Research Inventy: International Journal of Engineering And Science
Vol.14, Issue 3 (March 2024), PP 29-33
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

Urban Emergency Response Route Algorithm based on the Spatial Accessibility Search

Zhou Xiao[1], Ying Hua[2], Hu Yu[3], Pan Juan[1], Liu Mengyuan[1]
[1] *Institute of Cultural and Tourism, Leshan Vocational and Technical College, Leshan China, 614000.*
[2] *Institute of Modern Agriculture, Leshan Vocational and Technical College, Leshan China, 614000.*
[3] *Institute of Artificial Intelligence, Leshan Vocational and Technical College, Leshan China, 614000.*
Corresponding Author: Zhou Xiao, Pan Juan

Abstract: *Based on the analysis of the current problems in emergency response research, this paper proposes and constructs an urban emergency response route algorithm based on the spatial reachable search. Firstly, geographic information data was collected from urban emergency shelters and residential gathering places, and a spatial accessibility model for residential gathering places was established. On the basis of constructing a spatial accessibility model, a spatial clustering model for residential gathering places was constructed to explore the spatial relationship between emergency shelters and residential gathering places. On this basis, an optimal emergency route algorithm was constructed between residential gathering places and emergency shelters in spatial clustering clusters, outputting the shortest emergency shelter route, providing a scientific basis for urban emergency management and decision-making.*
Keywords: *Space accessibility, Urban emergency response, Emergency response, Emergency route.*

Date of Submission: 05-03-2024 Date of acceptance: 18-03-2024

I. INTRODUCTION

Urban emergency response is an important component of emergency management. In the event of natural disasters such as fires, earthquakes and floods, timely relocation of urban residents to shelters is an important measure to protect the safety of people's lives and property. Therefore, in the process of modern urban development, the construction of emergency shelters plays a crucial role. Their scale, size, site selection, spatial distribution, etc. must be based on strict scientific laws, especially the spatial relationship between them and surrounding residential gathering places plays a decisive role in emergency decision-making. When disasters occur, for places where residents gather, how to quickly evacuate the crowds and transfer them to nearby emergency shelters is the core issue of emergency management research, which is of great significance for saving rescue time and minimizing casualties. At present, research on emergency response mainly focuses on several aspects. Firstly, theoretical research on strategies to enhance emergency response capabilities. Secondly, preliminary exploratory research has been conducted on the informatization construction of emergency shelters. Thirdly, relevant theoretical and methodological research has been conducted on emergency shelter response drills. These studies remain at the level of theoretical analysis, lacking research on the spatial relationship between emergency shelters and residential gathering places from a spatial analysis perspective. Therefore, there is a lack of research on emergency response route decision-making, and a lack of reasonable route decision-making system based on urban spatial layout, road distribution, and spatial relationships of gathering places, resulting in a lack of scientific basis for emergency response decision-making. This paper is based on the basic principles of urban spatial distribution and emergency decision-making, establishing the spatial relationship between emergency shelters and residential gathering places, and constructing an urban emergency response route algorithm based on spatial reachability search, providing scientific basis for urban emergency response decision-making.

II. RESEARCH METHOD AND PROCESS

The core issue of urban emergency response is to establish the spatial relationship between residential gathering places and emergency shelters, and to construct the shortest emergency shelter route between the two objects based on the spatial relationship. Therefore, the prerequisite for establishing emergency route algorithms and decision-making plans is to first collect geographic information data of urban emergency shelters and residential gathering places. Secondly, it is necessary to collect road distribution data between emergency shelters and residential gathering places, in order to provide basic data for constructing spatial route search algorithms. We first constructed a spatial accessibility model for residential gathering places, and then established a route search algorithm between residential gathering places and emergency shelters based on the spatial accessibility model.

2.1 Spatial accessibility model for residential gathering places

The concept of spatial accessibility refers to the degree of accessibility between a point A and another point B in space. The high spatial accessibility between points A and B indicates that there is less obstacle and lower cost for A to travel to B. The low spatial accessibility between points A and B indicates that there is a larger obstacle and higher cost for A to travel to B. Based on this spatial relationship, a spatial accessibility model between emergency shelters and residential gathering places can be established to analyze the spatial accessibility relationship between representative residential gathering places and various emergency shelters in the city, thereby establishing spatial clustering clusters centered on emergency shelters.

The spatial coordinates of emergency shelters $U_{(u)}$ are defined as (x_1, y_1), and the spatial coordinates of residential gathering places $R_{(v)}$ are (x_2, y_2). Based on the definition of spatial accessibility, a spatial accessibility model between emergency shelters and residential gathering places is constructed as shown in equation (1), where S_A represents spatial accessibility and δ represents normalization factor, which is used to constrain the calculation results within the range $0 < S_A < 1$ of the interval.

