

Fuzzy analytic hierarchy process and its application in transit

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Abstract- The bus stop is an important node of the urban public transport and the whole transport system. Considering many influencing factors to the location of bus stops, this paper introduces fuzzy analytic hierarchy process to establish the evaluation index system of the scheme. And then using the fuzzy analytic hierarchy process to get the weight of each factor, and provides the basis for the optimal selection of specific programs. The application of fuzzy analytic hierarchy process makes the selection of bus stop more efficient, reasonable, and provides a basis for decision-making as a leader, it has a certain practicality.

Keywords –Bus Stop; Location Selecting; Fuzzy Analytic Hierarchy Process

1. The advantages of the public transport in traffic system

Compared with the private transport, public transport has the advantages of large capacity, low road occupation, saving energy and protection environment, safety and convenience, and is considered to be the most effective use of resources. Compared with other modes of transportation, public transport has a higher transport efficiency, the effectiveness of various modes of transport are shown in table 1^[2].

In the terms of easing urban traffic congestion and improving the resource utilization, the public transport has a significant advantage, but also the environment-friendly transportation. It can promote the development of the city economy, such as Curitiba of Brazil, Sao Paulo, Stockholm of Sweden, and San Francisco of the United States. The requirements of low-carbon, sustainable development, vigorously developing the public transport is a major strategy for urban development.

Table 1. The transport efficiency of the transport mode table^[2]

Passenger Transport	Conventional buses	Bicycle	Motorcycle	Car	Taxi
Occupy the length of road /m	7	1.5	2	3	3
Longitudinal safety clearance /m	3	1	3	3	3
Occupy the width of road /m	3.5	1.0	3.5	3.5	3.5
Average number of passengers /person	35	1	1.5	1.5	2

the accounted road area of per capita/m ²	1.0	3.8	14.0	14.0	10.5
The fuel consumption of per capita /L	0.125	0	1	1	0.75

2. The importance of the location of bus stop

The bus stop is the window directly to serve the residents of the public, and an important node of the public transport. The location of the bus stops reasonable or not directly affects the following points:

- (1) the capacity of the road and intersection
- (2) the share rate of the public transport in the entire urban traffic system
- (3) the service level and efficiency of the bus company
- (4) the advantages and disadvantages of the bus lines operation

2.1. The bus stop's settings determine residents walk to the site's time

The bus-sharing rate largely depends on the distance and the time of residents walk to the bus station, the location of bus stop determines the time.

If the walking time within the acceptable range, the utilization of the bus station, service level of public transportation vehicles and the bus lines are high. On the contrary, if the site is unreasonable, it will directly led to the low utilization rate of the bus station, decreasing the efficiency of the bus line and reducing the level of bus service, so the location of bus stop directly relates to walking distance and the level of the bus operation.

2.2. Bus station can drive the surrounding land development

Bus stops are the node of the hop and off, bring together a large number of passengers from different directions and regions, have a great role in promoting the economic development of the surrounding. The reasonable set of bus stop, it not only can improve the level of transit service and share rate of public transport, shorten the distance of residents walk to the destination, but also fully promote the development of surrounding high-density, diversity land use. At the same time, high-density development can shorten the travel distance and make it more suitable to transit trip, improve the attractiveness of public transport, improve number of passengers traveled by public transport and reduce the number of vehicle miles per capita. The virtuous cycle system of bus stops and land development promotes the development of economic and social public benefits. Bus station is the core content of transit-oriented development, the choice of the location of the bus stops has a direct impact on the development way and density of surrounding commercial, residence, office, hotel and others [4].

In summary, if the set of bus stops is unreasonable, it will lead to the result of the queuing length of the public transport vehicle too long, congesting stops, interfering with each other between the public transportation vehicles and social vehicles, and then forming the "bottleneck" in the road cross-section, seriously affect the normal operation of the urban road traffic. Therefore, the reasonable position of the bus stop has a very important meaning to the road traffic system [5].

3. The principles and influencing factors of the bus stop location

3.1. The principles of the bus stop location

Satisfy the principle of convenience for residents travel and reduce the walking distance, shorten the walking time, embody "people-oriented" in practice. Save residents' travel time and satisfy the life of the residents travel demand and Commuters travel demand maximize. Reduce travel expenses. With the increasing city's motorization level, residents put forward higher requirements of the time cost. Residents travel expenses includes the cost of travel and time cost. The bus stop location should follow the principle of reducing residents travel cost.

3.2. The influencing factors of the bus stop location

There are many factors affecting the bus station selection, this paper mainly analyzes from the following factors: the distance factor, other public transport vehicles influencing factors, capacity influencing factors, as well as other social vehicle. The distance of passengers walk to the site determines the utilization of bus lines. According to the "city road traffic planning design specification", the layout of bus site requires that the coverage of 500m range is greater than 90%, this shows that if the distances from the house to the bus stop is more than 500m, the transit is not competitive comparing with other modes of transportation. The location of the bus station impact on the road traffic capacity is also an important factor.

