Abstract: Seismic hazards, being the main natural disaster in cities, severely damages urban space. In addition, the current pandemic, as well as the concept of the community-life loop, necessitate a shift in urban space management to a more detailed and systematic assessment. From the perspective of community-life circles, this study assesses the evacuation capacity of open areas in Tianjin during earthquake disasters. It also considers the importance of open spaces for isolation and protection in major public health emergencies. Firstly, spatial analysis is done to locate open spaces that may be used for evacuation and to build urban community-life circles. Second, the open space evacuation capacity is computed, and the characteristics of the community-life circles are categorised and assessed as a unit. Finally, community-life rings are chosen depending on isolation and protection requirements. As a result, the evacuation map of community-life circles may be shown. The spatial properties of community-life circles are summarised in the fourth section. The findings show that open spaces located within the community with easy access to transportation and near the river system can better meet disaster prevention and evacuation requirements, whereas the closer the open spaces are to commercial facilities, the more difficult it is to meet the requirements.

Keywords: community-life circle; emergency evacuation; spatial analysis of isolation and protection; evacuation characteristics of open space; spatial characteristics of community-life circles

1. Introduction

Open spaces have an essential role in earthquake and pandemic prevention, among other things, as an integral component of comprehensive urban disaster prevention. Since 2000, earthquake disaster deaths have accounted for over 70% of all deaths from all natural disasters worldwide, with China accounting for more than half of all earthquake-related deaths. Seismic dangers not only endanger people’s lives, but they also cause major disruptions in metropolitan areas. The novel coronavirus that is currently sweeping the globe has resulted in substantial human and property losses, as well as a lot of thought about urban open space planning. China’s first specific proposal to establish community-life circles was made in 2018, with a hierarchy of “15-minute, 5-10-minute” community-life circles and the creation of a community evaluation system.
This paper determines the carrying capacity of evacuation sites by studying the location of evacuation sites and escape routes in the event of disasters to evaluate the evacuation capacity of open spaces during earthquake disasters in six districts within Tianjin from the perspective of community-life circles. Then, based on the isolation and protection ability under major public health crises, it screens community-life circles and builds an evaluation system for community-life circles in Tianjin.

For emergency shelters, specific criteria must be met in terms of siting principles and design methodologies. Almeida et al., studied the site selection for temporary shelters through a multi-objective planning model (Alcada-Almeida et al., 2009), Saadatseresht et al., studied the problem of staff allocation in shelter planning using a multi-objective evolutionary algorithm (Saadatseresht et al., 2009), Wu et al., optimised the number of required shelters, site selection, and service areas in cities through a multi-objective planning model (Jianhong & Wenguo, 2011). In this paper, open spaces that meet evacuation requirements, and isolation and protection requirements are screened by combining the relevant codes for emergency shelters in China.

The escape route during a disaster is the passage through which people escape and eventually reach the destination evacuation point, which has both spatial and social attributes. Korhonen. T.’s agent model (Korhonen et al., 2008) and Wood. N.J.’s minimum cost distance model, among others, plan suitable evacuation routes and calculate evacuation time and cost (Wood & Schmidtlein, 2012). Manley et al., simulated the process of evacuation and escape of vulnerable groups during a disaster (Manley & Kim, 2012). Zhou et al., proposed a network optimisation model and planned a general route for evacuation. In this paper, we consider both the spatial property conditions of alternative paths and the influence of the domain and privacy of closed communities on people’s psychological conditions and personal preferences to develop more scientific escape routes when studying the evacuation value of open spaces.

The carrying capacity of a refuge site is the ability to provide residents with the ability to conduct shelter, evacuation, and rescue. Zhu et al., calculated the carrying capacity of park green space based on the current situation of park green space and population distribution in Zhengzhou City (Zhenxing & Lijuan, 2011), and Zhang Haibo et al., calculated the medium- and long-term carrying capacity of emergency shelter places in Nanjing City by establishing a carrying capacity evaluation model (Haibo et al., 2019). From the perspective of population carrying capacity, we focus on the accommodative demand of open spaces and calculate the carrying capacity of open spaces inside and outside the community by constructing an open space evacuation value assessment system.

The isolation and protection value of open space means the role of open space emergency isolation and protection from viruses in the event of a major public health event. In the siting perspective of open space, Cai et al., constructed a model for siting disaster prevention and avoidance green spaces from an epidemic prevention perspective, incorporating three aspects of health and epidemic prevention needs (Yiran & Xi, 2020); In the management perspective of open space, Sun Li et al., construct a community public space resilience evaluation index system oriented to emergency management (LI & Yue, 2020); Wang Shifu et al., suggest incorporating health impact assessment in the whole planning process, taking into account the epidemic prevention measures of various countries in the COVID-19 (Shifu et al., 2021).

