Chapter

Enhancing the Community Resilience with a Network Structuring Model

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Abstract

Community resilience is a key index for describing the response of human habitat system against hazards. Enhancing the community resilience to flood disaster requires indicator identification and measurement system establishment, especially for flooding risk management. In this study, an advanced index framework for measuring community resilience to flood disaster is proposed integrating fuzzy Delphi method (FDM) and interpretative structural model (ISM). Based on the definition of community resilience, the indicators are classified into six dimensions, including environmental factors, social factors, economic factors, psychological factors, institutional factors, and information and communication factors. A simplified community resilience evaluation index system is established by using FDM, and the hierarchical network structure of the community resilience to flood disasters is confirmed, in which the direct influence indicators and the root influence indicators are analyzed. The proposed framework in this study contributes to the interdisciplinary understanding of community resilience to flooding disasters and building a more resilience community; it is also expected to be extended for risk reduction in other natural hazards.

Keywords: community resilience, flood disaster, fuzzy Delphi method, interpretative structural model

1. Introduction

Fighting with disasters is a common challenge of human beings from all parts of world since time immemorial. In recent years, hydrometeorological disasters are on the rise [1], which continues to threaten people's lives and belongings, bringing victims great misery. According to International Disaster Database, from 1990 to 2018, there were more than 4000 flood disasters with variant scales and levels around the world, resulting in great loss to people's lives and inhibiting the development of economy.

Additionally, the expansion of urban land use leads to the increase of the number of impervious areas, which would bring about poor drainage. Many flood plains have been overexploited, ending up in the damage of river courses, so rivers would be suffering more floods. Moreover, extreme weather is becoming a common phenomenon in urban districts due to a series of environmental damages, and extreme rainfall events appear frequently these years, which bring us the unpredictable devastation. In order to reduce the loss of flood disasters, many engineering and nonengineering measures have been conducted. For instance, numerous reservoirs and dykes have been constructed in China to prevent floods, and improving drainage systems in the urban area has been a common approach to ease waterlogging problem, and low impact development (LID) has become the popular concept, which serves as an easy and economical method to reduce flooding risk.

In terms of disaster risk reduction (DRR), many scholars put forward a novel concept named community resilience. This idea aims to resist disasters in a collective unit that is supposed to be regarded as a community; resilient communities are able to reduce, prevent, and cope with the flood risk [2]. Building the more resilient communities enhances our ability to defend the future disaster events and minimize the loss in the disaster events [3]. Community is the basic organizational form for social life and development of human. As the primary scene for disaster prevention and disaster relief, community serves as the primary-level organization in the process of disaster prevention and relief. The Second World Conference on Disaster Reduction of the United Nations in 2005 passed the Hyogo Declaration, which stipulated to “strengthening disaster resistance of countries and communities.” The International Conference on Disaster Reduction in Davos in 2006 also mentioned to “accelerating construction of community disaster information sharing project to increase self-rescue and mutual rescue abilities of communities.” The Sixth Asian Ministerial Conference on Disaster Risk Reduction in 2014 is themed at “construction of countries and communities with disaster resistance.” To sum up, using community as the basic unit of disaster prevention and risk reduction is widely accepted in the international society, and it is becoming a global concern.

Currently, studies on community resilience mainly focus on its connotation definition, theoretical framework, evaluation index, and assessment method. Relevant case studies involve natural disasters, epidemics, climatic activities, and similar fields. At the beginning, the simply sum of individual resilience had been conducted as the community resilience, which has resulted some reflections and doubts. Individual is the component of community; however, community resilience cannot be simply defined as the summing of individual resilience. Community resilience is a wider concept, including not only the individuals’ ability but also the external force, which refers to the speed improvement of returning to equilibrium after hazards in the community. Subsequently, connotation of community resilience was built up and perfected gradually. For example, the definition of community resilience proposed by Norris et al. covers four dimensions, including community ability, information and communication, social capitals and economic development, and dependence on resources and their dynamic attributes [4]. Morley et al. defined community resilience as “the ability of human and community to cope with, adapt to, learn and change if necessary their behaviors and social structure to reduce influences of disasters,” and the community disaster resilience scorecard (TCDRS) method has been used to recognize abilities of a community to resist disasters and extreme events [5]. Cutter et al. constructed a disaster resilience on residence level (DROR) model and proposed an index system covering six dimensions of community ability, infrastructure, institution, economy, sociology, and ecology [6]. Joerin et al. assessed community resilience of two different communities and then proposed a community resilience theoretical framework related with climatic disasters [7]. Tobin et al. disclosed influences of community resilience and community resilience to hazard risks [8].

