Assessing Community Disaster Reduction Capacity in Megacities Using Risk Census Data: A Case Study of Shanghai, China

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Key words: community disaster reduction capability; comprehensive risk census; TOPSIS model; Shanghai

SUMMARY

With socio-economic development, disaster risk response strategies in megacities gradually transform from emergency management to disaster mitigation. Communities constitute the essential building blocks of megacities' disaster risk prevention systems. Strengthening their disaster prevention and mitigation capacity constitutes a foundational strategy for mitigating disaster impacts. Community-level disaster reduction capacity assessments are vital for pinpointing weaknesses in local risk management and for strengthening grassroots capabilities. These assessments form a foundational strategy for enhancing disaster risk governance and advancing resilient city development. The first National Comprehensive Risk Survey of Natural Disasters in China (2020-2022) provided critical data for comprehensive assessments of community-level disaster reduction capacity. Based on natural disaster risk survey data for a district in Shanghai, we employed the TOPSIS evaluation model to calculate and classify the district's composite community disaster reduction capacity index and corresponding grades, enabling a quantitative assessment of the district's overall community disaster reduction capacity. Then, we analyzed the spatial distribution of this capacity and explored the influencing factors. Furthermore, we revealed the extent of impact—including disaster risk maps, material reserves, hazard point investigations, and the distribution of medical stations—on the composite community disaster reduction capacity. Consequently, this study assesses the community disaster reduction capacity in megacities, providing scientific support for improving disaster reduction capacity, advancing the philosophy of urban resilience, and fulfilling the Sustainable Development Goals (SDGs).

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1. Introduction

With rapid urbanization worldwide, megacities are facing more complicated disaster risks. Because of this, their strategy is moving from emergency response to disaster prevention (Cutter et al. 2013; Ma and Zhang 2022). Since communities are the building blocks of a city, keeping them prepared is the best way to protect the whole city and reduce the impact of disasters (Zubir and Amirrol 2011).

Assessing disaster reduction capacity is key to finding weak links in community risk management and strengthening local safety(Wang et al. 2022). However, due to the different definitions of capacity means, we still lack a unified model for evaluation. This makes it difficult to conduct large-scale studies or compare results across different communities (Hu et al. 2013). Since 2008, China began building “National Disaster Reduction Demonstration Communities” (Cao 2018). This helped create a foundation for evaluating community safety standards (Zhang et al. 2013; Zhou and Zhang 2013).

Between 2020 and 2022, the country conducted the first National Natural Disaster Risk Census. A key part of this census was assessing community (county) disaster reduction capacity(Wang 2021). Since its standards are consistent with the earlier ones, the census provided a wealth of community-level data. This has created a rare chance for further research.
Based on this data, some experts are now comparing evaluation methods and studying risk zoning (Ding et al. 2024a, b).

Our study is based on the natural disaster risk census of a district in Shanghai. We evaluate the disaster reduction capacity of local communities and explore the factors that affect it, providing a scientific basis for improving safety in big cities and helping to achieve the Sustainable Development Goals (SDGs).

2. Study area

Our study area, located in central Shanghai, represents a typical high-density built-up urban district. Featuring the characteristic economic structure and population agglomeration of megacity central areas, it serves as a representative case for examining urban disaster prevention and mitigation capacity.

3. Methods

The *Technical Specification for Disaster Coping Capability Assessment at Township and Community Levels* (FXPC/YJ P-15, hereafter referred to as the *Specification*) defines community disaster coping capability as the various skills and resources that a community (or administrative village) has for managing disasters, preparing for them, and aiding in self-rescue and mutual support. Based on this definition, an evaluation indicator system is developed. The Specification uses the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to create the evaluation model and applies the mean-standard deviation method to classify the levels of disaster coping capability.

3.1 Calculating community disaster reduction capacity

The evaluation system for community disaster reduction capacity has two levels. The overall Disaster Reduction Capacity (DRC) is made up of three first-level indicators and nine second-level indicators. These first-level indicators are Disaster Management Capability (DMC), Disaster Preparedness Capability (DPC), and Self and Mutual Aid (SMA) (Table 1).

