Comprehensive Evaluation of Urban Community Safety Based on Hayashi Quantification Theory Ⅲ

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Abstract—In order to comprehensively evaluate the risk degree of indexes that affected urban community safety we carried out this study. Those indexes not only have qualitative attributes but also quantitative attributes. Do a quantitative analysis on those qualitative indexes is not easy. Hayashi quantification theory Ⅲ have an obvious advantage that it can simultaneously analysis qualitative indexes and quantitative indexes. At the same give the objective evaluation results. So Hayashi quantification theory Ⅲ can be used in comprehensive evaluation of urban community safety field. Through the analysis of the present risk status of Pingdingshan and reference to a series of related studies.We screen 13 different types of risks which we concerned to construct the risk matrix. In this paper, though this method we do a quantitative analysis on those qualitative indexes. Based on the analysis of evaluation indexes of urban community safety, execute a cluster analysis about qualitative and quantitative evaluation indexes. Combined with Hayashi quantification theory Ⅲ, realize the target that make qualitative indicators quantitative of comprehensive evaluation. Draw the conclusion that there are seven indexes of high risk degree, among them perception and frequency play the leading roles. At the same time proposing pertinence protective measures and guided urban community safety building to the government.

***Keywords-** urban community safety; comprehensive evaluation; Hayashi quantification theory Ⅲ; cluster analysis; quantitative analysis*

I. INTRODUCTION

With the rapid development of social economy, accelerating the process of urbanization, improving the living standards, but attendant urban safety issues has become increasingly outstanding. Urban safety is a necessary condition for urban sustainable development. If there is no stability and security of social, economic and ecological environment, there can be no urban sustainable development. Urban safety issues had attracted wide attention of scholars. Jin Lei through the study of urban safety, proposed preparedness system of urban safety and the theory and evaluation method of safe capacity optimal allocation[1].Yang zhenhong through the integration of urban safety management organization, human resources etc, proposed an adaptive control equation of efficient and unified emergency response system[2].Luoyun through the analysis of relevant factors that affecting urban safety combined with the need of the government administration, divided the urban safety into twelve parts and designed an index system[3]. There are many factors that have an impact on urban community safety issues, these factors include both quantitative factors, but also includes qualitative factors. For the evaluation of the quantitative factors, experts and scholars have put forward a lot of evaluation methods for different application environments. Evaluation of qualitative factors, compared with the evaluation of quantitative factors is not very easy. Since Hayashi quantification theory Ⅲ can simultaneously evaluate the quantitative and qualitative indicators to evaluation object and make a cluster analysis, while its application in such areas, has obvious advantages. In this paper, through Hayashi quantification theory Ⅲ quantitative analysis the qualitative indexes that affect urban safety. In order to better reflect the security status of the city and its main influencing factors and provide a reliable theoretical support for government decision making.

II. THE SELECTION OF COMPREHENSIVE EVALUATION METHOD ON URBAN COMMUNITY SAFETY

Currently, there are many scholars have proposed a method for the evaluation of urban community safety, such as the analytic hierarchy process (AHP), fuzzy evaluation method, and BP neural network algorithm and so on. These methods in the implementation process, however, the weights of qualitative indexes often done by expert scoring. The consequences of such a treatment is excessive subjective factors are involved, and thus can not make a better quantitative assessment of the urban safety. The evaluation results have not a good guiding practice, resulting the method has a bad practicality and no better application space. Compared with other quantitative methods, Hayashi quantification theory Ⅲ has an obvious advantage. Its reaction matrix can obtain not only quantitative variables but also qualitative variables. By calculation, we can transform the qualitative variables into quantitative variables. This theory give the appropriate score for each sample based on reaction matrix [4].Because the theory can objectively transform qualitative classification into quantitative research, and simultaneously show qualitative and quantitative attributes in the matrix. So this theory had achieved good effect in HR performance evaluation [5],land quality assessment[6],the environmental impact assessment[7],the classification of dangerous goods accidents[8].It had also been widely used in geology, meteorology, forestry, environment protection, medicine, biology, business management, product design and other aspects.