Based on the principles of personnel allocation and shortest evacuation distance, this study synthesizes existing research results and uses the six districts of Tianjin as the research object to calculate the evacuation capacity of open space by calculating the accessibility and carrying capacity of open space. The idea of community-life circles has been included. By integrating the impact of the New Crown pandemic on the community, the community-life circles that fulfil the requirements of evacuation and isolation protection are filtered out, and proposals are provided for the future building of life circles and open spaces.

2. Construction of urban open space based on community-life circles

2.1 Delineation of community-life circles

The research object is a densely populated city, and the analysis region is Tianjin’s centre city, which has a total size of 181.12 square kilometers.
The first step was to split the community-life rings in Tianjin’s six inner districts. According to Google Earth, the road network data is crawled to map the boundaries of residential communities and open spaces, of which there are 1851 residential communities and 1838 open spaces. POI data was obtained using Baidu Map to collect existing public facility point data. To build a network dataset and assess the 15-minute service area range of commercial, primary school, medical, and open spaces, the road data were defined with attributes and allocated to pedestrian speed. The preliminary living circle range is then calculated by superimposing the service area range. Finally, limiting elements such as rivers, roads, and railways are eliminated, and the population number and density data are checked for accuracy using the life circle. Tianjin is divided into six districts, each of which is divided into 90 15-minute community-life circles.

![Figure 1. Division of community-life circle. a) Public facilities in six districts of Tianjin. b) Community-life circles of six districts in Tianjin (Source: Self-painted by the author)](image)

2.2 Screening of open spaces
In this paper, ‘open space’ refers to the open space that exists outside of the constructed environment in the built-up region of the city, and includes both natural and artificial places such as parks and green areas within the urban area. The open spaces within existing community-life circles are screened using Chinese emergency shelter selection criteria in this study (Construction standard of community emergency shelters, JB180-2017).

1. Total open space area more than 1000m2.
2. The selected open space is not a disaster area.
3. The slope of the open space shall be no greater than 7°.
4. There is a roadway within the open space that is greater than 12m in width.
5. The shortest distance between the open space and the surrounding building should not be less than the height of that building.
6. Gas stations, gas facilities, and hazardous chemical enterprises should not be located within 1km of each other.

A total of 1295 open spaces eligible for emergency sheltering were screened for the study.
3. Construction of a system for assessing the value of disaster prevention and risk avoidance

3.1 Method of evacuation value assessment

In this section, the evacuation capacity of open spaces in six Tianjin districts are calculated, as well as the evacuation accessibility of open spaces and the carrying capacity of accessible open spaces within 90 seconds, in order to obtain open spaces that meet the requirements for both accessibility and carrying capacity. The following are the specific steps:

1) The community and open space scopes were both imported at the same time to separate communities with and without open space, as well as open space within and outside the community.

2) To find the open space outside the community that the community without open space can reach in 90 seconds, it shows that only 45.4 percent of the community without open space can successfully escape.

3) The results of the two calculations were combined to determine the amount of open space that could be reached in 90 seconds in each of the city’s six districts, as well as the number of people that the accessible open space could accommodate by overlaying all of the open space with the community’s connectivity.

Figure 2. Evacuation value evaluation of open space. a) Bearing capacity of open space. b) Open space meeting evacuation requirements (Source: Self-painted by the author)

Calculating the carrying capacity of the accessible open space \( B \) requires calculating the number of evacuees each open space needs to carry \( P \) and the number of evacuees it can carry \( C \).

Firstly, we view the number of open spaces \( w \) that can be reached in 90 seconds in a community, and then allocate the total population \( p \) of the community to the open spaces that can be reached in proportion to the area \( S \). So, the number of evacuated population \( p' \) of the community that needs to be covered by the open space is obtained. If the open space has only one community’s evacuation population to bear, then \( p' \) is the total number of evacuation population \( P \) that the open space needs to bear; if the open space needs to bear more than one community’s evacuation population, then we need to check the number of communities \( m \) that can reach the open space and add up the number of people that can be reached by each community to get the total number of people \( P \) that each open space needs to bear. The total number of people \( P \) in each open space.

\[
pi' = p' - S / i
\]

\[
P = I'
\]
A review of the code shows that the area per person for disaster prevention and shelter is 2 m², which gives the number of people (C) that each open space can take.

\[ C = \frac{S}{2} \]

Calculating the ratio of the number of people that the open space needs to carry (P) to the number of people that it can carry (C) gives the carrying capacity of each open space (B).

\[ B = \frac{P}{C} \]

The calculated carrying capacity index (B) is classified with a cut-off of 1. Open spaces with \( B > 1 \) are those that have the capacity to carry the evacuated population of the surrounding community, and vice versa for \( B < 1 \).

