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Literature Review on Suitability Evaluation and Shelter Design of Existing Buildings as Disaster Prevention Shelters

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Abstract

With the increasing frequency of natural disasters worldwide, the planning and construction of emergency shelters have become critical components of urban disaster prevention and mitigation. Existing buildings repurposed as disaster prevention shelters have gradually attracted academic attention due to their economic efficiency, timeliness, and resource conservation advantages. This paper systematically reviews the research progress on suitability evaluation and design optimization of emergency shelters both domestically and internationally, focusing on four dimensions: shelter construction practices, suitability evaluation indicator systems, evaluation methods, and shelter design optimization. The review reveals that existing evaluation indicators primarily emphasize safety, accessibility, and service capacity, while evaluation methods mainly employ GIS spatial analysis, Analytic Hierarchy Process (AHP), entropy method, and their combinations. Design studies predominantly target outdoor open spaces, whereas systematic research on indoor shelter conversion of existing buildings remains relatively weak, and a comprehensive evaluation and design framework covering building performance, facility adaptability, and spatial conversion has yet to be established. Finally, this paper identifies the selection of suitability evaluation indicators for existing buildings as shelters, the integration of subjective and objective weighting methods, and the formulation of indoor shelter design guidelines as key future research directions, aiming to provide references for further studies in this field.

Keywords

Existing buildings; Disaster prevention shelters; Suitability evaluation; Shelter design; Literature review.

1. Introduction

The frequent occurrence of natural disasters poses severe challenges to urban emergency shelter systems. Traditional shelters predominantly rely on open spaces such as parks and plazas, which are vulnerable to extreme weather during medium- and long-term post-disaster accommodation, and often fail to meet basic needs for medical care, material storage, and privacy protection. Existing buildings (e.g., schools, gymnasiums, office buildings, hotels, etc.), with their enclosed spaces and well-equipped facilities, have the potential to be converted into indoor shelters, offering an effective means to compensate for the shortcomings of open-area shelters. However, how to scientifically evaluate the suitability of existing buildings as shelters and carry out targeted shelter design remains a critical issue to be addressed.

In recent years, scholars worldwide have conducted extensive research on the siting, evaluation, and design of emergency shelters, but most results focus on outdoor spaces, while systematic studies on indoor conversion of existing buildings are still in their infancy. By reviewing relevant domestic and international literature, this paper summarizes the state of the art from four perspectives—construction practices, evaluation indicators, evaluation methods, and

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design optimization—analyzes the contributions and limitations of existing studies, and points out future research directions, thereby providing theoretical support for in-depth investigation of existing buildings as disaster prevention shelters.

2. International Research Status

2.1. Disaster Prevention Shelter Construction Practices

Developed countries such as Japan and the United States have accumulated rich experience in the construction of disaster prevention shelters. Japan, as an earthquake-prone country, has conducted surveys of existing spaces, selected suitable candidates for shelter use, and strengthened them through seismic retrofitting and functional upgrades to meet standards for protection, earthquake resistance, fire prevention, and material storage. Emergency shelters are commonly established in urban planning, complemented by diverse disaster prevention signage (Tang, 2009)[1]. Particularly noteworthy is that Japanese primary and secondary schools are designated as "primary shelters," with seismic design standards far exceeding those for ordinary civilian buildings (Li et al., 2015)[2]. The United States has built a diversified system of disaster prevention shelter facilities to cope with hurricanes, blizzards, earthquakes, and other extreme meteorological and geological events, while also implementing large-scale civil protection programs and developing multi-purpose protective projects that can be readily converted into temporary shelter spaces during disasters (Yang et al., 2004)[3]. A typical example is the emergency activation of the Louisiana Superdome in New Orleans as a shelter during Hurricane Katrina (Zhao, 2010)[4]. These practices demonstrate that fully utilizing existing public buildings as shelters has become an international consensus.

