Optimal Path Selection under Emergency Based on the Fuzzy Comprehensive Evaluation Method

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Abstract

When emergency occurs, the city is vulnerable, city is the region of high concentration of population and economic activities, and the traffic system is the lifeline of urban disaster prevention and mitigation, it is material transportation channel, and it is the path of personnel evacuating, sending rescue personnel and engineering team, delivering relief supplies under emergency situations. The occurring of emergencies in addition to direct serious damage of transportation infrastructure, casualties and economic losses, it also make troubles for sending rescue workers, carrying relief supplies and disaster relief and emergency triggering of engineering team because of the stagnation of vehicles and interrupt of roads, it will trigger more indirect lose. In reaction to the phenomenon, this paper proposed an optimal route choice model under the emergency based on AHP-fuzzy comprehensive evaluation method, This article proposed algorithm based on fuzzy comprehensive evaluation algorithm, combining hierarchy analysis method (AHP), make the calculated conclusion more reliability and accuracy. By simulation show that the proposed algorithm based on AHP-fuzzy comprehensive evaluation method has higher accuracy compared with the general algorithm, it is more accord with people's demand for path under emergency conditions.

Key words: FUZZY COMPREHENSIVE EVALUATION METHOD, HIERARCHY ANALYSIS METHOD (AHP), THE OPTIMAL PATH UNDER EMERGENCY

1. Introduction

In recent years, along with our country's urbanization and the speed up of urban construction pace, road traffic volume is increasing, due to road traffic accidents, major group petitions, chemical, fire and other accidents caused the rise on of road traffic public emergency[1].Because of the public emergency repeating performance is strong, and the amplification effect of loss is significantly, it will cause severe damage to the social order, social function, social environment, and make a strong impact on the people's life and normal operation of social[2].Active prevention, timely treatment of natural disasters and other major road traffic public emergency, strengthen emergency response ability, it has great significance to ensure road traffic safety, smooth, and maintain social stability[3].After sudden incident, the rescue work carried out smoothly or not, depends largely on whe-

ther transport security work orderly. And the powerful guarantees of road transportation is the key to solve these problems quickly. After emergency happened, if the site and the surrounding road transportation system can operate orderly and efficiently, it will minimize disaster losses of property and population, and it will greatly improve the resist ability of national or local government to respond to disasters[4]. However, in face of these unpredictable or unavoidable sudden event, what we need to do most is that we should reduce the harm done by the public emergency utmostly, protect people's life and property safety, this requests us to do a good job of emergency transportation evacuation. According to the needs and requirements of public emergency, use accordingly, quickly and efficiently emergency evacuation strategy to evacuate hurt people to the safety area or specify shelters, reduce the harm to the surrounding crowd by emergency, protect the public safety. Based on this phenomenon, the choice of the optimal path becomes very important under emergency[5].The shortest path problem is to look for the shortest path from the starting point to the target point in a given network, at the same time minimizing the total cost. The shortest path problem has a wide application, including traffic route navigation, computer network routing and robot path planning, etc[6].In addition, the shortest path problem also refers to the minimum weight and the fastest path problem, and so on. Due to the problem characteristics and network characteristics are complicated, the shortest path algorithm showed diversity. In general, the shortest path algorithm can be classified according to the problem type, network characteristics and solving technology and so on. The shortest path problem has been extensive research, because it is the basic problem to analyze transmission network. Bellman algorithm and Dijkstra algorithm is effective to solve the problem of the shortest path algorithm, for different network, it has developed many different algorithms[7].A * algorithm is a heuristic search algorithm, through the path line up, make its search scope shrunk. However, only when the weights of segment is certain and can't change that we can use these algorithms[8].In many applications of path planning, the important index of measuring path optimization is running time (The change of time depend on the various factors in the Internet). In this case, the selection of the optimal path depends on the driver's driving target. When the driver's goal is the least expected travel time, we can solve the shortest path problem through changing the weight of all the segment[9].Through the monte carlo procedure, find the probability distribution of the shortest path. Loui recommended that using the unfall drab and utility function of arrival time to represent the probability of reaching the destination within a certain time range, and the corresponding algorithm is given. The algorithm can find the utility function of the path's maximum expected value, but the example show that the algorithm running time is too long[10].