Equation 1: A spatial accessibility model between emergency shelters and residential gathering places.

$$S_A = \delta \cdot \frac{1}{\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}}$$

Based on the spatial accessibility model S_A, we constructed a spatial clustering model centered on various emergency shelters to deeply explore the spatial relationship between emergency shelters and residential gathering places. The following is a spatial clustering algorithm for residential gathering places based on spatial accessibility ranking algorithm.

Input: p number of emergency shelter locations, k number of residential gathering locations, emergency shelter location coordinate set $\{x_1, y_1 \mid (x_1, y_1)_{(u)}\}$, residential gathering location coordinate set $\{x_2, y_2 \mid (x_2, y_2)_{(v)}\}$, where $0 < u \le p$, $0 < v \le k$, $u, v, p, k \in \mathbf{N}$.

Output: Spatial clustering cluster $C_{(i)}$ of residential gathering places.

Step 1: Take $v = 1$ from the coordinate set $\{x_2, y_2 \mid (x_2, y_2)_{(v)}\}$ and calculate the spatial accessibility between the first residential gathering place $R_{(1)}$ and p number of emergency shelter places, $0 < u \le p$.

Step 2: Sort and compare p number of $S_{A(u)}$, take the maximum value $\max S_{A(u)}$, and obtain its corresponding emergency shelter $U_{(u)}$.

Step 3: The current residential gathering place $R_{(1)}$ is included in the corresponding spatial cluster $U_{(u)}$ where the $\max S_{A(u)}$ emergency shelter is located.

Step 4: Return to Steps 1-Step 3, take $v = 2$ from the coordinate set $\{x_2, y_2 \mid (x_2, y_2)_{(v)}\}$, calculate and output the spatial cluster that the second residential gathering place $R_{(2)}$ belongs to.

Step 5: Traverse $0 < v \le k$ and calculate the spatial clusters that the k number of residential gathering places $R_{(v)}$ belongs to. The clustering algorithm has ended.

2.2 Emergency shelter route search algorithm

On the basis of constructing the spatial relationship between emergency shelters and residential gathering places, we have developed an emergency shelter route search algorithm between emergency shelters and residential gathering places. Firstly, determine the starting point as a residential gathering place $R_{(v)}$ and the endpoint as an emergency shelter $U_{(u)}$ in the spatial cluster where the residential gathering place is located. Secondly, obtain the main city roads and road node sets between $R_{(v)}$ and $U_{(u)}$ from the city map. Finally, collect the movement distance between adjacent nodes and store it in the database. On the basis of collecting geospatial basic data, we constructed an emergency shelter route search algorithm between $R_{(v)}$ and $U_{(u)}$.

Input: $R_{(v)}$, $U_{(u)}$, Road node set $\{i \in \mathbf{N} \mid N_{ode(i)}\}$, node movement distance set $\{i \in \mathbf{N} \mid s_{(i)}\}$.

Output: The optimal emergency shelter route between $R_{(v)}$ and $U_{(u)}$.

Step 1: Search for feasible pathways $Path_{(1)}$. Starting state as shown in Figure 1 (1), determine the initial pathway, connect $R_{(v)}$ and $N_{ode(1)}$, as shown in Figure 1 (2), the pathway is feasible, save it;

Step 2: Determine $Node_{(4)}$ and $Node_{(5)}$. Among them, $Node_{(4)}$ reverse and discard. Connect $Node_{(5)}$ to form a feasible pathway, as shown in Figure 1 (3), and save it;

Step 3: Determine $Node_{(2)}$, connect $Node_{(5)}$ and $Node_{(2)}$ to form a feasible pathway, as shown in Figure 1 (4), save it;

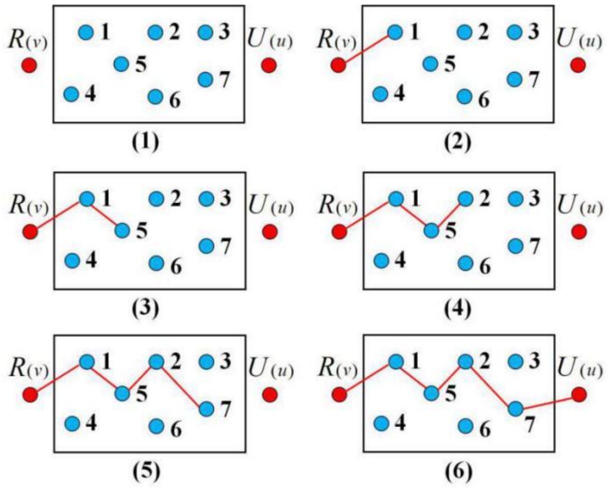
Step 4: Determine $Node_{(6)}$, reverse, discard. Connect $Node_{(2)}$ and $Node_{(7)}$ to form a feasible pathway, as shown in Figure 1 (5), and save it;

Step 5: Connect $Node_{(7)}$ and $U_{(u)}$, generate a complete pathway $Path_{(1)}$.

