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Identification of Key Indicators of Flood Resilience in Riverside Urban Communities Based on SNA

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Abstract. In order to strengthen the ability of riverside urban communities to cope with flood disasters, the evaluation indicators of flood resilience of riverside urban communities are constructed by literature review and field investigation, and the relationship network was constructed by the matrix of interaction among indicators. The social network analysis (SNA) indexes are used to measure and analyze the relationship of the constructed indicators network from the dimension of overall network and individual indicator. The results of indexes show that location, business type, business density, non-vulnerable groups, population density, ability to eliminate stagnant water, building density, and disaster relief are the key indicators among all the indicators. Therefore, locating risk groups, strengthening rescue and evacuation capacity, and building rainwater blocking and restoring facilities are of great importance to improve the flood resilience of riverside urban communities.

Keywords: riverside urban communities; community flood resilience; social network analysis

1. Introduction

As an urban community directly adjacent to surface waters in a river-across city or a riverfront single-shore city, riverside urban communities have the following characteristics: (1) Strong exposure to floods. Relying on the waterscape, riverside urban communities have built many recreational facilities and buildings, resulting in complex and dense human flow; (2) The ability to resist flood risk is weak. The main industries of riverside urban communities are tertiary industries including commerce, service industry, and tourism which influence the water environment less, however, the direct impact of disasters and subsequent secondary disasters have great harm to them. (3) The stricter requirement of emergency management. The higher the ratio of shoreline to community boundary, the less the community evacuation means, therefore the emergency management department should make timely response to the disaster to reduce the loss of life and property. Based on the above characteristics, riverside urban communities are more vulnerable to floods. So it is particularly important to make contributions to flood control and disaster reduction by taking advantage of their distance to deal with flood disasters.

Since 1973, when Canadian ecologist Holling used the concept of resilience in ecology [1], the concept has been subsequently extended. Folke et al. proposed that resilience is the ability to maintain stability within key thresholds, strong adaptability and transformation. The simple explanation is that resilience emphasizes the ability to manage the present situation and the ability to create new stable states when out of control [2]. UNDRR proposed that resilience is the ability of a system exposed to hazards to resist, absorb, withstand and recover from the impact of hazard-causing factors in a timely and effective manner [3]. It can be seen that the concept of resilience mainly covers maintaining a certain degree of function or structure and the ability to adapt and change. In terms of disasters and public emergencies, resilience is linked with government departments and residents with the emergence of concepts such as "urban resilience" and "community resilience" [4,5]. Based on the perspective of flood disaster, the resilience of riverside urban community includes the community's ability to maintain the basic operation of the community when dealing with flood disaster, the integration of multi-dimensional resources to deal with post-disaster recovery and suitable construction to meet local disaster characteristics. In view of this, this paper measures and analyzes the flood resilience indicators of riverside urban communities from five dimensions of nature, economy, society, infrastructure and management through social network analysis.

2. Method

2.1. Determine the evaluation indicators for resilience

Based on the research on evaluation of community resilience [6-8] and visits to several riverside urban communities, candidate evaluation indicators were obtained. Treat the characteristics of waterfront urban communities and the concept of waterfront urban community resilience from the perspective of flood disasters as filter rules, an evaluation indicator system was established from five aspects of nature, economy, society, infrastructure and management. Natural resilience refers to the quality of community environment when dealing with flood disaster; economic resilience is the economic basis for community residents to cope with disasters; social resilience reflects the ability to adapt to flood of population structure. Infrastructure resilience shows the ability of communities to construct facilities according to the characteristics of disasters; management resilience is the effectiveness of integrating disaster preparedness resources and disaster response. Eighteen evaluation indicators were selected according to the principles of relevance, comprehensiveness and comparability (see Table 1).

