Study on the Characteristics of Risk Factors in Urban Crowded Places

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Abstract. In order to scientifically assess the risk of urban crowded places and improve the safety of urban crowded places. Firstly, 25 typical cases of accidents in urban crowded places were coded at 3 levels using the rooting theory, and 16 risk factors were extracted. Based on this, the causal relationship between the 16 factors was analyzed using the DEMATEL method to obtain a comprehensive influence matrix, and the ISM method was applied to obtain a multi-layer recursive structure model of the risk factors. Using the MICMAC method, the driving forces and dependencies were calculated and a quadrant diagram was drawn. The study shows that: crowd disturbance behavior, crowd density and flow rate, and directional signs are the direct causes of accidents in urban crowded places; managerial response capability, security agencies and management status, and safety inspection are the root causes of accidents. The results of the study can provide a strong reference basis for effective early warning and control of safety risks in crowded urban places.

Keywords: urban crowded places · Grounded theory · risk factors · Decision Making Trial and Evaluation Laboratory (DEMATEL) · Interpretative Structural Modeling (ISM)

1 Introduction

Urban crowded places refer to specific areas and places that need to be managed and pre-controlled because of a large number of people gathered simultaneously due to functional needs, which may cause safety accidents [1]. With the acceleration of urbanization, the number and scale of urban crowded places have significantly increased. Based on the classification of public places and the necessity of analyzing accident risks, urban crowded places are divided into eight categories: school education places, cultural exchange places, tourist attractions places, leisure and entertainment places, etc. [2]. The risks brought by cultural entertainment and leisure in urban crowded places are also increasing. Therefore, it is necessary to comprehensively identify risk factors, construct a scientific risk evaluation index system and identify key risk factors, which are of great practical significance for the safety management of urban crowded places.

Many scholars have made a lot of progress in the research of crowded stampedes and emergency evacuation in urban crowded places. In terms of crowded trampling in

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urban crowded places, detectors are used to detect and identify threat vectors in crowded places, and they are applied to Pulkovo Airport [3]; the MORT and FIST models are used to analyze the causal factors of the trampling accident in Mexican dance halls [4]; based on the theory of accident cause, a control model of disturbance factors in urban crowded places is proposed [5]. In the aspect of emergency evacuation in urban crowded places, by analyzing the exit choice in crowd evacuation, it is found that even if the nearest exit is crowded, pedestrians still choose the nearest exit [6]; considering the factors before and after disasters, the evacuation evaluation model is established [7]; the demand for refuge is obtained through mobile phone signaling data, and the shortage of refuge demand prediction and evacuation distribution is analyzed, and the optimization method of refuge layout is put forward [8]. In order to realize the scientific evaluation of urban crowded places, it is necessary to assign appropriate weight to each evaluation index. There are two kinds of commonly used methods to calculate index weights: subjective weighting and objective weighting. Although research on the risks of urban crowded places is available, there is less research on the interactions and transmission pathways between the risk factors of accidents in urban crowded places.

In view of this, the risk factors are extracted by coding with rooting theory, then the integrated DEMATEL [9]-ISM [10] to sort out the hierarchical structure and internal logic of each factor in the impact factors of urban crowded places, and analyze them through the MICMAC [11], to analyze the results, so as to provide ideas and management solutions for improving safety and reducing accidents in urban crowded places.

2 Research Methodology

DEMATEL [9] is a system analysis method using graphical and matrix tools to analyze the cause-effect relationships and associations among factors in complex management problems. ISM [10] decomposes a complex system into several subsystem elements, and the process of decomposing a complex system into a multi-level hierarchical model is eventually achieved through practical experience and the use of computers. Based on this, the combination of DEMATEL and ISM can not only identify the key elements of the indicator system and the degree of influence, but also construct the hierarchical structure of the indicator system [12]. MICMAC [11] method of analysis is used to analyze the position and role of the influencing factors in order to propose targeted improvement measures.

(1) The influence relationship between risk factors is rated by issuing questionnaires to experts, and the evaluation scale is 0–3, representing the strength of the influence relationship, and the meaning of the score is shown in Table 1.