Therefore, developing evaluation index system and framework of community resilience to flood disasters could provide the beneficial reflections and policy guidance to responses of flood disasters. This study has expanded the application of community resilience in flood disaster field; the results are expected to guide the flood disaster risk management in the community scale.

2. Definitions

2.1 Community

The concept of "community" is blurred and has been defined in various ways according to different research fields. Both a small neighborhood and a large county could serve as a community. A definition in the social sight states that "community is a group of individuals in a shared geographical area, who have common interests, are linked by dynamic socio-economic interactions, and engage in collective action," which emphasizes that community is a dynamic concept [9]. Community can also be illustrated as a multilayered notion, for instance, a community can be nested within larger communities, even overlaps can be existed between different community, and the individuals can belong to more than one community [10]. In conclusion, community is not a static entity; its flexible concept makes it apply in widely and varying study field.

2.2 Resilience

The word "resilience" is derived from the Latin word "resilientem"; it could be explained as "the ability to rebound to the original condition." Resilience was firstly appeared in the field of ecology and was regarded as "the size of a stability domain or the amount of disturbance a system could take before it shifted into an alternative configuration" [11]. This definition demonstrated that the study objects of "resilience" should be a sophisticated and integrated system but not a single entity. In the social field, resilience can be illustrated as "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change" [12], which broadens the scope of this word. However, the word "resilience" has no universally accepted definition. Through referring to heaps of literatures, a relative formal and commonly adopted explanation, in the field of hazard risk management, resilience is widely recognized as the ability of a system to respond to and recover from disasters and to absorb the impacts as well as cope with a hazard event. This explanation emphasizes the importance of the recovering process speaking of resilience, and the process can be divided into several stages.

2.3 Vulnerability

Vulnerability is another conception of disaster risk reduction, which is closely related with resilience. Many scholars have compared community resilience and community vulnerability and analyzed their differences and connections. Vulnerability reflects the likelihood of damage and can be related to the exposure and sensitivity of the system [13]. Moreover, vulnerability is the component of risk, shown as "risk = hazard × vulnerability" [14]. Resilience analysis refers to the speed of returning to the equilibrium after hazards, whereas vulnerability analysis refers to the susceptibility to hazard events on a dynamic system [15, 16]. Community vulnerability emphasizes on possibility that the community suffers direct loss from risks. In details, even if hazards in the communities are recognized, risk reduction and vulnerability often are not salient concerns until after the disaster occurs.

2.4 Community resilience

Community resilience stands for the capacity of a community to resist disasters and to take alleviating actions that are consistent with achieving the expected level of protection [12]. If a community can respond and recover from a hazard event and return to normal quickly, with good preparedness to reduce disaster losses rather than waiting for an event to occur [17], it is recognized to have a high resilience level.

Previous researches have shown that the level of resilience is affected by a series of factors. First of all, groups in the community are closely related to its resilience. Ainuddin et al. found that collective activities and reorganization ability could make a difference in enhancing the influence of resilience after disasters [18]. Mileti et al. argued that it was critical to reply on residents' action in order to mitigate the destruction from natural disaster [19]. Moreover, population structure, gender differences, educational level, income structure, and social capital are also contributed to community resilience. Norris et al. claimed that community resilience was derived from four adaptation capability, namely, economic level, social capital, information and communication, and organization ability [4]. To analyze and evaluate community resilience, Cutter et al. proposed an index system of community resilience, in which ecology, society, economy, institution, infrastructures, and community capital were included [20]. Paton et al. discussed the importance of self-efficacy, problem-focused coping, sense of community, and age, when assessing resilience to volcanic hazard [21]. Sherrib et al. reckoned that improving individuals' defensive ability to disaster is critical when enhancing community resilience [22]. Based on individuals' capability, we selected economic condition, social support, disaster event itself, social capital, and information transmission to construct a community resilience analysis model. Studies on resilience can help to improve the adaptation of the community quickly and try to reduce loss in the hazards.