III. CONSTRUCTION OF URBAN SAFETY COMPREHENSIVE EVALUATION MODEL

A. *Hayashi quantification theory Ⅲ*

Hayashi quantity theory Ⅲ can convert qualitative indexes to quantitative indexes then do cluster analysis [9]. Its basic principle was built based on the construction of "0-1"response matrix, calculation of vector-valued, cluster analysis of the results. The format of data source was shown in Table 1.

TABLEI. RESPONSE MATRIX OF HAYASHI QUANTITY THEORY Ⅲ

Category number / Sample number	1	2	3	4	5
A	1	0	0	0	0
B	1	0	1	0	1
C	0	0	1	0	1
D	0	$\delta_i(j)$	1	1	1
E	0	0	1	1	0
…					

In this theory, we usually called qualitative variables for the project, and the different values of qualitative variables are called category. Corresponding assumptions to table 1 is that there are *n* quantitative samples, *m* qualitative variables. The matrix was denoted by X.

$$\text{Note } X=\begin{bmatrix} \delta_1(1)\ldots\delta_1(m)U_1 1\ldots U_1 s \\ \delta_2(1)\ldots\delta_2(m)U_2 1\ldots U_2 s \\ \cdots \\ \delta_n(1)\ldots\delta_n(m)U_n 1\ldots U_n s \end{bmatrix} \qquad (1)$$

$\delta_i(j)$ is a reaction number that i sample corresponding to j category. $U_I 1$ is the value that the first qualitative variable corresponding to i sample.

$$\delta_i(j)=\begin{cases}1, \text{ recation} \\ 0, \text{ no recation}\end{cases}, \ i=1,2,\ldots,n; j=1,2,\ldots,m \qquad (2)$$

The purpose of the theory is to achieve a value vector about *(m + s)* variables.

$$b=(b_1,b_2,\ldots b_m,a_1,a_2,\ldots a_s)' \qquad (3)$$

For each sample, each project has exactly only one responsive category. So the total reaction number is *m*. There are *s* quantitative variables. So the average score for sample is *Y*.

$$Y=(Y_1,Y_2,\ldots,Y_n)'=\frac{1}{m+s}Xb \qquad (4)$$

Because *n* samples total score is *n (m + s)*, so the total average is $\overline{Y}$.

$$\overline{Y}=\frac{1}{n(m+s)}\sum_{i=1}^{n}\left(\sum_{j=1}^{m}b_j\delta_i(j)+\sum_{i=1}^{s}a_1U_i 1\right) \qquad (5)$$

$$\text{Note } g_j=\sum_{i=1}^{n}\delta_i(j), g=\left(g_1,g_2,\ldots,g_m,0,\ldots,0\right)' \qquad (6)$$

$$\text{Then } \overline{Y}=\frac{1}{n(m+s)}g'b \qquad (7)$$

The total variance of *n* samples is σ^2 .

$$\sigma^2=\frac{1}{n(m+s)}\sum_{i=1}^{n}\left[\sum_{j=1}^{m}\left(b_j\delta_i(j)-\overline{Y}\right)^2+\sum_{i=1}^{s}(\alpha_1 U_i 1-\overline{Y})^2\right] \qquad (8)$$

$$\text{Note } G=diag(\sum_{i=1}^{n}\delta_1(1)^2,\ldots,\sum_{i=1}^{n}\delta_1(m)^2,n,\ldots,n) \qquad (9)$$

$$\text{Then } \sigma^2=\frac{1}{n(m+s)}b'\left[G-\frac{1}{n(m+s)}gg'\right]b \qquad (10)$$

$$\text{Note } L=G-\frac{1}{n(m+s)}gg' \qquad (11)$$

$$\text{Then } \sigma^2=b'Lb\cdot\frac{1}{n(m+s)} \qquad (12)$$

The variance between groups is σ'^2 .