Although the bus station is a very short period of urban roads, the buses in this dock almost occupy one lane and have a great impact on the road capacity, thus it always forms a bottleneck on the space-time. it has become an important factor causing traffic jams[6]. Bus stop impacting on the road capacity is mainly reflected in delays caused by the public transport vehicles to other vehicles when it stops in the bus station[7]. The setting form of the bus stops has a certain impact on road capacity, and its form can be seen in figure1.

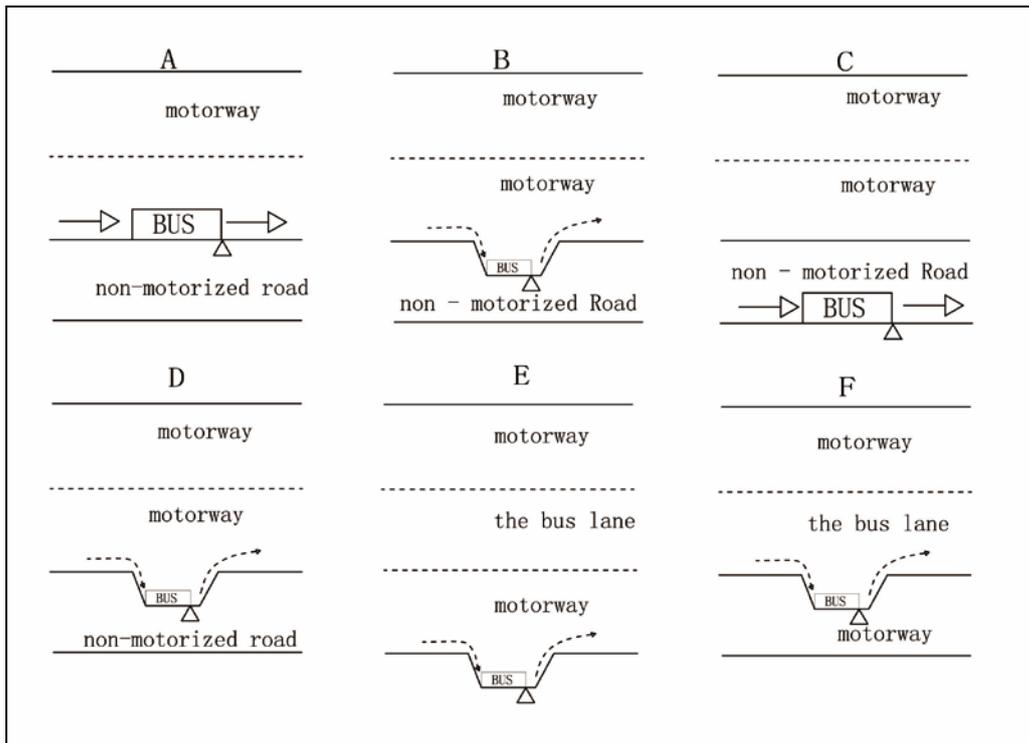


Figure1. The setting form of bus station

4. Fuzzy analytic hierarchy process

Fuzzy Analytic Hierarchy Process (FAHP) is an evaluation method, combines analytic hierarchy process (AHP) and fuzzy math, and has quantitative analysis and

qualitative analysis, the hierarchical structure is shown in figure 2. The factors affecting the bus station site can be summarized in three aspects: the economic, social and technical performance.

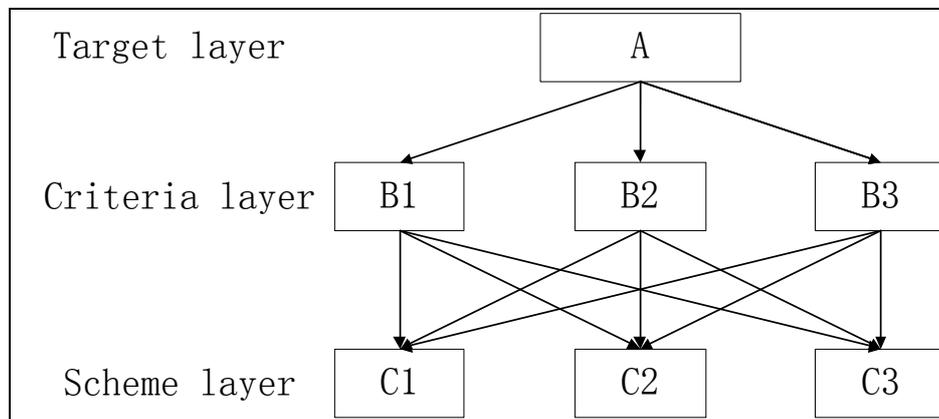


Figure2. The hierarchical structure

The steps of fuzzy analytic hierarchy process are as following:

Steps 1: Establish the hierarchy based on the requirements of the decision problem

Steps 2: Construction of judgment matrix A. The Construction of judgment matrix is the core steps of the Analytic Hierarchy Process, then use pairwise comparisons of different elements of the same level to determine the relative degree of importance according to the scaling theory, and then establish judgment matrix A. Fuzzy scale and its meanings can be seen in table 2.