Table 1. Indicators and Calculation Methods for Community Disaster Reduction Capacity

Primary Indicator (Weight)	Secondary Indicator (Weight)	Specific Indicator	Calculation Method
1 DMC (0.4)	1-1 Emergency Planning (0.1)	Presence of community disaster emergency plans	Yes = 1, No = 0
	1-2 Hazard Identification (0.1)	Presence of lists for vulnerable groups and hazards	Both = 1; Only one = 0.5; None = 0
	1-3 Risk Assessment (0.1)	Presence of disaster risk maps	Yes = 1, No = 0
	1-4 Financial Support (0.1)	Funding per 10,000 people	(Disaster reduction funds / Total population) × 10,000
2 DPC (0.3)	2-1 Resource Stockpile (0.18)	Value of supplies per 10,000 people	(Total value of stored supplies / Total population) × 10,000
	2-2 Medical Reserves (0.12)	Medical facilities per 10,000 people	(Number of medical facilities / Total population) × 10,000
3 SMA (0.3)	3-1 Rescue Team Strength (0.1)	Reservists and volunteers per 10,000 people	(Number of reservists + volunteers) / Total population × 10,000
	3-2 Public Risk	Percentage of residents	(Total participants in drills

	Awareness (0.1)	participating in drills/training (%)	and training / Total population) × 100
	3-3 Evacuation Capacity (0.1)	Emergency shelter capacity rate	Total shelter capacity / Total population

We calculate the scores based on each indicator's weight, specific content, and scoring method (Table 1). After that, we normalise the values for each indicator. This step removes the influence of different measurement units, making sure all indicators can be fairly compared. A higher normalised value means a stronger capability in that area.

3.2 Building the Evaluation Model

We use the TOPSIS method, which is the standard used in disaster risk censuses (Cheng et al. 2023; Ding et al. 2024b). This method makes full use of original data and has no limits on data distribution or the number of indicators. It is especially good for ranking and comparing different subjects within a study. In this research, we use the highest and lowest values of each indicator to create the best and worst scenarios. We then calculate how close each community is to these scenarios to determine its disaster reduction capacity (C_{DRC}). The CDRC score ranges from 0 to 1; a higher score means the community has a stronger capacity to handle disasters.

4. Results and Discussion

4.1 Analysis of the Community Disaster Reduction Capacity Index

Based on Section 3.1, we calculated the normalized values for the nine secondary indicators and performed a K-W test with Bonferroni correction (Figure 1). We found that Emergency Planning (1-1), Hazard Identification (1-2), Rescue Team Strength (3-1), and Public Risk Awareness (3-2) had the highest scores. There were no significant differences among these four indicators. However, the scores for Risk Assessment (1-3), Resource Stockpile (2-1), Medical Reserves(2-2), and Evacuation Capacity (3-3) were relatively low. Finally, Financial Support (1-4) had the lowest score of all the indicators.