Table 1: Flood resilience evaluation indicators of riverside urban communities

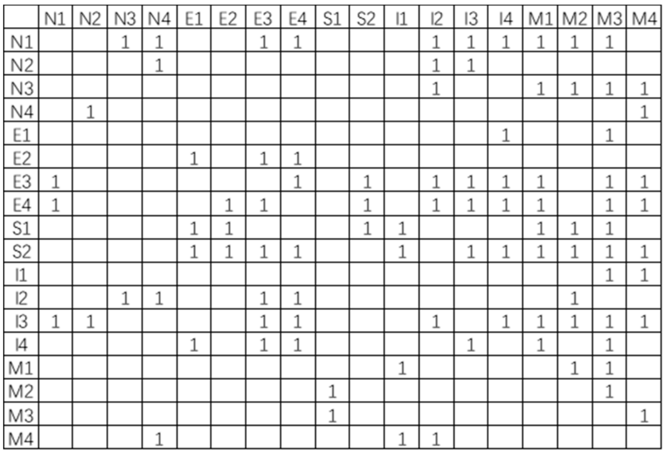
First-class indicator	Second-class indicator	Code name	Meaning of indicator
Natural Resilience	Location	N1	Average distance between geometric centroid of densely populated area and surface water
	Vegetation coverage	N2	%Vertical projected area of vegetation on the ground of the total community area
	Frequency of flood	N3	The number of floods in past 20 years
	Water environment quality	N4	Environment grade of surface water
Economic Resilience	transportation	E1	Population/number of vehicles in the community
	Saving level	E2	Per capita savings
	Business type	E3	The complexity of business distribution and service object
	Business density	E4	Average number of retailers per 100m
Social Resilience	Non-vulnerable groups	S1	Non-disabled population aged 15-59 in the community
	Population density	S2	Population per square kilometer
Infrastructure Resilience	Medical facilities	I1	The number of clinics, health service centers and hospitals which are in the community or within 1.5km around the community
	Ability to eliminate stagnant water	I2	The ability to eliminate stagnant water of blocking and restoring facilities for rainwater and vegetation
	Building density	I3	%Building base area to the total area of community
	Road conditions	I4	Grade of evacuation roads
Management Resilience	Disaster drill	M1	The frequency of flood disaster drills and disaster knowledge publicity
	Disaster warning	M2	The effectiveness of flood disaster warning system and the number of disaster warning channels

Table 1(Continued)

First-class indicator	Second-class indicator	Code name	Meaning of indicator
Management Resilience	Disaster relief	M3	Emergency command, rescue team and emergency material reserve
	Public health management	M4	Public hygiene, epidemic prevention and residents' health management

2.2. Social network analysis

Social network analysis originated in the 1930s and Thomas initially used the social network to solve the relationship between people in society [9]. A social network is a collection of actors and their relationships. Based on graph theory, social network analysis focuses on the characteristics of relationships among parties and quantifies relationships in the form of data. It depicts abstract relationships more intuitively in the form of network diagrams, and a series of indexes to measure relationships and networks composed of relationships are used to analyze the characteristics of network structures, changes in relationships, and the roles of participants. This paper uses Ucinet6 to analyze the flood resilience indicators network of riverside urban communities.



	N1	N2	N3	N4	E1	E2	E3	E4	S1	S2	I1	I2	I3	I4	M1	M2	M3	M4
N1			1	1			1	1				1	1	1	1	1	1	
N2				1								1	1					
N3												1			1	1	1	1
N4		1																1
E1														1			1	
E2					1		1	1										
E3	1							1		1		1	1	1	1		1	1
E4	1					1	1			1		1	1	1	1		1	1
S1					1	1				1	1				1	1	1	
S2					1	1	1	1			1		1	1	1	1	1	1
I1																	1	1
I2			1	1			1	1								1		
I3	1	1					1	1				1		1	1	1	1	1
I4					1		1	1					1		1		1	
M1											1					1	1	
M2									1								1	
M3									1									1
M4				1							1	1						

Figure 1: Interaction matrix of flood resilience indicators for riverside urban communities