Steps 3: The single ranking of hierarchical. According to the judgment matrix A, calculate the level weights of the order of importance relative to the upper hierarchy.

Steps 4: The total sorting of the hierarchy.

Steps 5: consistency check

Table 2. 0.1~0.9 fuzzy scale and its meanings

fuzzy scale	definition	explanation
0.5	Equally	Compared with the two elements, equally

	important	important
0.6	Slightly important	Compared with the two elements, the former slightly important than the latter
0.7	Obviously important	Compared with the two elements, the former obvious important than the latter
0.8	Strong important	Compared with the two elements, The former strongly important than the latter
0.9	Extremely important	Compared with the two elements, The former extremely important than the latter
0.1,		
0.2,	Converse comparison	If element a _i Compared with a _j to get a _{ij} , the Converse comparison a _{ji} =1- a _{ij}
0.3,		
0.4		

$$\begin{bmatrix} 0.5 & 0.5 & 0.7 \\ 0.5 & 0.5 & 0.7 \\ 0.3 & 0.3 & 0.5 \end{bmatrix}$$

Similarly, the fuzzy judgment matrix of the sub-criteria layer M relative to the criteria layer S is shown as follows:

$$A_{S1-M} = \begin{bmatrix} 0.5 & 0.6 & 0.8 \\ 0.4 & 0.5 & 0.7 \\ 0.2 & 0.3 & 0.5 \end{bmatrix}$$

$$A_{S2-M} = \begin{bmatrix} 0.5 & 0.6 & 0.6 \\ 0.4 & 0.5 & 0.5 \\ 0.4 & 0.5 & 0.5 \end{bmatrix}$$

$$A_{S3-M} = \begin{bmatrix} 0.5 & 0.7 & 0.7 \\ 0.3 & 0.5 & 0.5 \\ 0.3 & 0.5 & 0.5 \end{bmatrix}$$

The consistency test of the fuzzy judgment matrix. The first row elements as a reference, the result of the other row elements minus the first row elements are a constant. According to the fuzzy consistent matrix and hierarchical single ranking formula:

$$w_i = \frac{1}{n} - \frac{1}{2\alpha} + \frac{1}{n\alpha} \sum_{k=1}^n r_{ik}, i \in \{1, 2, \dots, n\}$$

N is the order fuzzy consistent matrix matrix. $\alpha = n-1/2$. To hierarchical single sort from the above equation, take the A_{F-S} for example, $n=3, \alpha=1$, we get the following:

$$w_{s_1} = \frac{1}{3} - \frac{1}{2} + \frac{1}{3}(0.5 + 0.5 + 0.7) = 0.4$$

$$w_{s_2} = \frac{1}{3} - \frac{1}{2} + \frac{1}{3}(0.5 + 0.5 + 0.7) = 0.4$$

$$w_{s_3} = \frac{1}{3} - \frac{1}{2} + \frac{1}{3}(0.3 + 0.3 + 0.5) = 0.2$$

$$w^S(w_{s_1}, w_{s_2}, w_{s_3})^T = (0.400, 0.400, 0.200)^T ;$$

$$w_1^M(w_{M_1}, w_{M_2}, w_{M_3})^T = (0.400, 0.367, 0.167)^T ;$$

$$w_2^M(w_{M_4}, w_{M_5}, w_{M_6})^T = (0.400, 0.300, 0.300)^T ;$$

$$w_3^M(w_{M_7}, w_{M_8}, w_{M_9})^T = (0.467, 0.267, 0.267)^T ;$$

$$W^M = \begin{bmatrix} W_1^M & 0 & 0 \\ 0 & W_2^M & 0 \\ 0 & 0 & W_3^M \end{bmatrix} W^S$$

$$=(0.160, 0.147, 0.068, 0.160, 0.120, 0.120, 0.094, 0.054, 0.054)$$

It can be drawn that shorten the time and improve the rate of bus-sharing occupy a larger weight in determining the objective function. So based on the sorting of each program weight, identify the specific practical solutions.

6. Conclusion

The stop's location is an important node in the public transportation network layout planning. Affecting by many factors, it belongs to problem of multi-objective levels. Fuzzy Analytic Hierarchy Process is a comprehensive evaluation method to clarify the complex decision-making problems. By using the fuzzy analytic hierarchy process, we are able to accurately select the optimal location scheme, provide scientific support for the leader, improve the utilization of public transportation and make the good development of the city in a low-carbon, environment-friendly.

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