Study on Influence of Opening Roads in Community on Urban Traffic Planning and Scheduling

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Abstract. With the development of modern economy and society, the urban population grows and the number of motor vehicles keeps increasing. The traffic jam follows up, and has become a common problem in many cities, especially in the large cities. How to plan and schedule in advance is an intelligent planning problem. Reasonable planning and scheduling can effectively alleviate the urban traffic jams. In this paper, AHP method is used to establish a hierarchical structure, and demonstrate the effect of opening roads in community in different time by the qualitative to quantitative principle. In view of this, this paper gives rational suggestion of the opening roads in the community, and provides reference for the construction of the new intelligent living community in the future.

1. Introduction

With the rapid development of social economy, the scale of a city expands larger and larger. Consequently, urban road traffic congestion is becoming more and more serious. To solve this problem, it is not feasible to enlarge the road area blindly. The State Council, China's cabinet, issued the document *Several opinions on further strengthening the administration of urban planning and construction* in the year of 2016. "In principle, no new gated communities will be built, and existing residential communities and Unit Compound will be gradually opened," mentioned in the document. To this, citizens have put forward different opinions, such as opening community may bring security risks and it is a question that if security issues can be guaranteed. There is a case in foreign that the new roads lead to jam because the sudden increase in traffic. Even more, once the community is open, the road sanitation and the around living environment may change largely, and so on. Therefore, this paper tries to give a result with AHP process, so as to provide a reference for traffic planning and scheduling.

2. Building Hierarchy Structure in AHP Process

In the process of road construction, the research on its traffic capacity is important. The research can not only determine the urban road planning, but also provide more scientific basis for other aspects of road planning.[1] However, there are many criteria for traffic capacity evaluation, such as the number of lanes, road entrances and exits proposed in [2]. Considering the actual situation, this paper establishes a relatively simple target layer and criterion layer as shown in figure 1, uses the idea of mathematical modeling, and constructs three project. The target layer, criterion layer, sub-criterion layer and project layer can be seen in Figure 1.

Herein the paper takes the “Reasonable planning the community open, such that the comprehensive benefits is highest” as goal, and takes the main two criterion: Overall traffic capacity and Road
structure outside the community; the number of sub-criterion is seven, the details is as follows. Finally, three projects are determined. It is worth mentioning that the overall traffic capacity includes both human and vehicle. Meanwhile, the road structure outside the community can provide traffic scheduling reference for relevant departments, so as to facilitate the reasonable setting of traffic lights once the community is open. Here is the hierarchical structure:

![Hierarchical Structure](image)

Notice that in this paper, if the location of the community is the core of the city, larger weight will be given. If the parking area of the community is set underground, then the carrying capacity weight will be larger. If the internal road area and public transportation service is good, the big number weight is given as well.

3. Constructing Judgment Matrices and Assigning Values

According to the hierarchical structure in Figure 1, it is simple to construct the judgment matrices. The construction criterion is that the two elements are pair wise comparing which is important and how much, and the importance degree is assigned a value of 1-9 (importance scale value is shown in the table below).[3]

| Importance Scale | The meaning (imply that) |
|-------------------|--------------------------|
| 1                 | The two elements are of equal importance |
| 3                 | The former is slightly more important than the latter |
| 5                 | The former is obviously more important than the latter |
| 7                 | The former is more strongly important than the latter |
| 9                 | Compared with the two elements, the former is extremely important |
| 2, 4, 6, 8        | Represents the intermediate value of the above judgment |
| Reciprocal        | If the ratio of the importance of element i to element j is $a_{ij}$, then the ratio of the importance of element j to element i is the reciprocal of $a_{ij}$ |

The judgment matrix constructed should satisfy the following properties:

(1) $a_{ij} > 0$, 

(2) $a_{ii} = 1$ for all $i$ 

(3) $a_{ij} = 1/a_{ji}$ for all $i, j$ 

(4) The matrix is consistent if the following condition is satisfied: 

$$\sum_{j} a_{ij} = m_i$$ 

for all $i$, where $m_i$ is the number of sub-criteria in layer $B$. 

The consistency index ($CI$) is defined as:

$$CI = \frac{1}{n-1} \left( \frac{1}{m} \sum_{i} \sum_{j} a_{ij} - m \right)$$ 

where $m$ is the number of criteria in layer $B$.

The consistency ratio ($CR$) is defined as:

$$CR = \frac{CI}{RI}$$ 

where $RI$ is the average random index that depends on the size of the judgment matrix.

If $CR < 0.1$, the judgment matrix is considered consistent.
(2) \( a_{ij} = \frac{1}{a_{ji}}, i \neq j \),

(3) \( a_{ii} = 1 \).