This paper proposed the optimal route choice model based on AHP-fuzzy comprehensive evaluation method under the emergency, the presented algorithm based on fuzzy comprehensive evaluation algorithm, combining hierarchy analytic method (AHP), it makes the calculated conclusion has higher reliability and accuracy. The simulation show that the proposed fuzzy comprehensive evaluation method based on AHP has higher accuracy compared with the general algorithm, it is more according with people's demand of path under emergency conditions.

2. Fuzzy Comprehensive Evaluation Method

Using fuzzy comprehensive evaluation can effectively deal with people's subjectivity in its evaluation process, as well as the objective ambiguity phenomenon, fuzzy comprehensive evaluation is usually proceed in the following steps:

(1) Determine the evaluation factor set $U=\{u_1,u_2,\cdots,u_N\}$

Among them, $u_i(i=1,2,\cdots,N)$ is the evaluation factor, N is the number of single factor on the same level, the collection constitutes the evaluation framework

(2) Determine the evaluation grade standard collection $V=\{v_1,v_2,\cdots,v_n\}$

Among them, $v_j(j=1,2,\cdots,n)$ is evaluation grade standard, n is the number of element, namely it is the number of count or evaluation grade level. This collection provides a range of evaluation results of the evaluation factors. Evaluation element can be either qualitative or quantitative score.

(3) Determine the membership degree matrix

Assume that make single factor evaluation to the i th evaluation factor u_i, get a fuzzy vector relative to the v_j.

$$R_i=(r_{i1},r_{i2},\cdots,r_{ij}) \quad (1)$$

r_{ij} is factor u_i which has the degree of v_j, $0<r_{ij}<1$, if make the comprehensive evaluation to n factors, its result is a matrix of N rows n columns, it is called the degree of membership R. Obviously, the each line of matrix is the evaluation results for each single factor, the matrix contains all the information which is obtained by the evaluation that evaluation standard set V to the evaluation factors set U. In this paper, using expert scoring method to determine the mem-

bership degree of qualitative index, membership functions are used to calculate the quantitative index membership degree, to generate the evaluation set.

(4) The multi-level comprehensive evaluation

According to the principle of maximum membership, decide the level of evaluation object, evaluation conclusions are given. The evaluation index can be divided into two categories, qualitative indexes and quantitative indexes:

1) The determination method of the qualitative indexes membership degree

Qualitative index refers that people cannot expresse it with quantitative method in judging a thing, and usually use some expression of fuzzy significance, such as: rational, good and poor.

This article uses the percentage statistical method, This method makes percentage statistics of the evaluation results of evaluation object, and make the results as the index's membership. The determination of membership degree method is as follows (make sheer level comprehensive evaluation method as example) :

For evaluating factors domain contains m elements, there is n levels in the evaluation level field, the evaluation result is:

$r_{ij}(i=1,2,3,\cdots,m;j=1,2,3,\cdots,n)$. Assuming that there is H evaluators to participate in the evaluation, for the evaluation result $u_{i1}^k,u_{i2}^k,\cdots,u_{in}^k(k=1,2,\cdots,H)$ which is evaluator k to evaluation object i, $u_{i1}^k,u_{i2}^k,\cdots,u_{in}^k$ has a weight of 1, the rest of the component is zero, as shown in table 1, evaluation elements in each row in the table is only one of 1, all the rest is 0.The determination of membership degree matrix is calculated by type.

$$r_{ij}=\sum_{k=1}^{H}u_{ij}^k \tag{2}$$

In the equation: u_{ij}^k is the evaluation result which is evaluator k to evaluation object i; H is the number of invited evaluators; m is the number of evaluation object; n m is the number of evaluation levels.