Step 6: Develop other feasible pathways $Path_{(i)}$, $0 < i \le \max i$, $i \in \mathbf{N}$.

Step 7: Search for the path with the minimum iterative distance $\min Path_{(i)}$, corresponding to the optimal emergency shelter route between $R_{(v)}$ and $U_{(u)}$. The algorithm ends.

Figure 1. Algorithm process for searching emergency shelter routes



III. EXPERIMENT AND ANALYSIS

Taking the tourist city of Leshan as an example, we selected several emergency shelters and residential gathering places within Leshan city, and obtained the longitude and latitude coordinates of emergency shelters and residential gathering places from the Leshan city geographic information database. At the same time, we obtained the roads, road nodes, and path distances between each residential gathering place and emergency shelter. Firstly, the constructed spatial accessibility algorithm is used to calculate the spatial accessibility between each residential gathering place and emergency shelter. Then, a spatial clustering algorithm of residential gathering places is constructed based on the spatial accessibility. Finally, the emergency shelter route search algorithm is used to output the shortest route between each residential gathering place and the emergency shelter place in the cluster. The longitude and latitude coordinates of the emergency shelter and residential gathering places we collected are shown in Table 1, where the emergency shelter is $U_{(1)}$: Leshan Square, $U_{(2)}$:Leshan Sports Cente, $U_{(3)}$:Dongpo Square, $U_{(4)}$:Haitang Square. Representative residential gathering places are $R_{(1)}$: Shihao Square, $R_{(2)}$:Chongbai Shopping Mall, $R_{(3)}$:Hualian Commercial Building, $R_{(4)}$:Wanda Plaza, $R_{(5)}$:Wangfujing; $R_{(6)}$: Traditional Chinese Medicine Hospital , $R_{(7)}$: Lianyun bus stations, $R_{(8)}$:Leshan High-Speed Railway Station.

Table 1. Longitude and latitude coordinates of emergency shelters and residential gathering places

	$U_{(1)}$	$U_{(2)}$	$U_{(3)}$	$U_{(4)}$	$R_{(1)}$	$R_{(2)}$
longitude	103.752	103.760	103.770	103.769	103.733	103.772
latitude	29.594	29.586	29.597	29.561	29.607	29.564
	$R_{(3)}$	$R_{(4)}$	$R_{(5)}$	$R_{(6)}$	$R_{(7)}$	$R_{(8)}$
longitude	103.753	103.744	103.758	103.755	103.761	103.718
latitude	29.592	29.626	29.589	29.592	29.603	29.607

3.1 Spatial accessibility and spatial clustering results

Based on the latitude and longitude data in Table 1, the spatial accessibility of residential gathering places relative to various emergency shelters was calculated, and the results are shown in Table 2. Based on the results in Table 2 and the spatial clustering algorithm, the spatial clustering clusters of residential gathering places were obtained. The results are shown in Table 3, where the symbol "√" represents the cluster where the residential gathering places are located.

Table 2 Spatial accessibility of residential gathering places for various emergency shelters

	$R_{(1)}$	$R_{(2)}$	$R_{(3)}$	$R_{(4)}$	$R_{(5)}$	$R_{(6)}$	$R_{(7)}$	$R_{(8)}$
$U_{(1)}$	0.434	0.277	4.472	0.303	1.280	2.774	0.786	0.275
$U_{(2)}$	0.292	0.399	1.085	0.232	2.774	1.280	0.587	0.213
$U_{(3)}$	0.261	0.302	0.564	0.257	0.693	0.632	0.925	0.189
$U_{(4)}$	0.171	2.357	0.287	0.144	0.332	0.294	0.234	0.146

Table 3 Spatial clustering of residential gathering places

	$R_{(1)}$	$R_{(2)}$	$R_{(3)}$	$R_{(4)}$	$R_{(5)}$	$R_{(6)}$	$R_{(7)}$	$R_{(8)}$
$C_{(1)} \sim U_{(1)}$	√		√	√		√		√
$C_{(2)} \sim U_{(2)}$					√			
$C_{(3)} \sim U_{(3)}$							√	
$C_{(4)} \sim U_{(4)}$		√						

Analyzing the results of Table 2 and Table 3, it can be seen that the spatial accessibility of emergency shelters varies for each residential gathering place, showing significant differences. For the same residential gathering place, the emergency shelter with the highest spatial accessibility is the cluster where the residential gathering place is located. The minimum spatial cost and fastest time to reach the emergency shelter place can help in quickly transferring personnel in case of emergencies, minimizing the casualties.

3.2 Output results of emergency shelter route

Based on the spatial clustering results in Table 3 and the emergency shelter routes constructed in this paper, we search for the optimal route mileage for each residential gathering place to reach the emergency shelter within the cluster. The results are shown in Table 4.