3. Construction of an evaluation index system for community resilience

Community resilience evaluation requires a pre-understanding on composition of the community. Composition of a community generally can be divided into two types, which are subjective elements and objective elements. Strengthening the community resilience is actually strengthening the construction of subjective and objective elements of the community. Subjective elements include demographic structure of the community and psychological factors of community members. Objective elements include geographical environment, community infrastructure, and institutional improvement. The influencing factors of community resilience of flood disaster are summarized into six dimensions in this study, namely, environmental factors, social factors, economic factors, psychological factors, institutional factors, and information and communication factors. These six dimensions were used as the first level in the community resilience evaluation system of flood disasters and lay a foundation for refining the index layer.

3.1 Environmental factors

Environmental factors reflect the hazard-inducing environment in the study area, thus enabling to describe the intensity and scope of influence of disasters. Therefore, measuring environmental factors provide guidance to community resilience. Environmental factors of community resilience to flood hazards are mainly related with geographic features and precipitation characteristics in the study area. Hence, environmental factors are defined as hazard-inducing environment, factors leading to hazards, and underlying factors in this study. Besides, 10 indexes are selected as the level-3 indexes of environmental factors, including comprehensive daily precipitation quantity, comprehensive daily precipitation frequency, runoff capacity, relative elevation, slope, corrected river network density, vegetation coverage, land use zoning plan, proportion of waterproof surface, and influence of previous flood disasters.

3.2 Social factors

Social factors reflect the states of the study area before flood disaster, which decide the ability to bear flood disasters in the affected region. In this study, social factors are divided into demographic characteristics and physical factors. Demographic characteristics are manifested by gender, age, knowledge of hazards, escaping ability of residents, proportion of the disability, and education background. Physical factors are mainly reflected by physical structure of buildings and infrastructure construction in the community. Good condition of physical factors can effectively decrease community loss in flood disasters. A total of 18 elements were chosen as level-3 indexes of social factors, including community type, population density, age composition, gender composition, proportion of the disabled, proportion of patients with serious diseases, education background, water supply and drainage facility, power system facility, traffic network, medical insurance coverage, disaster relief facilities, household communication equipment, close to downtown, building density, proportion of high-elasticity building materials, proportion of old houses, and proportion of effective shelters. In this way, the social factor dimension of the community resilience evaluation system of flood disaster is formed.

3.3 Economic factors

Economic factors play a key role in community construction. It can be seen from historical natural disasters that regions with poorer economic development suffer more attacks and higher damages from natural disasters. Hence, community resilience cannot be constructed well without a good economic foundation. Nevertheless, many measurement indexes of economic factors are just descriptive concepts, which are difficult to be defined and quantified. For the purpose of index quantization and getting a relatively objective measurement in the economic dimension, the following four aspects were chosen as economic factor indexes in this study, which are income level, employment condition, resource condition, and public economic condition of the community. These four indexes not only reflect the mean individual economic condition of residents in a community but also measure the common assets of the community.

3.4 Psychological factors

Resilience firstly appears as a concept on individual psychology, and it is believed that individuals can gain positive outcomes through building resilience when they are facing with risks. A community is formed by clustering of population, when people in the community experience a sudden disaster, and psychological factors of residents are vital. Psychological factors include life satisfaction of residents in the community, as well as residents' relations with the community. Psychological factors reflect not only psychological condition of residents but also mutual assistance in the community. If residents in the community have good psychological state, they can support each other when they are facing with disasters, and they can gain better help after the disaster occurs, it is possible to decrease continuous loss of the community from disasters. As a result, life satisfaction of residents and the relationship between residents and community are selected as level-2 indexes that influence psychological factors of community resilience. On this basis, level-3 indexes of assessment system were refined by five indexes, including residents' satisfaction to life quality, residents' belonging to the community, engagement of welfare of the community, residents' hope to the community, and mutual support in the community.