In some special case, judgment matrix can be transitive, i.e. the equality \( a_{ij}a_{jk} = a_{ik} \) holds, the matrix is called the consistency matrix in this case. However, in practical application, the judgment matrix constructed by us often cannot strictly meet the consistency requirement, so consistency test is needed in the judgment matrix assignment whenever one uses the AHP method. Here, the criteria for testing the consistency of judgment matrix are as follows: it is divided into three steps:

Step 1: Calculating the consistency index (Briefly C.I.)

\[
C.I. = \frac{\lambda_{\text{max}} - n}{n - 1}
\]

Step 2: Table look-up to determine the corresponding average random consistency index (Briefly R.I.)

| Matrix Order | Average Random Consistency Index R.I. |
|--------------|---------------------------------------|
|              | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| R.I.         | 0 | 0 | 0.52 | 0.89 | 1.12 | 1.26 | 1.36 | 1.41 |

(A thousand Calculating Result of Forward and Inverse Matrices)

According to the different order of the judgment matrices, one can get the corresponding average random consistency index. For instance, for the judgment matrix of order 4, the look-up table shows that R.I.=0.89.

Step 3: Calculating the consistency ratio (Briefly C.R.) and making the judgment

\[
C.R. = \frac{C.I.}{R.I.}
\]

In the case of C.R.<0.1, the consistency of the judgment matrix is acceptable; the other case of C.R.>0.1, the judgment matrix does not meet the requirements of consistency. Then the judgment matrix needs to be revised until it meets the requirements of consistency.

4. Problem Solving

As set in Figure 1, project D1 represents open always, D2 represents open in peak hours, D3 represents gated(closed) always. According to the standards build in this paper, the second layer judgment matrix from layer B to layer A is set as follows:

\[
A = \begin{pmatrix}
1 & 5/2 \\
2/5 & 1
\end{pmatrix},
\]

the maximal eigenvalue of A is 2, the corresponding eigenvector is \( w_1 = (5/2, 1)^T \), normalized eigenvector is \( w_1 = (0.714, 0.286)^T \). The sum normalized method is adopted in this paper.

Similarly, the third layer judgment matrix from layer C to layer B is set as follows. Firstly, set the relative weight as Table 3.
The third layer judgment matrix is constructed as follows:

\[ A_{21} = \begin{bmatrix} 1 & 5/3 & 5/3 & 5/4 \\ 3/5 & 1 & 1 & 3/4 \\ 3/5 & 1 & 1 & 3/4 \\ 4/5 & 4/3 & 4/3 & 1 \end{bmatrix}, \quad A_{22} = \begin{bmatrix} 1 & 2/3 & 2/3 \\ 3/2 & 1 & 1 \\ 3/2 & 1 & 1 \end{bmatrix}. \]

Calculated by Matlab software, the maximal eigenvalues of \( A_{21}, A_{22} \) and the corresponding normalized eigenvectors are showed in the following.

For \( A21 \) \( n = 4, \lambda_{\text{max}} = 4, w21 = (0.33,0.2,0.2,0.27)^T \), \( C.I. = 0, C.R. = 0. \)

For \( A21 \) \( n = 3, \lambda_{\text{max}} = 3, w22 = (0.25,0.375,0.375)^T \), \( C.I. = 0, C.R. = 0. \)

After the results of \( C.I. = 0, C.R. = 0 \), it can be seen that \( A_{21}, A_{22} \) meet the requirements of consistency both.

Meanwhile, the similar process in the fourth layer judgment matrices shows that

Table 4. Relative Weight Table in the Fourth Layer

| Index in Sub-criterion | C1 | C2 | C3 | C4 | C5 | C6 | C7 |
|------------------------|----|----|----|----|----|----|----|
| Index Name             |    |    |    |    |    |    |    |
| Location and Environmental Information |    |    |    |    |    |    |    |
| carrying capacity      | 5  | 3  | 3  | 4  | 2  | 3  | 3  |
| Internal road area     |    |    |    |    |    |    |    |
| Public transport services |    |    |    |    |    |    |    |
| T cross Road           |    |    |    |    |    |    |    |
| Cross Road             |    |    |    |    |    |    |    |
| Straight Road          |    |    |    |    |    |    |    |