Table 4 Optimal route mileage from residential gathering places to emergency shelter places (km)

	$R_{(1)}$	$R_{(2)}$	$R_{(3)}$	$R_{(4)}$	$R_{(5)}$	$R_{(6)}$	$R_{(7)}$	$R_{(8)}$
$C_{(1)} \sim U_{(1)}$	2.60		0.30	3.90		0.47		4.00
$C_{(2)} \sim U_{(2)}$					0.50			
$C_{(3)} \sim U_{(3)}$							1.30	
$C_{(4)} \sim U_{(4)}$		0.45						

Analyze the results in Table 4, the mileage under each residential cluster represents the optimal route mileage between it and the emergency shelter in the cluster it belongs to. The shortest distance from Shihao Square to Leshan Square for emergency shelter is 2.60 kilometers; The shortest distance from Chongbai Shopping Mall to Haitang Square for emergency shelter is 0.45 kilometers; The shortest distance from Hualian Commercial Building to Leshan Square for emergency shelter is 0.30 kilometers; The shortest distance from Wanda Plaza to Leshan Square for emergency shelter is 3.90 kilometers; The shortest distance from Wangfujing to Leshan Sports Center for emergency shelter is 0.50 kilometers; The shortest distance from Traditional Chinese Medicine Hospital to Leshan Square for emergency shelter is 0.47 kilometers; The shortest distance from the Lianyun bus station to the emergency shelter at Dongpo Cultural Square is 1.30 kilometers; The shortest distance from Leshan High-speed Railway Station to Leshan Square for emergency shelter is 4.00 kilometers.

IV. CONCLUSION

Urban emergency response is an important component of emergency management, and emergency response route planning is also an important part of emergency response. This paper proposes and constructs an urban emergency response route algorithm based on spatial accessibility search to address the current problems in emergency management and emergency response. Firstly, the geographic spatial data of urban emergency shelters and residential clusters were collected, and a spatial accessibility algorithm model was established. By calculating the spatial accessibility, the spatial relationship between residential clusters and emergency shelters was determined. Based on this process, a spatial clustering model of residential clusters was generated to explore the spatial patterns. By establishing spatial clustering algorithm of residential gathering places, an emergency shelter route algorithm was designed and developed between emergency shelters and residential gathering places, searching for the shortest path from residential gathering places to emergency shelters. The algorithm model constructed in this paper provides scientific basis and method flow for emergency management and emergency response, and provides decision support for urban emergency work.

Conflict of interest

There is no conflict to disclose.

ACKNOWLEDGEMENT

The authors are grateful to the support of the Key Project of the Sichuan Emergency Management Knowledge Popularization Base of Leshan Normal University in 2023, "Urban Emergency Refuge Site Emergency Planning Model Based on the Spatial Cell Clustering of the Multiple-Center Buffer Zone " (No. SCYJ2023-02), and the Leshan Science and Technology Plan Project (No. 22ZRKX025).

REFERENCES

[1]. Wang,S., Xu,X. 2024. Research and optimization path of flood disaster emergency management in Heilongjiang Province. Heilongjiang Environmental Journal, 37(01), 26-29.

[2]. Sheng,D. 2023. The Dilemma and Solution Path of Emergency Management for Rural Emergencies under the Background of Rural Revitalization: Taking T County in Anhui Province as an Example. Village Committee Director, 12, 28-30.

[3]. Guo,Y., Zhang,Y., Wu,Z. 2023. From the Characteristics of Emergency Management Data Resources to the Governance of Big Data in Emergency Management. Journal of China Emergency Management Science, 12, 58-61.

[4]. Lu,D. 2023. Measures to improve the emergency management level of public health emergencies. Chinese journal of urban and rural enterprise hygiene, 38(12), 226-228.

[5]. Jiang,F., Fu,X., Zhao,L., Xie,Z., Wang,Z. 2024. Urban emergency shelter planning based on GIS spatial quantitative evaluation of flood resilience. Bulletin of Surveying and Mapping, 01, 169-174.

[6]. Li,P., Jiang,J., Gao,W. 2023. Research on emergency shelter in historic district: A case of Laoshe Park in Qingdao. Urbanism and Architecture, 20(24), 146-148.

[7]. Zhang,Y., Xie,Q., Yan,H., Yang,J. 2023. Assessment and Layout of Earthquake Emergency Shelter Capacity Based on ArcGIS: A Case Study of the Main Urban Area of Chengdu City. Resources and Habitant Environment, 11, 36-43.

[8]. Li,H., Zhou,J., Liu,K., Zhang,H. 2023. The hot spots and trends analysis of emergency shelters research in China−based on the perspective of knowledge graph. Journal of Xihua university natural science edition. 42(06), 83-92.