$$\sigma'^2=\frac{1}{n}\sum_{i=1}^{n}(Y_i-\overline{Y})^2$$

$$=\frac{1}{n}\sum_{i=1}^{n}Y_i^2-\overline{Y}^2$$

$$=\frac{1}{n}Y'Y-\frac{1}{n^2(m+s)^2}b'gg'b$$

$$=\frac{1}{n(m+s)^2}(b'X'Xb-\frac{1}{n}b'gg'b)$$

$$\text{Note } H=X'X-\frac{1}{n}gg' \qquad (13)$$

$$\text{Then } \sigma'^2=b'Hb\cdot\frac{1}{n(m+s)^2} \qquad (14)$$

b can be calculated by maximum principle of the two variance ratio.

$$\eta^2 = \frac{\sigma'^2}{\sigma^2} = \frac{1}{(m+s)} \cdot \frac{b'Hb}{b'Lb} \quad (15)$$

To obtain the relative relationship between each score we add two constraint conditions.

$$b'Lb = 1, b'g = 0 \quad (16)$$

Then, we can obtain the characteristic equation.

$$Hb = \lambda (m+s) Lb \quad (17)$$

Thus, the problem is transformed into to solve the maximum eigenvalue corresponding vectors. Thus the theory can solve the evaluation object of multi-index and multi-attribute. Another characteristic is that it can do quantitative analysis to qualitative indexes. In the application process, we usually obtained the k maximum eigenvalue$K_1 \geqslant K_2 \geqslant ... \geqslant K_k$ corresponding eigenvectors b_1, b_2,..., b_k. Through the value b_i, we make the classification of variables, then according to the formula (4) samples were classified. From the geometric sense, a feature vector can be seen as a factor axis, sample points can be seen as the sample vectors in the projection axis. The axis corresponding to the maximum eigenvalue indicates that in order to the projection has the greatest degree of dispersion (correlation ratio) direction. If you feel that a one-dimensional representation is not ideal, you can further consider the issue of multi-dimensional representation. The classification principle of Hayashi quantification theory Ⅲ is as follows. Data form of Hayashi quantification theory Ⅲ model besides the situation described above which both have qualitative and quantitative variables, you can also include only qualitative or quantitative data. When only includes qualitative data, the quantitative part of reaction matrix X was removed, then s is 0; for the case that contains only quantitative data, b can be solved in accordance with $Hb = Ksb$, where H represents a correlation matrix corresponding to s quantitative variables. So this theory has unique applicability over other evaluation methods on urban community safety comprehensive evaluation.

B. Building risk reaction matrix of urban community safety--with Pingdingshan city as example.

Most scholars make the classification of risks mainly from the perspective of qualitative references. Then make the classification the consideration of risk incentives, objects, attribution of risk classification methods. But the real point of view from the quantification of risk classification study to explore rare. The quantization process of risk classification needs the support of data. In order to build the matrix of risk quantification we need the special data. Taking into account the elements of the classification framework requires an explicit value. That is, "yes" or "no" clear judgment, so that the matrix is a 0-1 matrix. We called it as 0-1 reaction matrix. To the risk property if there is an artificial reaction, otherwise it is 0. Risk response matrix construction is a key to risk classification. It is related to the final result and the closeness of reality. More objective of response matrix, more correct response to objective reality. Therefore, successfully construct risk reaction matrix is the basis for objective results. In this paper, through the analysis of the present risk status of Pingdingshan and reference to the 1980s the paper that described 30 kinds of risk published in Science[10],draw lessons from 30 risk events that were most concerned by China in 21 century[11], as well as the risk survey aiming at Hong Kong, Macao and Taiwan students[12] and the risk report which was put forward on the first World Risk Congress in June 2003[13]. Then we screen 13 different types of risks which we concerned to construct the risk matrix. The results were shown in Table 2.