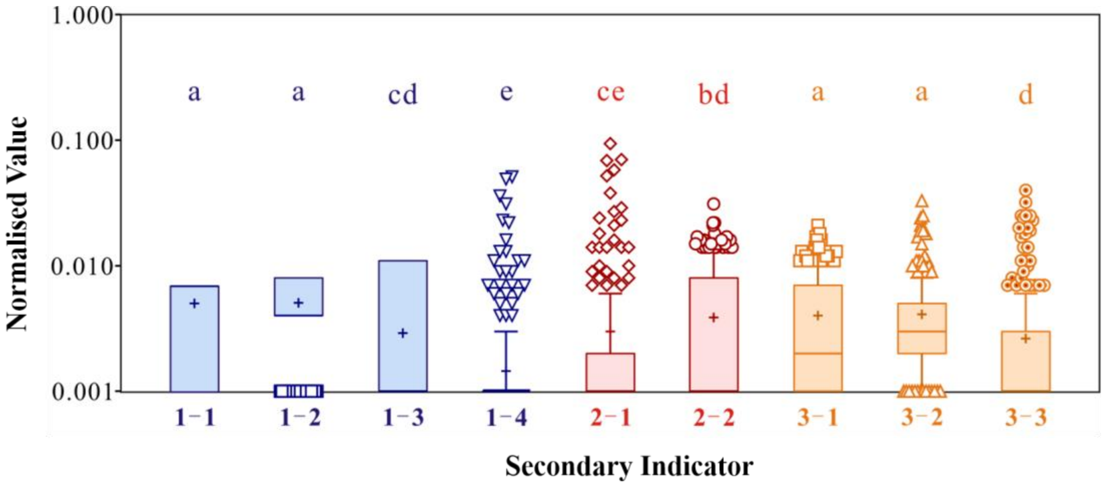

Figure 1 Distribution of Normalized Values for Secondary Indicators

We obtained index values for the three primary indicators and the C_{DRC} for all communities (Figure 2). There are significant differences between the averages of the three indicators ($P<0.01$). DMC scored the highest (0.160), SMA was next (0.126), and DPC was the lowest (0.061). These results show that communities are strongest in management, followed by self-rescue, but they are relatively weak in preparedness

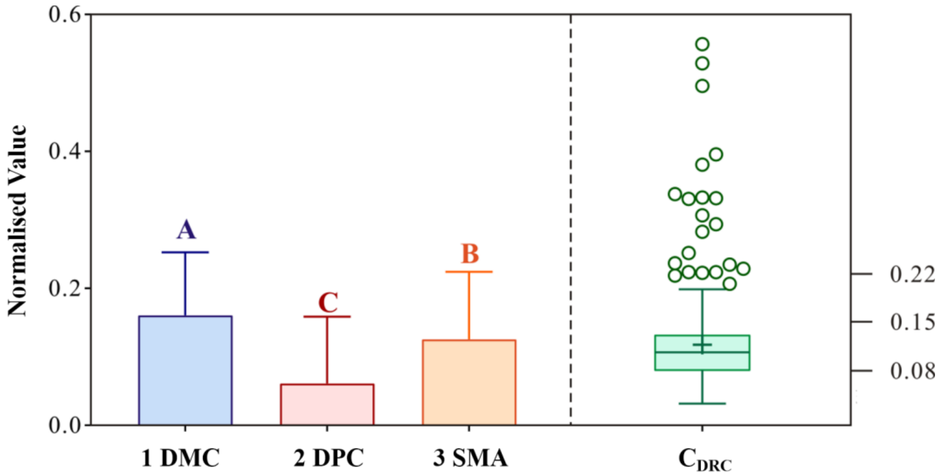

Figure 2 Distribution of mean values for primary indicators and the C_{DRC} index

4.2 Evaluating Community Disaster Reduction Capacity

The community C_{DRC} scores range from 0.032 to 0.557, with an average of 0.118 ± 0.069. Using 0.22, 0.15, and 0.08 as cutoff points, we divided the communities into four levels: strong, relative strong, moderate and weak (Figures 2 and 4a).