3.5 Institutional factors

Institutional factor is a relatively macroscopic and abstract concept that reflects inputs on community disaster prevention and reduction from government administration. In this study, institutional factors that influence community resilience of flood disasters are divided into the following four indexes which are easy to be quantized: implementation disaster reduction plan, professional disaster reduction service, municipal service, and social institution service. On this basis, level-3 indexes of assessment system were refined by 10 indexes. Specifically, disaster reduction plan can be reflected by its coverage and implementation intensity; professional disaster reduction service can be measured by popularizing rates of knowledge about flood disaster, flood publicity and education, flood emergency practice, flood warning, and professional team construction (e.g., firefighters and medical staffs); municipal service is reflected by the proportion of government expenditures for disaster prevention; social institute service is reflected by administrative efficiency and cooperation efficiency in the community. Cooperation efficiency is defined as the purposeful cooperation within parties, groups, or organizations in the community. Effective cooperation may have a major influence on how well the institutes in community cope with the flash flood disaster and improve the resilience.

3.6 Information and communication factors

When facing with natural disasters, it is important to explore the ability and the efficiency for a community to accept risk information and to transfer the information to residents, which would influence the community's response to disaster prevention and reduction. Thus, information and communication is an influencing factor of community resilience which cannot be ignored. Five indexes are selected in terms of communication methods, information source, and residents' experiences in information acquisition, which belong to information and communication factors of community resilience. They are information dissemination methods, information source acquisition methods, trust of information source, information on how to cope with disasters, and information acquisition from the community.

To sum up, this study preliminarily constructed an index database to evaluate community resilience of flood disaster, which covers 26 level-2 indexes and 56 level-3 indexes from 6 dimensions, including environmental factors, social factors, economic factors, psychological factors, institutional factors, and information and communication factors.

4. Theory and methods

4.1 Fuzzy Delphi method

Fuzzy Delphi method is an improvement method of Delphi method. Delphi method, or known as export grading method, is used to collect opinions of various

Importance	Single value	Triangular fuzzy numbers
Very important	9	(7,9,9)
Important	7	(5,7,9)
Neutral	5	(3,4,7)
Less important	3	(1,3,5)
Quite less important	1	(1,1,3)

Table 1.
Triangular fuzzy numbers of importance in fuzzy Delphi method.

experts and scholars, and the organizer is held responsible to summarize these opinions. These behaviors are repeated until reaching a relatively consistent opinion. It is an experience-based judgment method. Since the traditional Delphi method was firstly developed, it is widely used in decision-making and group consensus in various areas [23]. However, Delphi method may involve uncertainties, which could be reduced by fuzzy theory [24]. Hence, FDM has been applied to combine participants' viewpoints, which can provide more objective and reasonable results [25, 26]. The procedures of FDM are introduced as follows:

1. Proposing questions, establishing the indexes in evaluation system.

2. Design and sent questionnaires. Based on the collected experts' opinions, a summary on exports' scoring results was carried out.

3. In determining the number of triangular fuzzy numbers, in order to simplify questionnaire, experts are asked to score a single value of the importance of indexes. Therefore, accordingly the triangular fuzzy numbers should be confirmed, as shown in **Table 1**.