Table 1. Impact relationship evaluation scale

Influencing relationship	None	Weak	General	Strong
Numerical value	0	1	2	3

(2) The direct impact matrix Z is established by calculating the mean value of each value of the questionnaire $\overline{a}$, determining the final aij according to Eq. (1).

$$a_{ij} = \begin{cases} 0, & 0 \le \overline{a} < 0.5 \\ 1, & 0.5 \le \overline{a} < 1.5 \\ 2, & 1.5 \le \overline{a} < 2.5 \\ 3, & 2.5 \le \overline{a} < 3 \end{cases} \tag{1}$$

(3) The canonical influence matrix X is obtained by normalizing the direct influence matrix.

$$X = S * Z \tag{2}$$

$$S = \min\left\{ \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}, \frac{1}{\max\limits_{1 \le j \le n} \sum_{i=1}^{n} a_{ij}} \right\} (i, j = 1, 2, \cdots, n) \tag{3}$$

(4) Calculate the integrated impact matrix T based on the canonical impact matrix.

$$T = X(I - X)^{-1} \tag{4}$$

(5) Calculate the overall impact matrix H.

$$H = T + I = h_{ij} \tag{5}$$

(6) Calculate the reachable matrix M. The threshold value λ can be obtained by calculating the average of all terms in the integrated impact matrix T. The transformation of the overall impact matrix to the reachable matrix is as follows.

$$M = \left[m_{ij}\right]_{m \times n}, (i, j = 1, 2, \cdots, n)$$

$$m_{ij} = \begin{cases} 1 \; h_{ij} \ge \lambda \\ 0 \; h_{ij} < \lambda \end{cases} \tag{6}$$

(7) Calculate the reachable set R(Si) and the prior set A(Si) for each influencing factor. The reachable set R(Si) is the set consisting of the elements corresponding to the rows with rij = 1 in the rows corresponding to the factor Si in the reachable matrix M. The prior set A(Si) is the set consisting of the elements corresponding to the columns with rij = 1 in the columns corresponding to the factor Si in the reachable matrix M.

$$R(S_i) = \left\{S_j \in S \,\middle|\, r_{ij} = 1\right\} \tag{7}$$

$$A(S_i) = \left\{S_j \in S \,\middle|\, r_{ji} = 1\right\} \tag{8}$$

(8) Modelling the multi-layer progressive structure of urban crowded places.

(9) Using the MICMAC method, draw a quadrant diagram by the calculated dependency and driving force results, further analyze the status and the role played by the influencing factors, clarify the different characteristics of each influencing factor, and provide a basis for making suggestions or taking measures.

3 Identification and Analysis of Risk Factors in Urban Crowded Places Based on Grounded Theory

3.1 Identification Methods and Data Sources

The Grounded Theory was first put forward by Glaser and Strauss in the 1960s [13], which is a qualitative research method that systematically sums up original data to form new concepts and ideas. It mainly includes open coding, spindle coding, selective coding and theoretical saturation test. This paper selects 25 cases of typical urban crowded places from 2001 to 2022 as raw materials.

3.2 Qualitative Coding

(1) Open coding. Open coding is a process of sorting out and extracting original sentences from accident cases and then conceptualizing the original sentences. The original data from 20 accident cases were analyzed, and 55 original sentences were obtained. After conceptualizing the original sentences, 38 initial categories were obtained.
(2) Spindle coding and selective coding. Based on the results of open coding, the potential generic relationship between categories is established, and 16 higher-level main categories are obtained. Then, the main categories are coded selectively. The risk factors of urban crowded places are classified into 4 core categories: crowd safety risk, equipment risk, site environment risk and organizational management risk. Table 2 for coding process.
(3) Theoretical saturation test. The remaining five accident cases are used for recording analysis, and it is found that no new category is found in the 4 core categories of risk factors in urban crowded places, which indicates that the theory has reached a saturation state, and the analysis can be finished.

4 Example Analysis

4.1 Risk Factor Association Characteristics Analysis Based on DEMATEL

Taking the urban tourist attractions as an example for analysis, ten professionals were hired to score and evaluate the influence relationships between risk factors in urban crowded places. The normative impact matrix X is calculated by Eqs. (1)–(3), as shown