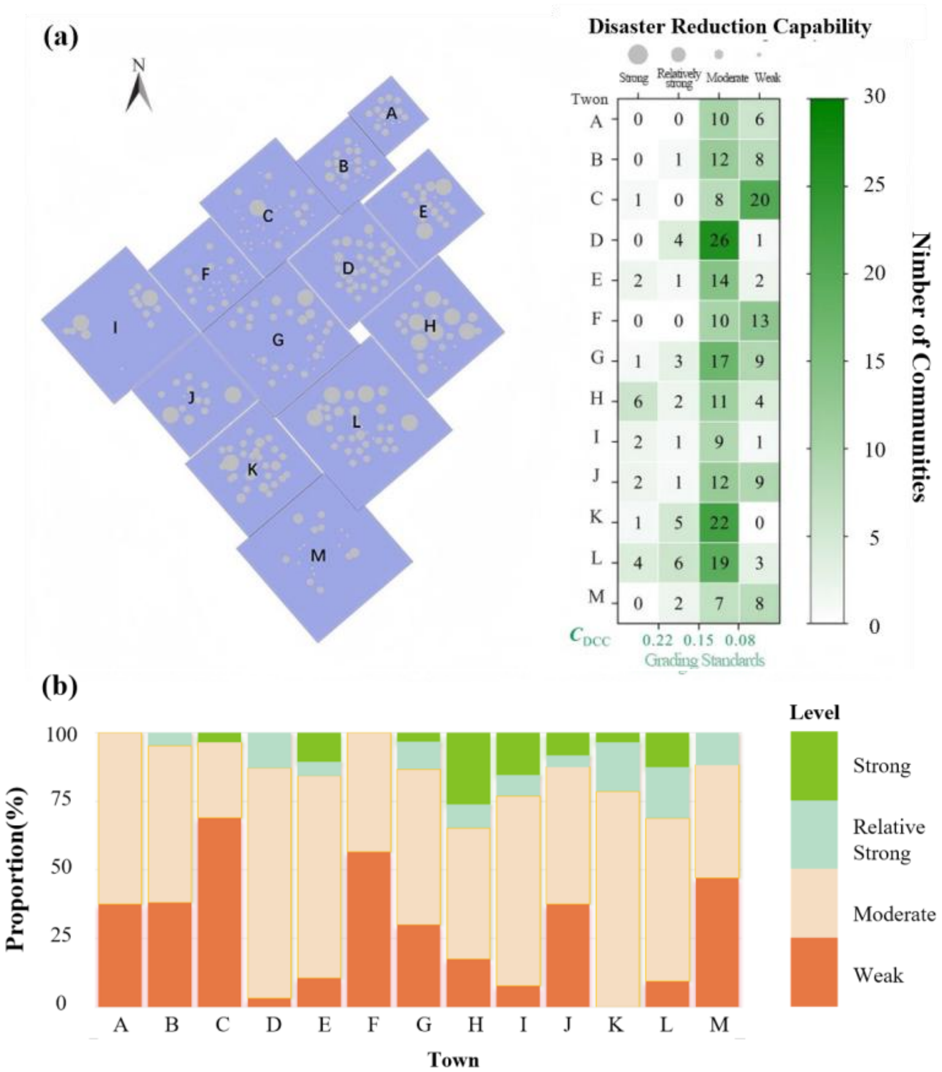

Figure 4. Levels of community disaster reduction capacity (Note: This map has been reshaped to show the relative sizes of the towns.)

Overall, the disaster reduction capacity in the study area is weak. Most communities (57.8%) are at a moderate level. The communities at a weak level are the next largest group at 27.5%, and they are mostly located in the two towns. The strong and relative strong communities are less common, making up only 6.2% and 8.5%, respectively.

Disaster reduction capacity varies between different towns and even among communities within the same town. This assessment helps quickly identify weak areas (Figure 4b), providing a basis for better resource allocation. These differences may be linked to factors such as community type, building age, population density, and emergency resource allocation.

4.3 Factors Affecting Community Disaster Reduction Capacity

Further, we use factor analysis and the CHAID decision tree model to identify the main factors driving community capacity. We also analyze how these factors influence different capacity levels (Figure 5). The decision tree has three levels, and four nodes passed the significance test ($P < 0.05$), showing the key factors and how they interact. We divided the communities into six groups. The result show that those with both disaster risk maps and material reserves are the strongest. In contrast, communities without disaster risk maps, hazard point investigations, or medical stations are the weakest, with 62% of them rated at a weak level.

Having a disaster risk map is the most important factor for community capacity. Among communities with disaster risk maps, 27.2% are at strong or relative strong level, which is approximately twice the proportion of the full sample (14.7%), and none are at weak level. In contrast, among communities without disaster risk maps, only 10.2% reach the level of strong or relatively strong, which is significantly lower than the overall sample proportion, and all communities rated as relatively weak level fall into this category.

Collaborating with disaster management departments and receiving government funding is an effective way to improve community capacity. Risk Assessment Capacity represents the combined effort of both the government and the communities. Similarly, Resource Stockpile Capacity relates to government funding (PC3), while Hazard Identification Capacity reflects work done by communities independently (PC1). We found there are 45.8% of communities with both disaster risk maps and material reserve are rated as strong or relative strong level, making this the strongest group overall.

