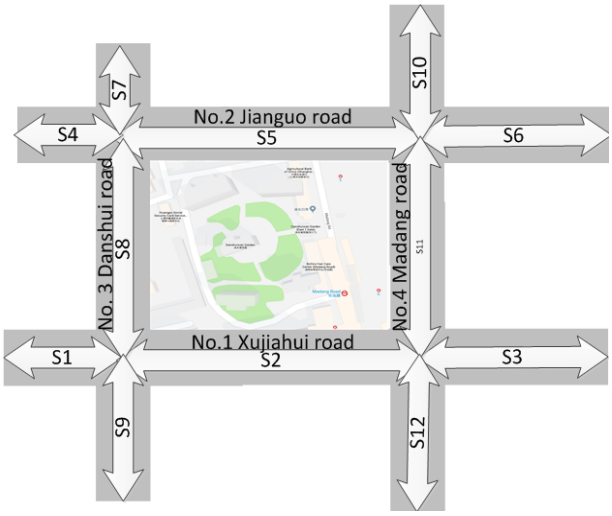


Figure 4. Boundary road network system.

As indicated in Figure 4, the boundary road network at the gated community case is equipped with four roads and a total of 12 sections, where road 1 consists of sections 1, 2 and 3, road 2 includes sections 4, 5 and 6, road 3 is divided into sections 7, 8 and 9, road 4 includes sections10, 11 and 12. Traffic information including volume, average velocity and time occupancy are obtained from the simulations, and data are selected in the case study.

In order to obtain the fuzzy range standard in different states to verify the model result, the FCM clustering analysis is performed for boundary road network in this case study. The FCM results are shown in Figure 5. The FMC clustering model is employed to classify traffic flow data at the boundary into five different states, and the fuzzy standard range evaluation is given in Table 2.

Furthermore, the travel time of a road network is one of the most intuitive and effective traffic flow parameters that characterizes traffic congestion. The travel time may be used as a comparative evaluation verified criterion for the discrimination of traffic conditions. Therefore, we calculate the corresponding the journey time delay value and also show in Table 2. We set the threshold value of the journey time delay is 14.4. The inter-road of the gated community tends to open when the threshold value reaches 14.4. On the other hand, it closes when the threshold value is less than 14.4.

Table 2. Influent factors of fuzzy standard ranges in different states of specific gated community.

State \ factor	Average speed (V_s)	Journey time delay(JTD_s)
Smooth	44 - +∞	0.50 - 16.8
Stable	30 - 44	11.4 - 12.6
Slow(open)	26 - 30	12.6 - 14.2
Congested(open)	17 - 26	1.42 - 16.8
Very congested(open)	0 - 17	16.8 - +∞

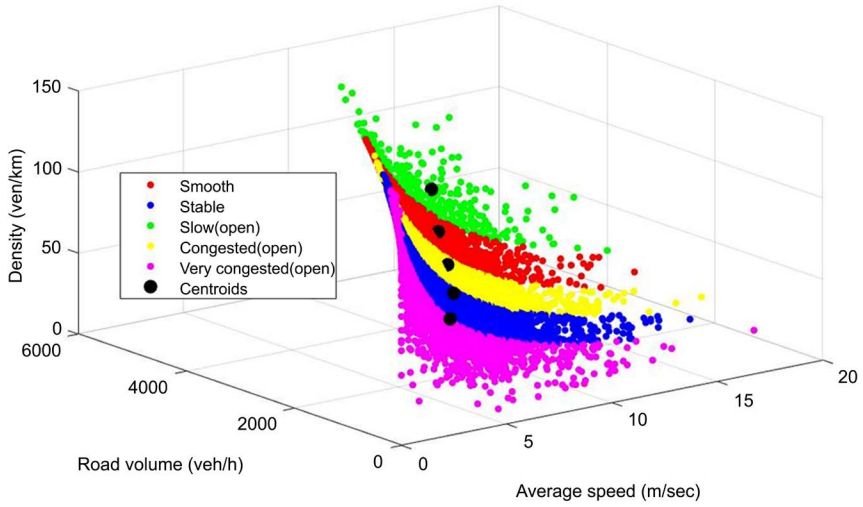


Figure 5. Improved FCM clustering analysis for standard range.

6. Conclusions

A comprehensive opening framework on qualified communities and its appropriate opening time were studied by developing an improved opening evaluation model. The opening evaluation values and its visual present were mainly investigated. Simulation results indicate that the proposed analysis and model are capable of capturing the real opening stated of gated communities.

Since the simulations are implemented in the comprehensive opening evaluation model that should be improved in the future, the mechanism of opening and congestion characteristic should be paid more attention.

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