4. Fuzzification of expert scores: the expert scores were defined by triangular fuzzy numbers; suppose that the scores of the ith expert of kth index are:

$$\omega_{ik} = (l_{ik},\ m_{ik},\ u_{ik}),\ i = 1, 2,\ \dots, m \tag{1}$$

5. Opinions of several experts were integrated into a comprehensive number describe by triangular fuzzy numbers:

$$\omega_k = (l_k,\ m_k,\ u_k),\ k = 1, 2,\ \dots, n \tag{2}$$

   where $l_k = min\,(l_{ik}),\ \ m_k = \frac{1}{m}\sum_{i=1}^{m} m_{ik},\ \ u_k = min\,(u_{ik})$

6. Defuzzification: the triangular fuzzy numbers are defuzzified through a centroid method:

$$S_k = \frac{l_k + m_k + u_k}{3} \tag{3}$$

7. Setting threshold ρ: only the indexes with $S_k \geq \rho$ are retained, and the rest are deleted. Finally, indexes with relatively higher importance are screened, and a simplified index system is established.

4.2 Interpretative structural model

Interpretative structural model (ISM) is a technology that organizes, analyzes, and determines the overall structure of a system. It searches and judges relations of elements in the system structure, by easy-to-understand forms, such as a binary relation-directed graph, a matrix, and other relatively intuitive methods; a network structural model based on complicated systems is constructed [27, 28].

Take the community resilience index (a_i), for example. Its influence degree (f_i) and being influenced degree (e_i) were calculated by Eqs. (4) and (5):

$$f_i = \sum_{j=1}^{n} t_{ij}, (i = 1, \ldots, n) \tag{4}$$

$$e_i = \sum_{j=1}^{n} t_{ji}, (i = 1, \ldots, n) \tag{5}$$

Centrality degree (m_i) and reason degree (n_i) of a_i are calculated by Eqs. (6) and (7):

$$m_i = f_i + e_i, \ (i = 1, \ldots, n) \tag{6}$$

$$n_i = f_i - e_i, \ (i = 1, \ldots, n) \tag{7}$$

Let $H = [h_{ij}]_{n \times n}$ be the overall influence matrix of the disaster resilience system:

$$\mathrm{H} = \mathrm{T} + \mathrm{I} \tag{8}$$

where the matrix I is a unit matrix.

Then, the accessibility matrix of the disaster community resilience system is $K = [k_{ij}]_{n \times n}$:

$$k_{ij} = \{1 | h_{ij} \geq \lambda\}, (i = 1, \ldots, n; j = 1, \ldots, n) \tag{9}$$

$$k_{ij} = \{0 | h_{ij} < \lambda\}, (i = 1, \ldots, n; j = 1, \ldots, n) \tag{10}$$

where the threshold λ can be set by experts or decision-makers according to practical problems. According to the preset threshold, relations with small influence degree were deleted, which can simplify the community resilience system structure of flood disasters; thus the hierarchical network structure of the system is constructed.

On this basis, accessibility set and antecedent set of influencing factors were determined. Meanwhile, whether these two sets meet the inclusion relation was judged by Eq. (11):

$$R_i = R_i \cap S_i, \ (i = 1, \ldots, n) \tag{11}$$

The above steps were repeated for every indexes of community resilience; finally, a multidimensional network system of community resilience can be constructed.

5. Case study: community resilience to flash floods

A flash flood is, in general, defined as a rapid onset of flood with a short duration and high intensity at small spatial and temporal scales [29]. The annual casualties and economic losses caused by flash floods constitute a large proportion of those caused by natural disasters and have an increasing trend [30]. Thus, flash floods are recognized as one of the most catastrophic natural disasters worldwide. The communities affected by flash floods are various, and includes different types of community; thus, community resilience to flash floods is taken as a case study in this research.

The Qingyuan district of Guangdong province in China was taken as the study area, which is a prone area of flash floods, covering approximately 19,000 km^2. The region has a subtropical monsoon climate, with warm and rainy in summer. The average annual precipitation is 1600 mm. The annual precipitation is uneven, mainly from April to July. Heavy precipitation accompanied by steep terrain leads to the frequent outbreaks of flash floods. For example, a large-scale flood occurred in Qingyuan on May 22, 2014, which affected a population of 712,500, of which 5 deaths and 1 missing persons were reported. The direct economic loss reached US $363.3 million in this flash flood event.