Table 2. Analysis of Spindle Encoding and Selective Encoding

Main category	Core category
crowd safety awareness and ability (S_1)	crowd safety risk
age structure and physical condition of the population(S_2)	
crowd density and flow rate(S_3)	
crowd disturbance behavior(S_4)	
professional competence of security personnel(S_5)	
directional signs(S_6)	equipment risk
safety status of equipment(S_7)	
allocation of emergency relief materials(S_8)	
ambient temperature(S_9)	site environmental risk
channel standardization(S_{10})	
on-site appeal(S_{11})	
managerial response capability(S_{12})	organizational management risk
security organization and management status(S_{13})	
safety-check(S_{14})	
communication for information(S_{15})	
contingency plan(S_{16})	

below. The comprehensive impact matrix T was calculated by Eq. (4), as shown below.

$$X = \begin{bmatrix}
0.00 & 0.05 & 0.11 & 0.05 & 0.00 & 0.00 & 0.05 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.05 & 0.00 \\
0.11 & 0.00 & 0.05 & 0.05 & 0.00 & 0.00 & 0.05 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.05 & 0.00 \\
0.05 & 0.05 & 0.00 & 0.11 & 0.00 & 0.00 & 0.11 & 0.00 & 0.00 & 0.11 & 0.00 & 0.00 & 0.00 & 0.00 & 0.16 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.11 & 0.05 & 0.11 & 0.16 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.11 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.11 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.11 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.05 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.05 & 0.16 & 0.00 & 0.00 & 0.05 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.11 & 0.05 & 0.05 & 0.16 & 0.00 & 0.05 & 0.11 & 0.00 & 0.00 & 0.11 & 0.05 & 0.00 & 0.00 & 0.00 & 0.16 & 0.05 \\
0.00 & 0.00 & 0.00 & 0.05 & 0.00 & 0.11 & 0.00 & 0.00 & 0.00 & 0.00 & 0.05 & 0.00 & 0.00 & 0.00 & 0.00 & 0.05 \\
0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.05 & 0.00 & 0.05 & 0.05 & 0.11 & 0.05 & 0.00 & 0.00 & 0.00 & 0.05 & 0.05 \\
0.00 & 0.00 & 0.00 & 0.05 & 0.05 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\
0.00 & 0.00 & 0.00 & 0.16 & 0.00 & 0.00 & 0.11 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.05 & 0.00
\end{bmatrix}$$

Calculate the integrated influence matrix T with rows and ri, columns and ci, ri+ci is the centrality of factor i; ri-ci is the cause degree of factor i. The larger the cause degree, the stronger the correlation, as shown below.

$$T = \begin{bmatrix}
0.000 & 0.003 & 0.013 & 0.005 & 0.000 & 0.000 & 0.004 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.004 & 0.000 \\
0.013 & 0.000 & 0.004 & 0.004 & 0.000 & 0.000 & 0.004 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.004 & 0.000 \\
0.004 & 0.003 & 0.000 & 0.016 & 0.000 & 0.000 & 0.012 & 0.000 & 0.000 & 0.011 & 0.000 & 0.000 & 0.000 & 0.000 & 0.029 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.013 & 0.004 & 0.013 & 0.031 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.015 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.011 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.011 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.003 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.003 & 0.025 & 0.000 & 0.000 & 0.003 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.014 & 0.004 & 0.004 & 0.036 & 0.000 & 0.003 & 0.014 & 0.000 & 0.000 & 0.012 & 0.003 & 0.000 & 0.000 & 0.000 & 0.032 & 0.003 \\
0.000 & 0.000 & 0.000 & 0.003 & 0.000 & 0.011 & 0.000 & 0.000 & 0.000 & 0.000 & 0.003 & 0.000 & 0.000 & 0.000 & 0.000 & 0.003 \\
0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.003 & 0.000 & 0.003 & 0.003 & 0.011 & 0.003 & 0.000 & 0.000 & 0.000 & 0.003 & 0.003 \\
0.000 & 0.000 & 0.000 & 0.003 & 0.003 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 \\
0.000 & 0.000 & 0.000 & 0.029 & 0.000 & 0.000 & 0.011 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.000 & 0.004 & 0.000
\end{bmatrix}$$

When the cause degree is greater than 0, it means that the risk factor has a greater influence on other factors and becomes the cause factor; when the cause degree is less