3. Results

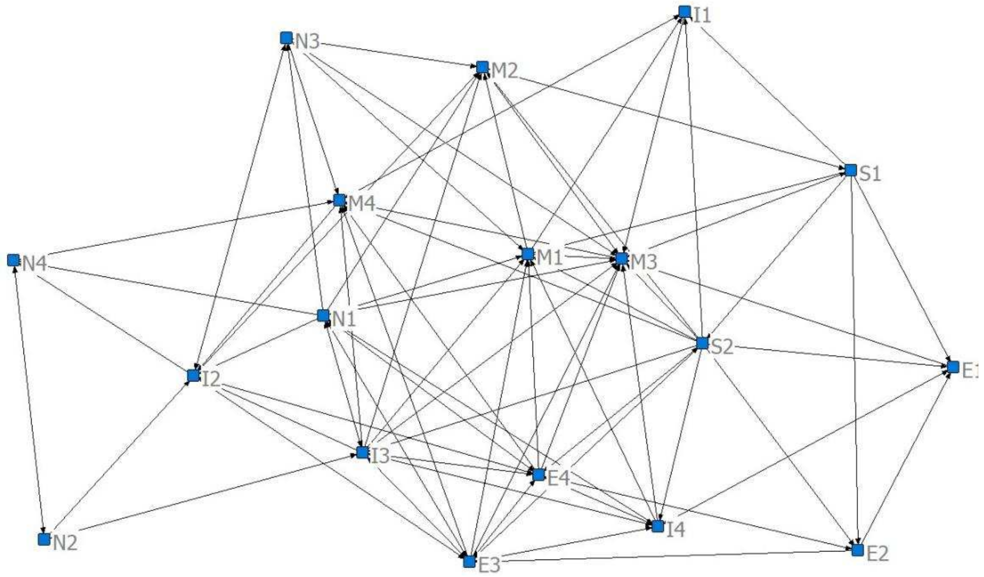


Figure 2: Network of flood resilience indicators for riverside urban communities

In the flood disaster resilience indicators network of riverside urban communities, the "impact" and "affected" relationships are the basis of social network analysis. 5 experts in disaster resilience, urban disaster reduction, emergency management and other fields were invited to obtain the correlation relationship of indicators through expert questionnaire, and the correlation matrix was drawn accordingly: The first row and the first column represent the resilience indicators, the value at the intersection of row i and column j is the influence of the two indicators, Eij=0 means that indicator i does not affect index j, Eij=1 means that index i affects index j, and then an 18×18 asymmetric matrix is obtained, as shown in FIG. 1. Based on this, the network relationship of flood resilience indicators of riverside urban communities is established. Then Ucinet6 is use to analyze the overall and individual dimensions of the indicators network on the network density, average distance and centrality.

3.1. Overall dimension

The numerical magnitude of the indicators network density reflects the closeness of the relationship between each indicator, and the network also has influence on a single resilience indicator. The network density is between 0% and 100%, and the network density of frequent or very frequent contact interactions is between 5% and 30% [10]. The network density of riverside urban community flood resilience indicators network is 0.3105 which is exceeding 0.3, indicating that the network density is relatively high, as a consequence each indicator does not exist in isolation in the network, but is closely related. In addition, the average distance between the indicator nodes is 2.078, which means that an indicator node only needs to pass 2.078 distances to reach another node on average, in other words, the influence is easy to spread in the network, and the indicators will eventually cause the change of flood resilience for riverside urban communities through interaction. Therefore, it is of great significance to analyze the network constructed by these indicator nodes.

3.2. Individual dimension

3.2.1. Degree centrality

The indicator with high degree centrality is associated with many indicators and can cause a wide range of influence on the network which belongs to the core node in the network. This paper uses relative degree centrality to measure it. As can be seen from Table 2, the following six indicator nodes are in the top third of relative degree centrality: The highest relative degree centrality of E4 is 0.500, indicating that it is in the core position of the network. Followed by E3 (I3), S2(M3) and N1, with relative degree centrality of (0.471, 0.471), (0.412, 0.412) and 0.382, which are relatively important in the network. It is worth noting that the relative degree centrality of M3 comes from its high in-degree, indicating that disaster relief can make a greater contribution to the improvement of resilience after other nodes in the network are developed. In addition, in the natural resilience dimension, N2, N3 and N4 interact less with other indicators, so natural resilience is a second concern in the resilience indicators network.

3.2.2. Closeness centrality

The closeness centrality is used to measure the independence and effectiveness of a node in the network operation. This paper adopts the absolute value of in-closeness and out-closeness to measure. The out-closeness and in-closeness respectively represent the ability of an indicator node to influence other indicator node to contribute to resilience and the ability of the indicator node to be transformed into resilience by the influence of other indicator nodes [11]. It can be seen from Table 2 that N1 (E4, S2, I3), E3 and I4 have higher out-closeness, the values are 70.833 (70.833, 70.833, 70.833), 68.000, and 56.667 respectively, indicating that they can positively output resilience, their independence and effectiveness are relatively strong, which belong to the core nodes in the network. The indicators with high in-closeness ranked in the top third are M3, M4, M1, I2(M2) and E3(E4) have higher in-closeness, the values are 73.913, 65.385, 58.621, 54.839 (54.839) respectively, and 51.515 (51.515) respectively, indicating that they have a strong ability to transform resilience, which belong to the key nodes in the network, their independence and effectiveness are relatively strong.