2.2. Suitability Evaluation Indicator Systems

In terms of indicator selection, international scholars have constructed comprehensive frameworks from multiple dimensions. Joo et[5] (2025), for nuclear accident shelters, selected twelve evaluation factors—including distance to incident point, indoor protection factor, per capita shelter area, road capacity, and medical care conditions—from aspects of safety protection, survival security, accessibility, and operational management. Tang et al.[6](2025) incorporated indicators such as distance to open spaces, distance to hazards, distance to arterial roads, population density, slope, effective shelter area, and land use type, based on locational conditions, safety, and site attributes. Anhorn and Khazai[7](2015), for post-earthquake open-space shelter suitability, combined seismic hazard characteristics with spatial attributes and included site safety, accessibility, capacity, and infrastructure conditions. Chen et al.[8] (2020) combined POI data and evacuation simulation, categorizing evaluation indicators into shelter supply capacity and evacuation process efficiency. Ye et al.[9](2010), using 3S technology, evaluated urban green parks for earthquake disaster prevention and refuge, selecting key indicators such as topography and traffic accessibility. Overall, safety, accessibility, capacity, and infrastructure have become universally recognized core evaluation dimensions.

2.3. Suitability Evaluation Methods

Regarding evaluation methods, GIS spatial analysis has been widely employed in shelter site selection and suitability assessment (Kar & Hodgson[10], 2008; Akamatsu & Yamamoto[11], 2019). Nyimbili and Erden[12] (2020) proposed a hybrid approach integrating Entropy-AHP and GIS, which combines subjective and objective weighting to enhance evaluation reliability. Su et al.[13] (2021) adopted the variable two-step floating catchment area method to measure potential spatial accessibility of urban emergency shelters. Zhou et al.[14] (2025) employed a Bayesian network model incorporating population evacuation, safety, and spatial connectivity. Li[15](2013) conducted a GIS-based suitability analysis of green parks in Xiamen for

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earthquake disaster prevention. These methods balance spatial analysis depth and subjective decision-making, providing methodological support for building evaluation models.

2.4. Shelter Design Optimization

In shelter design, Faturechi[16] (2016) proposed a risk-based mathematical model for internal evacuation and shelter design, covering shelter area layout, exit location, passage capacity, and pedestrian flow efficiency. Mounaim[17](2020), focusing on functional practicality and environmental adaptability, offered design solutions for structural type selection, spatial layout, natural ventilation, and lighting. Al-Shoubaki[18] (2024) emphasized user social culture and living experience, stressing human-centered design elements such as spatial privacy, family unit layout, thermal performance, and community shared spaces. Rahmayati and Altassan[19] (2025) systematically reviewed climate-resilient design strategies—including structural elevation, flood-resistant materials, vertical evacuation, and multifunctional integration—for flood emergency shelters. Although these studies touch upon indoor design, they mainly target new temporary shelters, with limited research on functional conversion of existing buildings.

3. Domestic Research Status

3.1. Shelter Construction Development in China

Since the establishment of China's first emergency shelter—the Beijing Yuan Dadu Ruins Park—in 2003 (Luo et al., 2016)[20], various regions have continuously built new shelters based on existing public infrastructure, primarily relying on parks and plazas. Shelters played an effective role in temporary accommodation and material support during major disasters such as the Wenchuan earthquake and the Henan rainstorm. However, current shelters are still predominantly outdoor open spaces, and the development and utilization of existing buildings as shelter resources remain severely insufficient, making it difficult to meet medium- and long-term accommodation needs (Ma, 2019)[21].

3.2. Suitability Evaluation Indicator Systems

Domestic scholars have produced rich results in indicator selection. Zhou[22](2024) established a comprehensive framework covering "safety, accessibility, service capacity, and spatial matching." Li[23](2018) constructed an evaluation system comprising fourteen elements across five dimensions, including safety and accessibility. Liu[24] (2017) developed an indicator system with five elements—shelter population capacity, distance to nearest road, etc.—based on effectiveness and accessibility, using entropy weighting and grey relational analysis. Shi[25] (2016) established nine indicators from three perspectives: effectiveness, accessibility, and safety. Li[26] (2018) integrated six basic factors including urban population density and service area of fixed emergency shelters. It is evident that safety, accessibility, and effectiveness have become core dimensions in domestic studies, but indicators specifically addressing existing building performance (e.g., structural seismic grade, equipment aging) are still insufficient.