Table 1. Qualitative Indicators to Evaluate Results

	1	2	3	…	n
1	0	0	1	0	0
2	1	0	0	0	0
3	0	0	1	0	0
…	0	0	0	0	1
m	0	1	0	0	0

The judgment matrix which is composed of r_{ij}:

$$R=\begin{bmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & r_{m3} & \cdots & r_{mn} \end{bmatrix} \tag{3}$$

2) The determination method of the quantitative indexes membership degree

Linear analysis method is commonly used to determine the quantitative index membership degree, first, the method determines the value which has a series boundary effect in a continuous interval, then the actual parameter values is processed by the linear interpolation formula, then we can get the index membership degree.

In this paper, we make the half trapezoid distribution function as membership function which is widely used in environmental science, specific method is as follows:

Assuming that the evaluation index factor set is $X^T=\{x_1,x_2,\cdots,x_m\}$, evaluation criterion is $V=\{v_1,v_2,\cdots,v_n\}$, v_j and v_{j+1} are adjacent two level standard, $v_{j+1}>v_j$, then v_j levels membership function is:

$$r_1=\begin{cases} 1 & x_i\le v_1 \\ \dfrac{v_2-x_i}{v_2-x_1} & v_1<x_i<v_2 \\ 0 & x_i\ge v_2 \end{cases} \tag{4}$$

$$r_2=\begin{cases} 1-r_1 & v_1<x_i\le v_2 \\ \dfrac{v_3-x_i}{v_3-x_2} & v_2<x_i<v_3 \\ 0 & x_i\ge v_3 \quad or \quad x_i\le v_1 \end{cases} \tag{5}$$

$$r_j=\begin{cases} 1-r_{j-1} & v_{j-1}<x_i\le v_j \\ \dfrac{v_{j+1}-x_i}{v_{j+1}-x_j} & v_j<x_i<v_{j+1} \\ 0 & x_i\ge v_{j+1} \quad or \quad x_i\le v_{j+1} \end{cases} \tag{6}$$

According to the equation, calculate the membership degree r_{ij} that evaluation indexes i affiliated to evaluation level j, generate the membership function R.

$$R=\begin{bmatrix} r_{11} & r_{12} & r_{13} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{23} & \cdots & r_{2n} \\ r_{31} & r_{32} & r_{33} & \cdots & r_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & r_{m3} & \cdots & r_{mn} \end{bmatrix} \tag{7}$$

3. The Introduction of the AHP Fuzzy Comprehensive Evaluation Method

3.1 Analytic Hierarchy Process (AHP)

The basic idea of analytic hierarchy process (AHP)

is that according to the engineering system order principle to all elements, a complex problem is expressed as an orderly class hierarchy, namely the hierarchical structure model, then through the comparing of two people, judgment and calculation, have the rank of the decision scheme. The calculation steps are:

(1) according to the established hierarchy analysis model, compared in the layers of elements, and comparative judgment matrix is constructed;

(2) After the judgment matrix is fomulated, according to the biggest characteristic root and corresponding eigenvectors of judgment matrix, calculate the relative importance value of a layer element which is relative to the layer before;

(3) After calculating the value of single sort of a layer element which is relative to the layer before, use the own value of the layer before, we can calculate the relative importance value of a layer element which is relative to the layer before, namely hierarchy total row value;

(4) Calculate the relative importance value of the bottom layer factors to top layer or the relative pros sorting values.

3.2 The Construction of AHP- Fuzzy Comprehensive Evaluation Model

The AHP -fuzzy comprehensive evaluation model has two main parts: the first part, the analytic hierarchy process (AHP);The second part, the fuzzy comprehensive evaluation.

Among them, the fuzzy comprehensive evaluation was conducted on the basis of the analytic hierarchy process (AHP), they are complement each other, improve the reliability and validity of evaluation together, the technical route is shown in figure 1. The training effect of AHP-fuzzy comprehensive evaluation method is to combine the analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method to evaluate enterprise training status, namely make sure the goals and each index weight through hierarchy analysis, using multi-level fuzzy comprehensive evaluation method to evaluate the situation of brain drain.