And seven judgment matrices \( B_i, i = 1, 2, 3, 4, 5, 6, 7 \) are constructed

\[ B_1 = \begin{bmatrix} 1 & 4/5 & 1 \\ 5/4 & 1 & 5/4 \\ 1 & 4/5 & 1 \end{bmatrix}, B_2 = \begin{bmatrix} 1 & 3/6 & 3/5 \\ 6/3 & 1 & 6/5 \\ 5/3 & 5/6 & 1 \end{bmatrix}, B_3 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}. \]

\[ B_4 = \begin{bmatrix} 1 & 3/5 & 3/4 \\ 5/3 & 1 & 5/4 \end{bmatrix}, B_5 = \begin{bmatrix} 1 & 4/3 \\ 3/4 & 3/4 \end{bmatrix}, B_6 = \begin{bmatrix} 1 & 5/6 \\ 3/5 & 3/6 \\ 3/4 & 3/4 \end{bmatrix}. \]

Calculated by Matlab software, the following corresponding results are get:

For \( B1 \) \( n = 3, \lambda_{\text{max}} = 3, w31 = (0.31,0.38,0.31)^T \), \( C.I. = 0, C.R. = 0. \)

For \( B2 \) \( n = 3, \lambda_{\text{max}} = 3, w32 = (0.21,0.43,0.36)^T \), \( C.I. = 0, C.R. = 0. \)

For \( B3 \) \( n = 3, \lambda_{\text{max}} = 3, w33 = (0.33,0.33,0.33)^T \), \( C.I. = 0, C.R. = 0. \)

For \( B4 \) \( n = 3, \lambda_{\text{max}} = 3, w34 = (0.25,0.42,0.33)^T \), \( C.I. = 0, C.R. = 0. \)

For \( B5 \) \( n = 3, \lambda_{\text{max}} = 3, w35 = (0.36,0.36,0.28)^T \), \( C.I. = 0, C.R. = 0. \)

For \( B6 \) \( n = 3, \lambda_{\text{max}} = 3, w36 = (0.36,0.43,0.21)^T \), \( C.I. = 0, C.R. = 0. \)

For \( B7 \) \( n = 3, \lambda_{\text{max}} = 3, w37 = (0.4,0.4,0.2)^T \), \( C.I. = 0, C.R. = 0. \)
The seven matrices all meet the requirements of consistency. Finally, combining the four layers, the weight vector directly from the project layer to the target layer is determined as follows:

\[ w = (0.306, 0.396, 0.300)^T, \]

calculated by matrices multiply of the above results of \( w_{11}, w_{21}, w_{22}, w_{31}, w_{32}, w_{33}, w_{34}, w_{35}, w_{36}, w_{37} \).

The final result shows that second project D2 is more optimal option, D1 follows and D3 is the last. This conclusion also directly supports our intuitive knowledge: peak opening has the best impact on road traffic capacity; gated community is the weakest.

5. Conclusion

Through information collection and scenario analysis, the important indexes established in this paper are reasonable and effective. Different evaluation results will be obtained under the conditions of different opening forms different road structures outside the community. One can see that the results are quantifiable, making it easy to have a good choice. The analysis method as a model in this paper will help to further study the influence of the opening community on the surrounding road traffic and provide some help in solving the urban traffic congestion. However, one can observe that the number is close, therefore more indexes are needed in the model.

Of course, you can set different relative weight coefficients, as long as the judgment matrix (pair-comparison matrix) must meet the consistency test. The evaluation of road network planning program is mentioned in reference [4-6], there are three aspects: technical evaluation, economic evaluation and social environment evaluation in [4], and other aspects and views in references [5] and [6]. Therefore, there must be more evaluation criteria which come from the practical cases. In the future, I’ll continue the evaluation study. The goal is constructing a multi-index and multi-level system of evaluating road network planning, and making it better. It is even more important that how to design a better road structure outside the community. Concrete examples of optimization planning in road network is the future study direction.

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References

[1] Shen Y. j., (2016)Research Status and Development Trend of Urban Road Traffic Capacity. J. Urban construction, 32:267-267.
[2] Wang R., Weng j. c., Qiao g. l., (2015)Study on the Influence of Different Road Conditions on Traffic Flow Characteristics of Urban Road Sections. J. Road traffic and safety, 1:8-14.
[3] Hu Y.q., (2012)Operational Research Course(4th edition). Tsinghua University Press, Beijing.
[4] Hu C., Zou Z. y., Mei Y. n., Zhou Zh. w., (2006)Study on Evaluation Indicators System of Urban Road Network Planning. J. Huazhong University of Science and Technology(Urban Science Edition), 23(s2):98-101.
[5] Liang J., Li X. h., Xu Zh. c., (2002)Research for Index System of Traffic Quality Valuation in Municipal Traffic Network Planning. J. Sci.&Tech. information of Water Transportation, 3:47-49.
[6] Tian Q. h., (2010)Discussion deeply on the Planning, Design and Evaluation of road network in Small and Medium-sized cities. Science and Technology Innovation Herald, 5:41-42.