3.3. Suitability Evaluation Methods

Domestic research methods exhibit diversified features. Chu[27](2014) constructed an integrated model of "site evaluation-layout optimization-responsibility zone division" combined with a GIS decision support system. Wang[28] (2023), Li[29] (2023), and Ji[30](2023) all adopted entropy weighting combined with GIS spatial analysis for suitability quantification. You[31](2024) applied an AHP-EWM coupled model to build a "space-resource-management" multi-dimensional evaluation system. Zheng[32] (2025) evaluated the distribution suitability of earthquake emergency shelters in Kuiwen District using GIS, entropy method, and AHP.

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These methods are largely suitable for regional-scale outdoor site assessment, yet there remains room for adaptation to the comprehensive evaluation of individual buildings.

3.4. Shelter Design Optimization

Domestic design optimization studies primarily focus on outdoor shelters. Lu[33](2022) proposed a "functional composite" design to achieve peacetime-disaster integration. Jin[34](2023) optimized community walking evacuation networks and temporary nodes. Lu[35](2023) proposed design solutions using vacant plots in ancient urban areas. Zhang[36](2024) focused on park green spaces and proposed an emergency facility supplementation list. Zou[37](2025) used simulation technology to optimize accessibility and emergency signage in old communities. Current design studies rarely address internal functional zoning, equipment conversion, and indoor evacuation design for existing buildings, indicating a clear research gap in indoor shelter design.

4. Critical Review and Future Directions

4.1. Contributions of Existing Research

Overall, existing studies have made significant progress in the following aspects: (1) The indicator system has gradually expanded from a single focus on safety to multi-dimensional aspects including accessibility, service capacity, and emergency management. (2) Evaluation methods show a trend of integration—combinations of AHP, entropy method, fuzzy comprehensive evaluation, and GIS spatial analysis balance subjective judgment and objective data characteristics. (3) Practical applications are abundant; most studies are grounded in specific urban contexts and provide scientific support for local shelter planning. (4) Design optimization has extended from physical space to functional facilities, evacuation connectivity, and other levels.

4.2. Limitations of Existing Research

Despite the notable achievements, the following gaps remain: First, the evaluation objects are predominantly outdoor open spaces; studies on the suitability of existing buildings (schools, hotels, office buildings, etc.) are extremely scarce, and there is a lack of dedicated indicator systems covering structural safety, facility integrity, and spatial conversion feasibility. Second, evaluation methods are mostly tailored to macro-regional layout and are not well adapted to fine-grained assessment of individual buildings; how to effectively combine subjective/objective weighting with building performance inspection data remains underexplored. Third, shelter design studies are almost exclusively oriented toward outdoor spaces or new temporary facilities; systematic achievements in indoor shelter design for existing buildings are rare, especially in terms of functional zoning, vertical evacuation, emergency equipment conversion, and accessibility design. Fourth, there is a missing link from "evaluation" to "design"—an integrated chain of "suitability classification → identification of renovation shortcomings → shelter design response" has not yet been established.

4.3. Future Research Directions

Based on the above review, future research should prioritize the following areas: (1) Construct a dedicated suitability evaluation indicator system for existing buildings as shelters, integrating building safety (structural seismic performance, fire protection), evacuation smoothness (exit width, vertical evacuation efficiency), and municipal facility completeness (water supply, drainage, power, communication). (2) Explore combined weighting methods suitable for single-building assessment, integrating AHP's subjective orientation with entropy method's objective correction, and incorporate field inspection data to enhance evaluation reliability. (3) Carry out systematic research on indoor shelter design for existing buildings, clarifying layout

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principles for accommodation, medical points, material storage, and other functional zones, and solving key design issues such as accessible passages, emergency lighting, and way-finding signage. (4) Establish a full-process technical framework of "suitability evaluation → renovation priority ranking → shelter design response," and validate its feasibility and replicability through typical case studies, thereby providing practical guidance for efficient utilization of existing stock resources in urban disaster prevention and mitigation.

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