5.1 Data preparation

FMD has been adopted to determine the final representative indicators, and experts' judgments have been collected through a single-round survey. In order to ensure the results are more reliable, the selected experts should be in the field of flash floods; besides, in order to enhance the efficiency, the number of the experts should not be too much. Therefore, 14 selected experts were questioned, including experts in the field of flash floods and residents in flooding prone communities. These 14 respondents were asked to measure the importance of indexes that may influence community resilience of flood disasters and evaluate relative importance of each index. Six questionnaire samples with the most integral information were chosen for data processing, which were collected from two scientific research designers, one worker from the hydraulic engineering department, one worker from the hydrology unit, and two representatives of the local residents.

5.2 Results

According to FMD, maximum, minimum, and geometric mean scores from experts' response were calculated [31], and the fuzzy triangle numbers are confirmed. Setting the threshold at $\rho = 5.8$, 37 indexes of level-3 indexes were retained, as shown in **Figure 1**.

Results showed that the invited experts generally gave low scores to some indexes concerning social factors, economic factors, and psychological factors, but they generally believe that environmental factors, institutional factors, and information and communication factors are more important in the framework of community resilience to flash floods.

In order to simplify the evaluation framework, a 2-level community resilience evaluation index system of flood disasters is constructed based on the 37 indexes, as shown in **Table 2**.

Based on the simplified community resilience evaluation index system, the ISM model was applied; the centrality degree and reason degree were calculated, as shown in **Table 3**; and the hierarchical network structure of the community resilience was constructed, as shown in **Figure 2**. In this way, the community resilience system structure was established, and the direct influence indicators, the indirect influence indicators, and the root influence indicators can be identified.

Results demonstrate that all influencing indicators of community resilience to flood disasters are closely related. Specifically, flood emergency practice (a6), flood

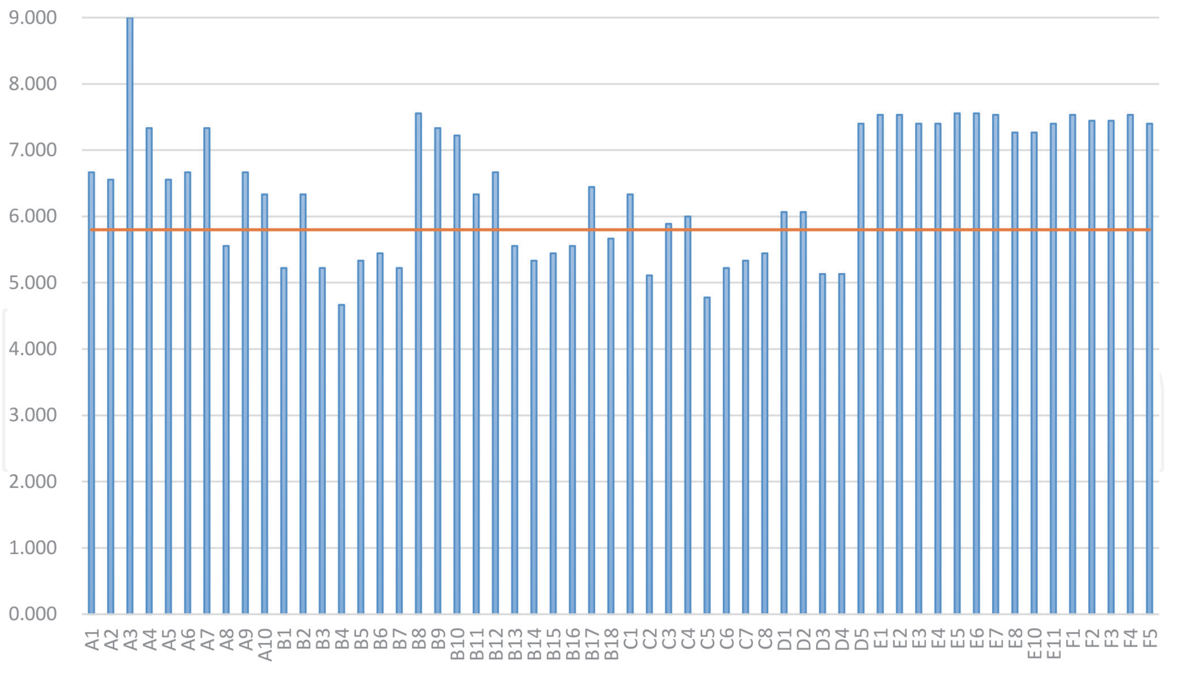

Figure 1.
Screening results of indexes based on fuzzy Delphi method (ρ = 5.8).