3.2 Method of isolation protection value assessment

The following steps will be taken in this section: calculate the isolation and protection capacity of open spaces that meet evacuation requirements, and obtain community-life circles that meet both evacuation, and isolation and protection requirements, and screen out life circles that do not meet disaster protection requirements.

1) At least two emergency evacuation and shelter areas should be provided in the life circle, according to the Technical Guidelines for Community Life Circle Planning, resulting in community-life circles that meet evacuation standards within each district.

2) Because many communities are being segregated as a result of the present pandemic, the next study will look into whether these living circles can meet the needs for isolation and protection. For the isolation and protection function, 363 open areas in the neighborhood were screened as study items. Then, using an OD cost matrix, compute the open places that can be reached by motor vehicles within the 3-minute ideal rescue time from logistic facility points. A total of 280 open areas, representing 218 villages, were reviewed in under three minutes.

These towns’ open space area per capita is assessed, and those that are bigger than the 3m² minimum open space area per capita required for isolation and protection are designated open spaces that meet the isolation and protection standards.

Figure 3. Evaluation of isolation and protection value of open space. a) Community-life circle meeting evacuation requirements. b) Open space meeting evacuation and isolation protection requirements. c) Six differentiation of community-life circle meeting the requirements of evacuation and isolation protection (Source: Self-painted by the author)

Loading open spaces that fulfill isolation and protection requirements, screening out community-life circles that meet both evacuation and isolation and protection requirements, and examining the disparities among the city’s six districts. Overall, the
Nankai District has the best comprehensive disaster prevention capabilities for community-life circles, while the Hebei and Heping Districts have the worst.

4. Tianjin City Community-Life Circle Assessment

4.1 Analysis of the evacuation value of community open space in Tianjin

The above calculations and analyses are being used to investigate the relationship between the distribution of open space that meets evacuation requirements and administrative zoning, communities, road networks, river systems, commercial facilities, tourism resources, and other factors.

1) When comparing the carrying coefficients of open space in the brownfield areas of Hongqiao District and the northern part of Hedong District, it can be concluded that the carrying coefficients of open space in the brownfield areas of Hongqiao District and the northern part of Hedong District are higher, and the open space meeting evacuation requirements are more densely distributed.

When the location of open space points that meet evacuation requirements is compared to community boundaries, it is discovered that 48.6% of open spaces within the community can meet evacuation requirements, while only 32.4 percent of open spaces outside the community can, indicating that open spaces within the community are more likely to meet evacuation requirements than open spaces outside the community.

Figure 4. Induction of open space characteristics meeting requirements: a) Relationship between open space and administrative regions; b) Buffer zone of river system; c) Relationship between open space and road network; d) Relationship between open space and commercial facilities; e) Relationship between open space and tourism resources (Source: Self-painted by the author).
2) It can be seen that many open spaces that meet the evacuation conditions are located within the buffer zone, especially in several areas where the open spaces that meet the conditions are concentrated and contiguous, such as the Hongqiao and Nankai Districts, by creating a 300m buffer zone outward from the river system in the six districts of the city. There are 418 open space points in the buffer zone and 215 open space points in the optimal location, accounting for 51.4 percent of all open space points. It signifies that the river system’s open space evacuation capacity is strong.

3) A comparison of the relationship between open space points that meet evacuation requirements and the traffic road network reveals that some open spaces have more evacuation options available to the communities surrounding them and have a higher carrying factor due to the higher density of the road network around them, as well as good traffic accessibility, which requires fewer people to be transported.

4) When we look at the relationship between open space locations that meet evacuation requirements and commercial facilities, we can see that places with a lot of commercial facilities have less open space that meets the standards, which is a generally negative association. The main reasons for this are the high intensity and density of growth in commercial areas, as well as the challenge of meeting catastrophe preventive and evacuation criteria with the limited available open space.

5) A study of the relationship between open space locations that meet evacuation standards and tourism resources found that places with a high concentration of commercial facilities had less open space that fits the requirements, with a positive and then negative correlation. Higher building densities in locations with more tourism resources in the city’s six districts, such as around the modest foreign building blocks of the Five Avenues, are the main causes for this.

Table 1. Relationship between open space and commercial facilities

<table>
<thead>
<tr>
<th>Nuclear density of commercial facilities</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tr>
<td>Number of optimal location points</td>
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<td>27</td>
<td>24</td>
<td>27</td>
<td>13</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>0</td>
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</table>

Table 2. Relationship between open space and tourism resources

<table>
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<tr>
<th>Nuclear density of tourism resources</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>Number of optimal location points</td>
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<td>49</td>
<td>95</td>
<td>79</td>
<td>31</td>
<td>12</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
4.2 Analysis of community-life circles that do not have the required evacuation capacity and isolation protection

Figure 5. Unsatisfactory community-life circle: a) Community-life circle meeting requirements and sub level community life circle; b) Community-life circle that still does not meet the requirements after supplement; c) community-life circle I; d) community-life circle II; e) community-life circle III (Source: Google Earth and Self-painted by the author)

Four community-life circles in the Hongqiao District, three in the Nankai District, three in the Hedong District, three in the Hexi District, one in the Hebei District, and zero in the Heping District were screened out because they did not meet the disaster preventive and avoidance requirements. Open spaces with $B$ less than one were given a spacing of 0.2, 1, 3, 5, 7, and 9, while those with $B$ more than one were given a consistent value of 11. The additional open spaces with sub-evacuation levels of 7 and 9 were chosen as open spaces that might still be used to meet evacuation standards with some optimisation and modification. After supplementing, it was discovered that certain community-life circles still lacked appropriate open spaces.