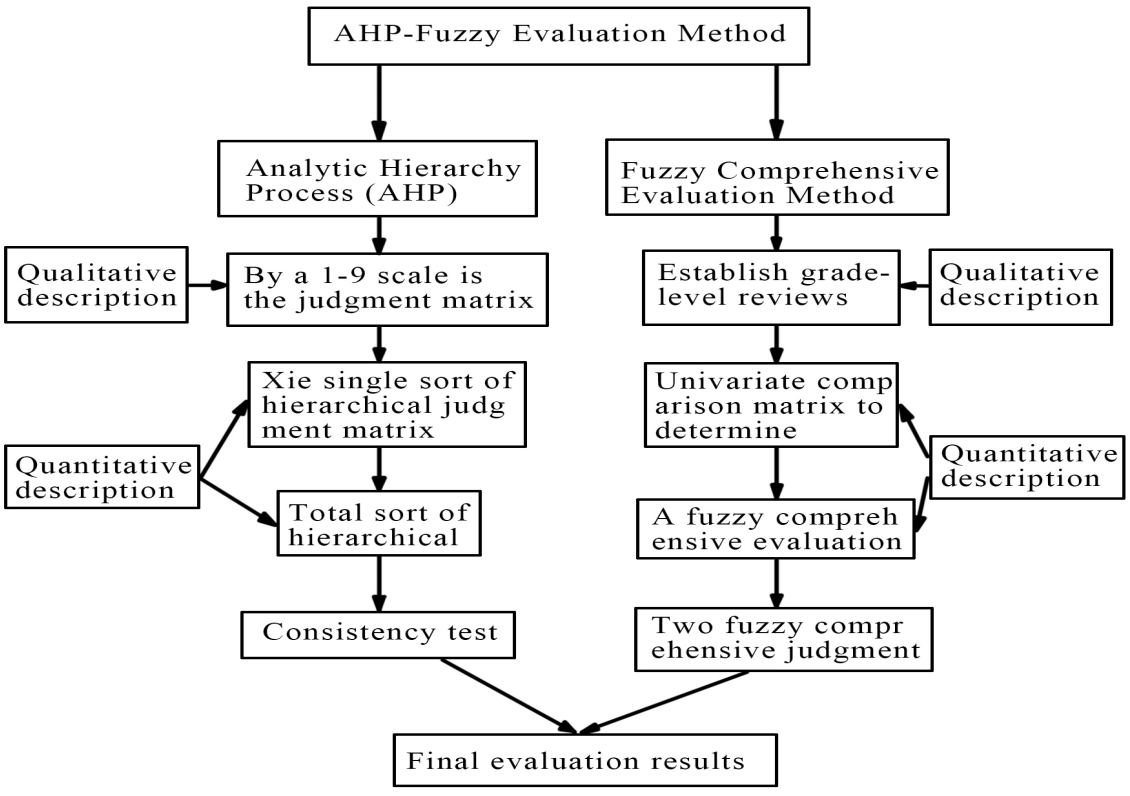

Figure 1. AHP A Comprehensive Evaluation Model

Analytic hierarchy process (AHP) in the process of application, first of all, through the analysis of the complex problems which contains factors of cause and effect to decompose the problem to solve into different levels of elements, constitute the recursive class hierarchy; And then the comparison of each level factors is done according to the standards, establish judgment matrix; Using a specific mathematical method to calculate the maximum eigenvalue and the corresponding orthogonal characteristic vector of the

judgment matrix, we can get the weight of each factor values at each level, then we do the consistency inspection; After the consistency check is passed, calculate the combination weighting of hierarchy factors corresponding with research questions, According to this, we can resolve the evaluation, sorting, index comprehensive and a series of problems.

Before the application of analytic hierarchy process (AHP), first of all, we need to establish the corresponding evaluation index system, namely do the hierarchical analysis of evaluation object, establish clear grading index system, such as the target layer A, criterion layer B, specific indicators C, evaluation object's factor set and the sub-factor set is given , they are shown as follows in figure 2.