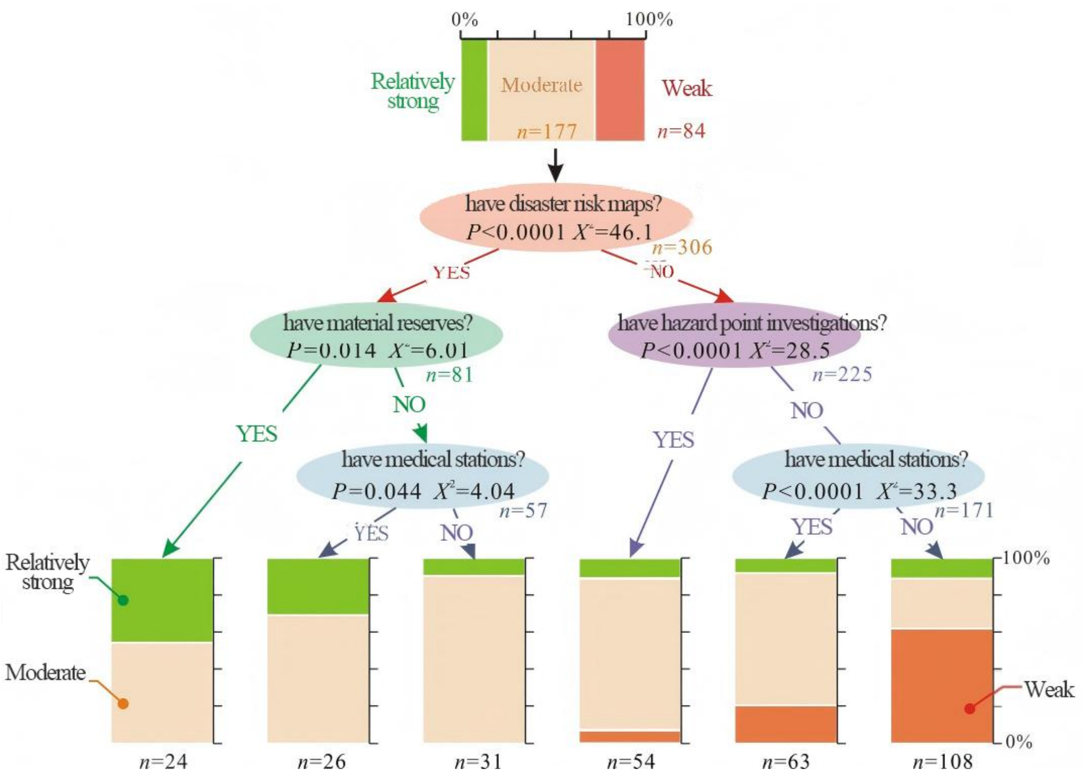

Figure 5 Decision tree analysis of factors affecting community capacity levels

Table 2. Principal Component Matrix of Secondary Indicator

Secondary Indicator	Component 1	Component 2	Component 3	Component 4
1-1 Emergency Planning		0.698		
1-2 Hazard Identification	0.735			
1-3 Risk Assessment		0.770		
1-4 Financial Support			0.757	
2-1 Resource Stockpile			0.705	
2-2 Medical Reserves				0.859
3-1 Rescue Team Strength	0.740			
3-2 Public Risk Awareness	0.677			
3-3 Evacuation Capacity		0.531		

For communities that do not work with disaster management departments, doing what they can on their own provides a safety net. Checking for local hazards is a key indicator that a community is taking independent action. For example, there are only 7.4% of communities with hazard point investigations and no disaster risk maps are at a weak level, which is much lower than the overall average. In contrast, among communities without disaster risk maps and without hazard inventory inspections, 46.8% are rated as relatively weak level.

5. Conclusion

Based on the first national survey on natural disaster risks in China, this study evaluated community disaster reduction capacity in a district of Shanghai. We used the index system from the Technical Specification for Assessment of Disaster Reduction Capacity (FXPC/YJ P-15) to calculate scores and levels. Further, we explored the key factors affecting safety in megacities. The results show that CDRC scores range from 0.032 to 0.557. Among the primary indicators, DMC scored the highest, followed by SMA and then DPC. For specific indicators, Emergency Planning and Hazard Identification had the highest scores, while Financial Support and Resource Stockpile scored the lowest. Developing disaster risk maps is the most important factor for community safety in megacities. Communities with both disaster risk maps and material reserves perform the best. The work that communities do independently sets the bottom line for their safety level, and characterizing for local hazards is a key part of this. Additionally, encouraging cooperation between the government and communities and increasing funding are the most effective ways to improve disaster safety.

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