Objective	Level-1 index	Level-2 index	Code
Community resilience evaluation index system of flood disasters	Hazard-inducing environment	Runoff capacity	a1
	Infrastructure construction	Water supply and drainage facility	a2
	Residents' relations with the community	Mutual support in the community	a3
	Professional disaster reduction service	Popularizing rate of knowledge about flood disaster	a4
		Flood publicity and education	a5
		Flood emergency practice	a6
		Flood warning	a7
		Professional team construction	a8
	Social institute service	Cooperation efficiency in the community	a9
	Communication methods	Information dissemination methods	a10
	Information source	Information source acquisition methods	a11
		Trust of information source	a12
	Residents' experiences in information acquisition	Information on how to cope with disasters	a13
		information acquisition from the community	a14

Table 2.
Simplified community resilience evaluation index system.

Index	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	a13	a14
Xi	2.20	1.38	1.22	2.39	2.26	1.23	0.91	0.95	1.07	1.48	1.54	1.59	1.46	1.36
Yi	1.17	0.23	−0.12	−0.01	−0.04	−0.19	−0.22	−0.05	−0.66	0.51	−0.26	−0.60	−0.47	−0.22

Table 3.
Results of centrality degree (xi) and reason degree (Yi).

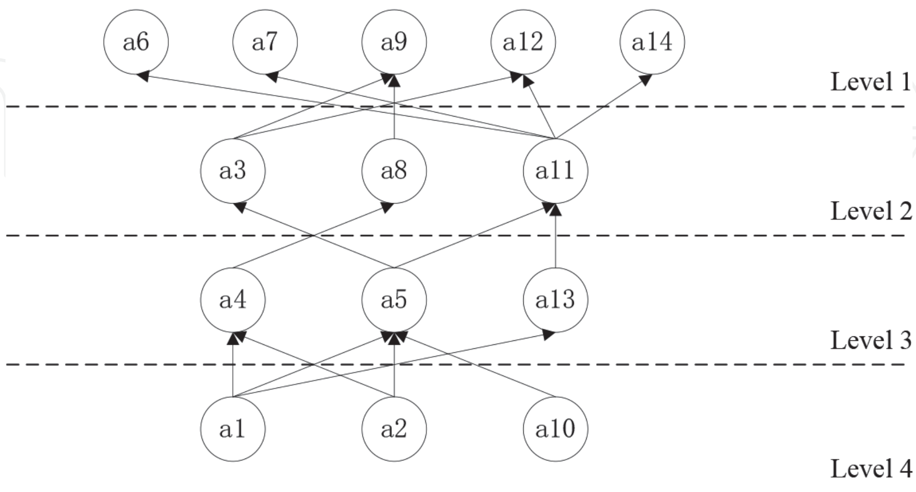

Figure 2.
Hierarchical network structure of the community resilience to flood disasters.

warning (a7), cooperation efficiency in the community (a9), trust of information source (a12), and information acquisition from the community (a14) are extracted, as shown in the first level of hierarchical network structure of community resilience, which stand for the direct influence indicators. Levels 2 and 3 are defined as the indirect influence levels, which demonstrate weak influences of community resilience to flood disasters, including mutual support in the community (a3), popularizing rate of knowledge about flood disaster (a4), flood publicity and education (a5), professional team construction (a8), information source acquisition methods (a11), and information on how to cope with disasters (a13). The lower level is defined as the root influence level, which is the most basic and objective indicator of community resilience to flood disasters, including runoff capacity (a1), water supply and drainage facility construction (a2), and information dissemination methods (a10).