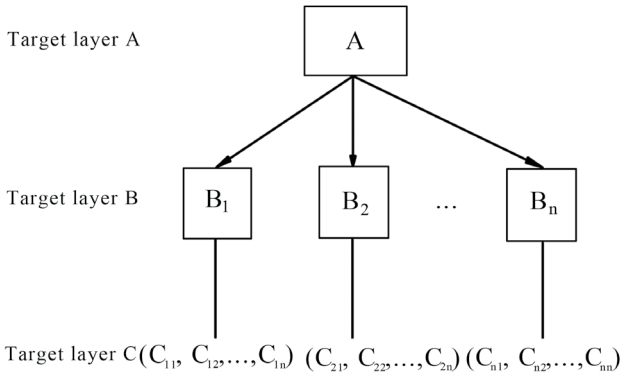

Figure 2. Framework of Hierarchical Indieators

Factor set $A=\{B_1,B_2,\cdots,B_n\}$

Factor set $B_i=\{C_{i1},C_{i2},\cdots,C_{in}\}$

Analytic hierarchy process(AHP) solve the problem of the process reflects the basic features of brain: decomposition - judge - comprehensive. It makes the judgment and decision process of complex problem to be systematic and quantification. Using analytic hierarchy process (ahp) to determine the weight of evaluation elements, usually it can be done in accordance with the following steps:

(1) Construct judgment matrix

Using the method of list 1-9 degrees by experts, the qualitative description to relative importance of evaluation indicators is done respectively, and use the exact figures to express quantify.

(2) Solve the judgment matrix

The calculation method of judgment matrix eigenvector are root method, sum method, the characteristic root method, logarithmic least squares method, least squares method, gradient method, etc. Among them root method is most convenient, it is used in the situation that accuracy is not high, in this paper, the precision of the judgment matrix eigenvector in volved is not very demanding. In order to simplify the calculation, this paper use root method to calculate the feature vector and the maximum root.

1.The approximate calculation of the weight vector

The root method to calculate the weight vector is to do the geometric average for each column vector of judgment matrix A , and then by the normalization process, calculation steps are as follows:

Calculate each row elements's product of judgment matrix

$$M_i=\prod_{j=1}^{n}a_{ij},\ i=1,2,3,\cdots,n \tag{8}$$

Calculate the n root of M_i

$$M_i=\prod_{j=1}^{n}a_{ij},\ i=1,2,3,\cdots,n \tag{9}$$

The standardized of M_i

$$M_i=\frac{\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}}{\sum_{k=1}^{n}\left(\prod_{j=1}^{n}a_{ij}\right)^{\frac{1}{n}}},\ i=1,2,3,\cdots,n \tag{10}$$

2. The calculation of maximum characteristic root

For the sake of consistency inspection, we need to calculate the maximum characteristic root $\lambda_{\max}$ of judgment matrix. In this paper, we use the following formula to calculate the maximum characteristic root $\lambda_{\max}$.

$$\lambda_{\max}=\sum_{i=1}^{N}\frac{(Aw_i)i}{nw_i},\ i=1,2,3,\cdots,n \tag{11}$$

Among them W is the weight vector which is obtained by root method

3. Do the normalized processing respectively to the obtained vector W , get the sorting weight vector of each compared element which is under single rule.

(3) The consistency check

The basic steps of consistency check are as follows: Use the equation to calculate the maximum eigenvalue of the judgment matrix, then compute the judgment matrix consistency index CI and consistency ratio CR , test its consistency.

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{12}$$

When judgment matrix consistency sex degree is higher, the value of CI is smaller. When $CI=0$, judgment matrix achieves consistency. But in the process

of establishing judging matrix, inconsistent thinking judgment affect is just one reason for the consistency of judgment matrix, with 1-9 percentage scale as a result of comparing two factors also cause the deviating from the consistency of judgement matrix. Set an acceptable standard of inconsistency according to the value of *CI* is clearly inappropriate. In order to get a consistency check critical value which is applicable to different order number judgment matrix, you must eliminate the influence of the matrix order.