Table 3. Centrality and causality of risk factors

Factors	Centrality	Centre Degree Ranking	Causality
S_1	0.0604	13	−0.0013
S_2	0.0647	11	−0.0059
S_3	0.1417	2	0.0165
S_4	0.1309	3	−0.1309
S_5	0.0704	9	−0.0704
S_6	0.0649	10	−0.0649
S_7	0.1092	4	0.0436
S_8	0.0311	16	−0.0086
S_9	0.0786	7	−0.0561
S_{10}	0.0388	15	−0.0332
S_{11}	0.0620	12	0.0004
S_{12}	0.1576	1	0.0979
S_{13}	0.0788	6	−0.0382
S_{14}	0.0583	14	−0.0008
S_{15}	0.1017	5	−0.0648
S_{16}	0.0756	8	−0.0181

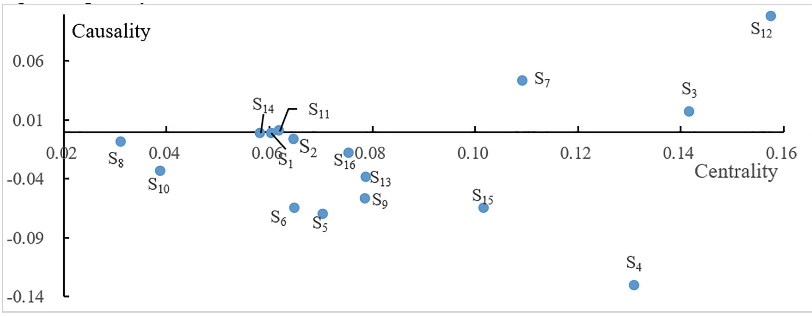

Fig. 1. Centrality-causality

than 0, it means that the risk factor is influenced by other factors and becomes the result factor, as shown in Fig. 1.

(1) Centrality analysis.

Higher centrality values indicate that risk factors play a greater driving role in urban crowded places and must be given high priority. According to Table 3, the centrality values of five factors, namely, managerial response capability (S_{12}), professional competence of security personnel (S_3), crowd disturbance behavior (S_4), safety status of equipment (S_7) and communication for information (S_{15}), are relatively high, indicating that they have a greater influence on the occurrence of accidents in urban crowded places and occupy a central position among other factors.

(2) Analysis of the degree of cause.

According to Table 3 and Fig. 1, the four factors of professional competence of security personnel (S_3), safety status of equipment (S_7), on-site appeal (S_{11}) and managerial response capability (S_{12}) are the causal factors, among which, manager's response ability, crowd density and flow rate have a greater influence on other factors, indicating that reasonable control of crowd flow and strengthening manager's safety ability play a vital role in urban crowded. The 12 factors of crowd safety awareness and ability (S_1), age structure and physical condition of the population (S_2) and crowd disturbance behavior (S_4) are outcome factors, of which safety-check (S_{14}), crowd safety awareness and ability (S_1) and age structure and physical condition of the population (S_2) are more influenced by other influencing factors and need to be investigated to further strengthen management. The outcome factors are the combined effect of the causal factors, the state of which changes as the structural function of the causal factors changes, thus creating a complex dynamic in the evolution of accident risk.

4.2 Risk Factor Cascade Characterization Based on ISM

In order to eliminate the factors with small influence, the threshold value $\lambda = 0.002$ can be obtained by calculating the average value of all the terms in the comprehensive influence matrix T. The reachable matrix M is shown below.

According to Eqs. (7) and (8) to calculate the reachable set and the prior set, if $C(S_i) = R(S_i) \cap A(S_i) = R(S_i)$, then we can get the highest level of influence factors C(Si), as shown in Table 4, and then the rows and columns corresponding to the highest level of risk factors are deleted in the reachable matrix, and then the division continues according to this principle, and the cycle continues, and finally the risk factors are divided into different levels. Then the hierarchy is divided to draw a multi-layer progressive structure model of urban crowded places, as shown in Fig. 2.