5.3 Discussion

According to the direct influence indicators in the first layer, the reason degree of a6, a7, a9, a12, and a14 is negative, which indicates that the above factors are cause factors and easy to be influenced by other factors; thus the community resilience to flood disasters is determined by the cause factors directly. When a flooding event occurs, the more accurate and effective ways would be adopted to decrease the influences in flood disasters based on the cause factors. Hence, it is more scientific and effective to assess the resilience community with the indicators in the first level of hierarchical network structure.

Indicators in the last layer of hierarchical network structure belong to the root influence level, which are easy to be ignored. In this study, a1, a2, and a10 are the root influence indicators of the community resilience to flood disasters, and they would significantly influence other indicators. Details are analyzed as follows.

Runoff capacity (a1) is one of the root influence indicators, which is mainly influenced by many inspects, such as soil properties, characteristics of the water network, vegetation cover, and terrain and slope of catchment area. If a1 is higher, the rainfall is relatively difficult to be absorbed by soil, and it is easy to generate the surface runoff, thus increasing loads of the drainage network and increasing the flooding risk. Therefore, the control of runoff capacity is one of effective methods to enhance community resilience of flood disasters.

Water supply and drainage facility (a2) is another root influence indicator in the last layer, which could influence a1, a4, a5, and a6. The more perfect the water supply and drainage facility construction is, the lower value of a1 will be. This is because floods flow out of the community through the perfect drainage facilities, thus decreasing runoff generation and runoff capacity accordingly. As a result, community loss and influences caused by flood disaster are decreased, and the community resilience is improved.

Information dissemination methods (a10) occupy as a basic role in the community resilience system of flood disasters, which could influence a3, a5, a11, a12, and a14. If there are more public-oriented information dissemination channels, residents can acquire more helpful information from the community, and the community can resist flood disasters more strongly. As a result, the community resilience increases accordingly.

When studying community resilience of flood disasters, it is necessary to make systematic analysis based on hierarchical network structure of the community resilience to flood disasters. Improving the direct influencing indicators is the most intuitive method to increase community resilience of flood disasters, while improving the root influence indicators can increase community resilience of the whole system continuously, effectively and stably, it is also the difficulty faced in the flooding reduction. Besides, the specific disaster prevention strategies could be used in planning and decision-making process, for example, the resilience index of environmental dimension refers to testing the strength of public facilities and land structure that could defend water flushing and soaking, which is important to enhance the flooding prevention planning and flooding facility construction. Consequently, the research on community resilience of flood disasters based on ISM is expert to propose some specific disaster prevention strategies, to promote flood disaster prevention and control, and also to relieve negative impacts of flood disasters on life and property safety of people.

6. Conclusions

This study proposed an integrated model of resilience indicators, in which FDM was applied for resilience indicator selection; ISM was used to establish the hierarchical structure of community resilience to urban floods. This approach on community resilience assessment can be applied to a group decision-making method in flooding management and can also be employed to identify the interdependence relationships among community resilience indicators. Some major conclusions can be drawn as follows:

1. The definitions of resilience and vulnerability were demonstrated, and the community resilience to flooding disaster was defined.

2. The influencing factors of community resilience of flood disaster are summarized into six dimensions in this study, namely, environmental factors, social factors, economic factors, psychological factors, institutional factors,

and information and communication factors. And the index database to evaluate community resilience of flood disaster was constructed, which covers 26 level-2 indexes and 56 level-3 indexes.

3. The integrated model of FDM and ISM can be used to analyze the relations among various indicators that affect the community resilience to flash flooding. A four-level evaluation network was constructed by ISM. The indexes of a6, a7, a9, a12, and a14 demonstrated a substantial causality degree, which was identified as the direct cause, and were classified in the upper layers of the hierarchical structure. The second and third levels were indirect influence levels, and a1, a2, and a10 in the fourth level were identified as the root causes.

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Conflict of interest

The authors declared that they have no conflicts of interest to this work.

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