Dingzigu Street in the northwestern portion of the Hongqiao District, which is one of the last communities in Tianjin to undergo shantytown restoration, is one of the three community-life circles in the city’s six districts. The life circles are primarily residential zones with densely built-up areas and limited open space. Large open spaces, most of which are closed playgrounds on campus, are inaccessible and unevenly distributed. To allow evacuation of residents, safe and regulated open spaces should be established within residential zones, while open spaces within the campus might be opened at different times to improve utilisation efficiency.

The Nankai, Hedong, and Hexi Districts, respectively, have community-life circles in the western and eastern regions of the city’s six districts. The life circles are largely industrial parks and hardware markets, with high building density and a lack of open space, and open space in residential neighborhoods is limited and does not meet evacuation criteria, posing significant dangers of safe evacuation. Efforts should be made in future building to improve the quality of public open space in residential areas and to establish emergency shelters in industrial zones.

The two community-life circles in the Hedong and Hebei Districts, respectively, are inconvenient for residents to evacuate due to the numerous railways, viaducts, expressways, and main roads in the vicinity; there are many demolition plots and abandoned sites in the life circles, which cannot be used as evacuation places; and there
are many old residential areas with a small nucleus. Demolition plots and abandoned sites should be turned to a central location in the future, while old residential districts should be revitalised.

5. Discussion and Conclusions
The suitability of open space as an evacuation site distribution is usually calculated by analysing criteria such as open space accessibility, disaster frequency, evacuation area per capita, or by constructing evacuation models during disasters. Most studies, on the other hand, only address one objective function: the shortest total evacuation distance of residents as the goal of evacuation sites, ignoring community-living circles, diseases, and open spaces.

The following are the paper’s main contributions: (1) This study investigates open space from the standpoint of a community-living circle, taking into account the influence of the New Crown epidemic, as well as the isolation and protective value of open space; (2) The fact that communities, as zones where populations live together, are inherently separated and blocked, while public attributes are weak, is taken into account in this research; and (3) The proportionate balance of personnel allocation is innovatively considered when calculating the carrying capacity of open space, and the number of people to be carried in each open space is calculated more precisely by calculating the area proportion and accessibility of open space.

From the perspective of community-life circles, this paper estimates the carrying capacity of evacuation sites by examining the location of evacuation sites and the escape routes in case of disasters, analyses the evacuation capacity of open spaces under earthquake disasters in six districts within Tianjin, screens community living circles, and sets the assessment system of community living circles in Tianjin by considering the isolation and protection capability. The following findings were made:

(1) While 85 percent of community-life circles can meet evacuation requirements, only about 30 percent of living circles can meet both evacuation and disaster prevention and avoidance requirements, and the majority of community-life circles struggle to meet isolation and protection requirements and do not account for major public-health emergencies;

(2) The open spaces meeting the requirements are densely distributed in the middle and southeast of the Hongqiao District and north of the Hedong District, which is related to the more open spaces in the waterfront area and the better environmental quality of the new community;

(3) Open spaces within the community, with high traffic access and near the river system, can better satisfy disaster prevention and avoidance needs, however the closer open spaces are to commercial facilities, the more difficult it is to fulfil disaster prevention and avoidance criteria;

(4) In the assessment of open space evacuation value, this study incorporates the steps of spatial screening, people allocation, and minimal time measurement, and extends to the community-life circle and epidemic prevention sectors. From the standpoint of urban planning specialty, these findings have theoretical and practical implications for partitioning community-life circles and building catastrophe prevention and evacuation zones in dwelling circles.

Data Availability Statement
Central urban area of Tianjin, such as water system and roads, was from the open data source of Amap API platform.
Tianjin high resolution remote sensing image data was from GL - 1 satellite (https://mall.charmingglobe.com/BaseMap).

Contributor statement
Xiaoyan Mi is in charge of conceptualisation, funding acquisition, methodology, project administration, supervision and writing - review & editing. Yumeng Wang and Ruiman Wang are in
charge of data curation, formal analysis, investigation, visualization, and writing – original draft. Delong Sun is in charge of conceptualisation, investigation, supervision, resources, and validation.

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