3.2.3. Betweeness centrality

Nodes in the middle position have greater control over resources and the interaction of other nodes [12]. In the riverside urban community flood resilience indicators network, the indicator with higher betweenness centrality plays the role of the middleman and belongs to the core node in the network. This paper adopts the relative value of betweenness centrality. From Table 2, it can be seen that I1, M4, S1, M, E4 and I3 have higher relative betweenness centrality ranked in the top third, the values are 15.886, 13.833, 13.433, 12.063, 11.87 and 10.962 respectively, indicating that they are more in the shortcut of the relationship between two nodes, and have strong control ability over other nodes, belonging to the core node.

Table 2: Centrality of indicator nodes of indicators network

Code number	Relative degree centrality	Code number	In-closeness	Code number	Out-closeness	Code number	Relative betweenness centrality
E4	0.500	M3	73.913	N1	70.833	I2	15.886
E3	0.471	M4	65.385	E4	70.833	M4	13.833
I3	0.471	M1	58.621	S2	70.833	S1	13.443
S2	0.412	I2	54.839	I3	70.833	M3	12.063
M3	0.412	M2	54.839	E3	68.000	E4	11.87
N1	0.382	E3	51.515	I4	56.667	I3	10.962
I2	0.353	E4	51.515	I2	54.839	E3	8.693
I4	0.353	I1	50.000	S1	51.515	S2	6.929
M1	0.324	N4	47.222	N2	47.222	I4	5.598
M4	0.324	I3	47.222	N3	47.222	N2	4.176
S1	0.265	S1	45.946	E2	45.946	M2	3.873
M2	0.265	I4	45.946	M3	42.500	N4	3.284
N3	0.206	E1	43.590	M4	42.500	M1	2.353
N4	0.176	E2	43.590	E1	40.476	I1	2.275
E1	0.176	S2	43.590	M2	38.636	E2	2.171
E2	0.176	N2	40.476	I1	36.170	N1	2.156
I1	0.176	N1	37.778	N4	35.417	E1	1.195
N2	0.147	N3	36.957	M1	33.333	N3	0.564

3.2.4. Key indicator identification

The frequency of core nodes from 3.2.1 to 3.2.3 is listed in Table 3. The results show that the frequency of N1, E3, E4, S1, S2, I2, I3, and M3 being rated as core nodes is higher than

2, therefore they are key indicators in flood resilience indicators for riverside urban community.

Table 3: Frequency summary of core nodes

Code number	Core nodes based on degree centrality	Core nodes based on in-closeness	Core nodes based on out-closeness	Core nodes based on betweeness closeness	frequency
N1	√		√		2
N2					0
N3		√			1
N4					0
E1		√			1
E2					0
E3	√		√		2
E4	√	√	√	√	4
S1		√		√	2
S2	√		√		2
I1					0
I2		√		√	2
I3	√		√	√	3
I4			√		1
M1		√			1
M2					0
M3	√			√	2
M4				√	1

4. Recommendations

Due to the relatively developed tertiary industry in riverside urban community, the magnitude of its service objects is wide and the types are complex, causing great suffering for rescue work and evacuation work. At the same time, numerous data show that the average age of flood victims is higher [7], and it’s not easy for disabilities to save themselves because of their physical defects. As a consequence, those vulnerable groups at risk points who bear severe life threats in flood disaster are priority rescue targets. Emergency management department should track their location. High water levels of part area caused by high building density will do harm to the power system, which not only can cause a series of secondary hazards such as electric shock and short circuit but also contribute to drowning to residents on the escape route, so it should be improved by constructing rainwater blocking and restoring facilities. Based on the above key indicators in 3.2.4, the following measures should be applied timely to improve flood resilience of riverside urban communities:

(1) Establish risk population files and build a corresponding positioning system. Files of risk are established by household registration information and permanent resident population statistics. The positioning system based on the LBS cloud platform is built in conjunction with communication operators which not only can locate the local risk group but also track the location of migrants visiting the community (2) Build rescue forces and strengthen evacuation capabilities. On the one hand, establish a cooperation mechanism between the street office and local non-governmental organizations in the community, including professionally capable residents' self-organized groups, socially responsible volunteers, and local enterprises that produce or store disaster relief materials into the disaster management force. On the other hand, in order to improve the efficiency and safety of the actual evacuation process, organizing residents to conduct flood disaster evacuation drills operates in favor of improving residents' familiarity with evacuation routes.

(3) Construct or remodel rainwater blocking and restoring facilities. Converting a single type of vegetation into a rain garden with multiple types of vegetation such as trees, shrubs and grass, can block and restore more rainwater. In addition, laying permeable pavement on the ground of sidewalks, parking lots and public leisure places, installing roof greening and rainwater tanks are also of great benefit.

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