4. Algorithm Performance Simulation

4.1 Experimental Data

In order to verify the validity of the model and algorithm, this paper established the simulation network as shown in figure 3, the network node number is 28, road number is 45, we specifie node 1 as a starting point and node 28 as the end. Use microscopic simulation software Vissim to obtain the average travel time of the road. The simulation time of this road network is 36000 seconds, stipulate that the calculation interval of the road travel time is 5 min.

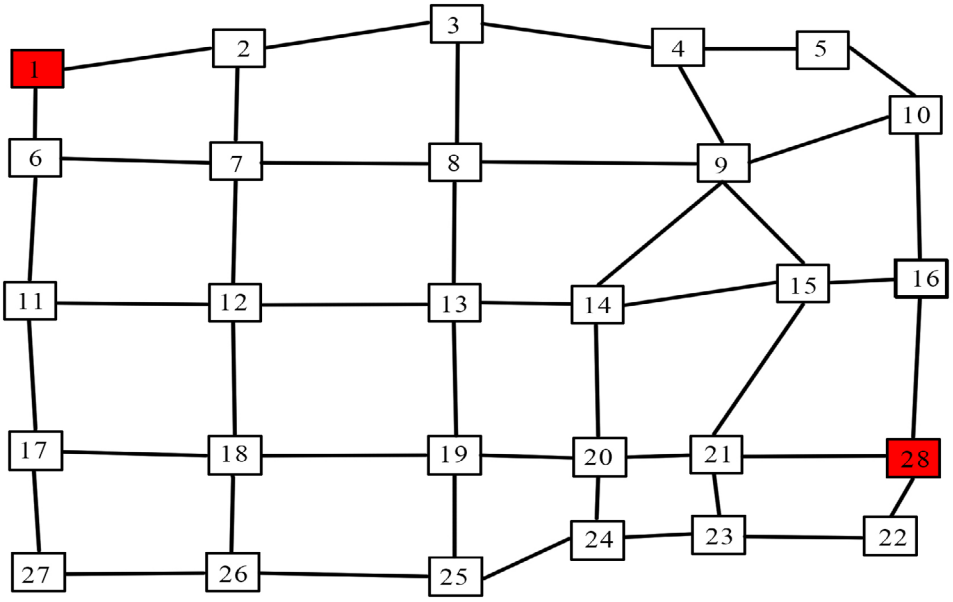

Figure 3. Simulation Road Network Structure

4.2 Comparation of Algorithm

Use pruning algorithm and AHP fuzzy algorithm based on the parameter optimization algorithm and improvement to find the shortest path for the road network, table 2 is the path selection results based on travel time.

Table 2. Travel Time Based on Path Selection Results

Algorithm	Shortest Path	Optimal path weight value (s)
AHP Fuzzy Algorithm	1-2-7-12-18-19-20-21-28	983.6
Parameter optimization algorithms	1-2-3-4-5-10-16-28	1024.2
Pruning algorithm	1-6-11-17-18-19-20-21-28	1206.7

Results show that the travel time of AHP and fuzzy comprehensive evaluation algorithm is the shortest, the second is the algorithm based on the parameter optimization, and the worst is the pruning algorithm.

In emergency situations, using the optimal shortest path to reach the scene is very important, therefore, the AHP-fuzzy comprehensive evaluation algorithm proposed in this paper has more advantages compared with general algorithm at this point, and it is more important to events' help.

5 Conclusion

At the beginning of this paper, the study model of optimal route choice based on emergency condition is proposed. In order to find the path of least expected costs, we propose the corresponding road impedance function. Based on the condition that road impedance function translates into the function of parameter form, random path model based on parameter optimization of λ is put forward. After comparison operations on different λ values, we can find the optimal solution in a limited range. But under the condition

of emergency random motion is nonlinear, so the AHP-fuzzy comprehensive evaluation algorithm is presented. Experiments show that the AHP-fuzzy comprehensive evaluation algorithm is more accord with people demand for path emergency conditions.

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Impact of Management Practices on Technical Efficiency Based on DEA and Decomposition Analysis

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