TABLE II. THE RISK RESPONSE MATRIX

Category / Sample	Risk type	Inducement	Frequency	Influence scope	Consequence	Duration	Perception
1	Earthquake	0	0	1	1	0	0
2	Drought	0	1	1	1	1	0
3	Torrential rain	0	1	1	1	0	0
4	Snow disaster	0	1	0	1	0	0
5	Fire	1	1	0	1	0	0
6	Traffic accident	1	0	0	0	0	0
7	Mass unexpected incident	1	0	0	1	0	1
8	Production accident	1	0	0	0	0	0
9	Food safety have	1	0	1	0	1	1
10	Public health event	0	0	1	1	0	1
11	Ecological destruction	1	1	1	1	1	1
12	Terror attack	1	0	1	1	0	1
13	Improper emergency decision	1	0	0	1	0	1

C. Evaluation result

Risk response matrix shows 13 samples and 6 categories. After calculating we can obtain the maximum eigenvalue and corresponding eigenvector. As shown in Table 3.

TABLE III. THE CORRESPONDING EIGENVECTOR

b_1	-0.1410	-0.4138	-0.3836	-0.3660	-0.2237	0.5658

According to the evaluation method we can obtain their scores. $R = | b_j |$, As shown in Table 4.

TABLE VI. THE SORT OF INFLUENCING FACTORS

Influencing factors	R	The sort
Inducement	0.1410	6
Frequency	0.4138	2
Influence scope	0.3836	3
Consequence	0.3660	4
Duration	0.2237	5
Perception	0.5658	1

As can be seen from the table, risk perception in these influence factors that complexity and frequency play the leading roles, the influence scope, consequence and duration time is the more important, risk incentive is the general role.

The risk degree is a coupling effect of a variety of factors. There will product a serious risk degree when those indexes have a high coupling reaction. We can get chart of coupling effect through drawing in the two-dimensional illustrations. The horizontal axis represents the number of risk sample. The vertical axis represents the risk degree. As shown in Fig .1.

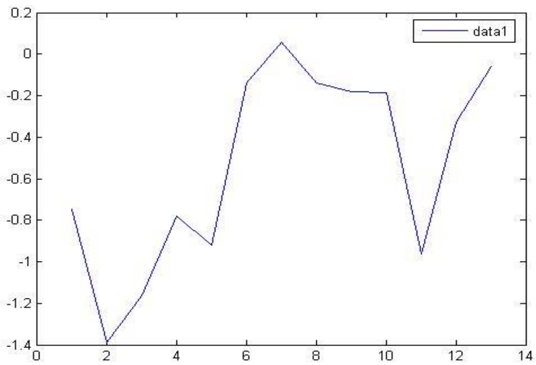

Figure1. The graph of risk degree

The figure shows that the risk degree of the 13 indexes. Take -0.6 as the boundary line 13 indexes can be divided into two categories. 6,7,8,9,10,12,13 corresponding to Traffic accident, Mass unexpected incident, Production accident, Food safety have, Public health event, Terror attack and Improper emergency decision. They have higher risk degree. So can be the main factors that cause risk of urban safety.1,2,3,4,5,11 corresponding to Earthquake, Drought, Torrential rain, Snow disaster, Fire and Ecological destruction. They have a lower risk degree.

IV. Conclusions

Hayashi quantitative theory Ⅲ is feasible when it as a method to make the risk classification. This classification based on the establishment of risk response matrix that reflects the risk process. This method mot only logically separate the risk categories, at the same time, you can choose the type of threshold to meet the need of classification requirements. So you can get the required amount of risk types. On the other hand, it is that the use of quantitative theoretical description of risk issues more convincing than just use a qualitative description for risk classification. If we have the judgment standard, it is easier to make a objective management. The method is a useful exploration to a multi-attribute risk analysis. This work analyses urban community safety by Hayashi quantitative theory Ⅲ. To identify risk factors of urban community safety, qualitative and quantitative analysis of risk degree that affected urban community safety to risk attribution indexes of each risk sample. Build risk reaction matrix of urban community safety--with Pingdingshan city as example. The results show that Traffic accident, Mass unexpected incident, Production accident, Food safety have, Public health event, Terror attack and Improper emergency decision have higher risk degree. Urban community safety is more likely to be significantly impacted by them. The evaluation results are useful for the Government to make prevention and control measures. Furthermore, improve the standard of urban community safety and meet the city need of healthy, sustainable and stable development.

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