$$M = \begin{bmatrix} 1&1&1&1&0&0&1&0&0&0&0&0&0&0&1&0 \\ 1&1&1&1&0&0&1&0&0&0&0&0&0&0&1&0 \\ 1&1&1&1&0&0&1&0&0&1&0&0&0&0&1&0 \\ 0&0&0&1&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&0&0&0&0&0&0&0&0&0&0&0 \\ 1&1&1&1&0&0&1&0&0&0&0&0&0&0&1&0 \\ 0&0&0&1&0&0&0&1&0&0&0&0&0&0&0&0 \\ 0&0&0&0&0&1&0&0&1&0&0&0&0&0&0&0 \\ 0&0&0&1&0&0&0&0&0&1&0&0&0&0&0&0 \\ 0&0&0&1&1&0&0&1&0&0&1&0&0&0&0&0 \\ 1&1&1&1&0&1&1&0&0&1&1&1&0&0&1&1 \\ 0&0&0&1&0&1&0&0&0&0&1&0&1&0&0&1 \\ 0&0&0&0&0&1&0&1&1&1&1&0&0&1&1&1 \\ 0&0&0&1&1&0&0&0&0&0&0&0&0&0&1&0 \\ 0&0&0&1&0&0&1&0&0&0&0&0&0&0&1&1 \end{bmatrix}$$

(1) Risk factors at the top level are crowd disturbance behavior (S4), crowd density and flow rate (S5), and directional signs (S6). The top-level factors are the most direct factors affecting the safety of urban crowded places, and starting from these aspects can rapidly improve the safety of urban crowded places in the short term so as to reduce the occurrence of risks and reduce the serious consequences of accidents to a certain extent, the top-level factors are influenced by the lower-level factors, and the risk control measures should be considered comprehensively when they are proposed.

(2) The risk factors located in the second layer are allocation of emergency relief materials (S_8), ambient temperature (S_9), channel standardization (S_{10}), and communication for information (S_{15}). They are indirect factors which indirectly affect the safety of urban crowded places through the three factors affecting the top layer while being influenced by the factors in the next layer.

(3) Risk factors located in the third layer are crowd safety awareness and ability (S_1), age structure and physical condition of the population (S_2), professional competence of security personnel (S_3), safety status of equipment (S_7) and on-site appeal (S_{11}).

(4) The risk factors located in the fourth layer are contingency plan (S_{16}), which are the same as the factors in the third layer as deep factors affecting the safety of urban crowded places and are directly influenced by the factors in the bottom layer, which in turn affect the factors in the upper layer, and should be considered comprehensively in risk control.

(5) The risk factors located at the bottom layer are managerial response capability (S_{12}), security organization and management status (S_{13}) and safety-check (S_{14}). It is

Table 4. Factor division

S_i	$R(S_i)$	$A(S_i)$	$C(S_i)$
1	1,2,3,4,7,15	1,2,3,7,12	1,2,3,7
2	1,2,3,4,7,15	1,2,3,7,12	1,2,3,7
3	1,2,3,4,7,10,15	1,2,3,7,12	1,2,3,7
4	4	1,2,3,4,7,8,10,11,12,13,15,16	4
5	5	5,11,15	5
6	6	6,9,12,13,14	6
7	1,2,3,4,7,15	1,2,3,7,12	1,2,3,7
8	4,8	8,11,14	8
9	6,9	9,14	9
10	4,10	3,10,12,14	10
11	4,5,8,11	11,12,13,14	11
12	1,2,3,4,6,7,10,11,12,15,16	12	12
13	4,6,11,13,16	13	13
14	6,8,9,10,11,14,15,16	14	14
15	4,5,15	1,2,3,7,12,14,15,16	15
16	4,7,15,16	1,2,13,14,16	16

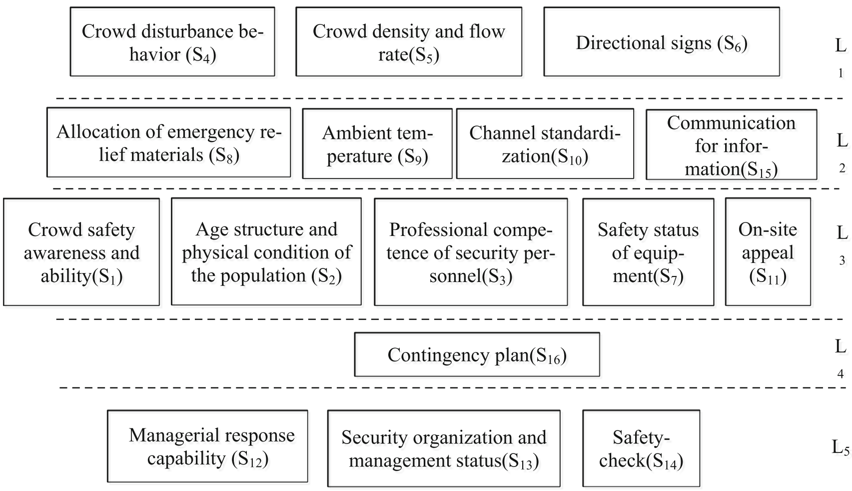

Fig. 2. Multi-layer progressive structure model of risk in urban crowded places

located at the bottom of the multi-layer recursive structure model, which is a fundamental factor that will continue to affect other factors in the long run. It should be considered when considering risk control measures, and it is the most basic and non-negligible factor affecting the safety of urban crowded places.

4.3 Characteristic Analysis of Risk Factor Attributes Based on MICMAC

The drivers are the sum of the elements of each row of the reachable matrix and the dependencies are the sum of the elements of the columns of the reachable matrix, as shown in Table 5. According to the mapping of risk factor classification, the mean values of drivers and dependencies are divided into four quadrants, as shown in Fig. 3. Quadrants I, II, III and IV are spontaneous factors, dependent factors, associated factors and independent factors respectively.

The factors belonging to the I quadrant are crowd density and flow rate (S5), allocation of emergency relief materials (S8), ambient temperature (S9), channel standardization (S10), on-site appeal (S11), and contingency plan (S16), which have a low driving force and dependency and need to be considered separately for these six factors in the evaluation. Those belonging to the II quadrant are managerial response capability (S12), security organization and management status (S13), and safety-check (S14), which have a lower dependency and higher driving force, and these three factors belong to management risk and should be focused on in the evaluation. The factors belonging to the III quadrant are crowd safety awareness and ability (S1), age structure and physical condition of the population (S2), professional competence of security personnel (S3), and safety status of and equipment (S7), which have a high and low dependency and driving force, and some correlations between factors are high. Those belonging to quadrant IV are crowd disturbance behavior (S4), directional signs (S6), and communication for information (S15), which have a low driving force and high dependency and need to be solved by addressing other factors.

Table 5. Values of driving forces and dependencies of risk factors

NO	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
driving force	6	6	7	1	1	1	6	2	2	2	4	10	5	8	3	4
dependency	5	5	5	12	3	5	5	3	2	4	4	1	1	1	8	4

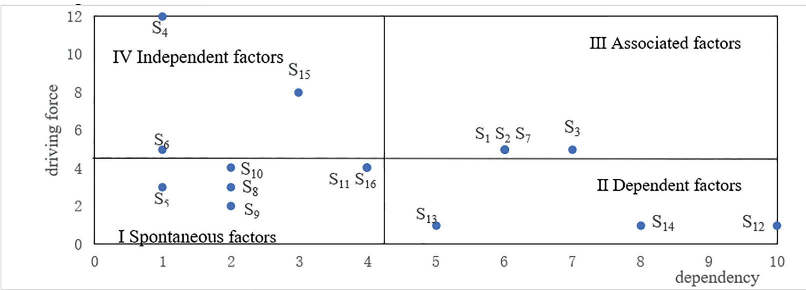

Fig. 3. MICMAC model of risk in urban crowded places

4.4 Risk Management Measures

(1) There should be clear signs indicating the location of exits, places of refuge and channels should be set up in a standardized manner, timely clearance of obstacles of people to escape.
(2) The responsible unit should prepare a perfect emergency plan and send it to the relevant departments for the record. A perfect emergency plan will play a vital role in the event of an accident.
(3) In the development of the security work program should take into account all possible problems, highlight the focus, achieve comprehensive control, the essential parts, key personnel to achieve critical protection, and pay attention to the security work carried out in a timely manner and management status.
(4) Relevant management departments regularly conduct comprehensive safety inspections while conducting risk assessments of crowded urban sites, formulating practical work plans and making contingency plans for emergencies for peak operation and management.

5 Conclusion

(1) Based on the rooting theory to identify and extract risk factors from urban crowded places, 16 main categories and 4 core categories were derived through 3 levels of coding: open coding, spindle coding, selective coding and theoretical saturation test.
(2) DEMTEL-ISM was applied to study the factors influencing accidents in urban crowded places, building multi-layer recursive structural models, the correlations and transmission relationships between the factors were identified, making the mechanism of accidents in urban crowded places clearer.
(3) The MICMAC method is used to identify the factors that need to be focused on according to the driving force dependency analysis chart and to propose corresponding control measures in order to control them at the source and reduce the occurrence of accidents in crowded urban places.

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