The Study on Optimization Location-Allocation of Emergency Shelter for Earthquake

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Key words: land science system; optimization location-allocation; the network model; Hierarchical analysis; Cadastre

SUMMARY

Purpose: study optimization location-allocation of emergency shelter for Earthquake after destructive earthquake disaster, so as to prevent or reduce the damage caused by the earthquake and its secondary disasters, to guide the resettlement and reconstruction of post-disaster. Methods: basis on GIS, by applying the location - allocation optimization of P - center model of geographical space geometric network model, through the analysis of the shortest path based on Dijkstra algorithm and the most convenient facilities as well as neighborhood analysis of Euclidean distance calculation, the study select the evaluation indicators of validity, safety, Facility to confirm optimization location-allocation of emergency shelter for earthquake, by virtue of linear efficacy function method and the hierarchy process analysis. Results: (1) the geographical spatial geometric network can realize the analysis of the most convenient facilities and the shortest path and tracking, consequently providing detailed route guidance, meanwhile, it's owing the obvious advantages in the aspect of emergency rescue and fast response, however, it is the key point to abide by strict network topology relationship when choose the shortest path algorithm;(2) it is the first consideration to ensure the safety of emergency shelter, therefore, optimization location-allocation must avoid the geological structure hazard, geological disasters, and post-earthquake secondary disasters such as inflammable and explosive hazard place etc., however, such impact factors are not affected by the constraint of the traffic network, it's more appropriate for the measure of Euclidean distance which have the characteristic of buffer damping;(3) by compared the optimal allocation scheme with the actual resettlement location, they present the higher compatibility and matching degree, and the field demonstration also illustrate that the whole methods have scientifisity and feasibility to some extent;(4)it's helpful to provide reference for land use planning of post-earthquake recovery and reconstruction, while the planning depends on more detailed ownership survey, disaster evaluation, safety evaluation, land supply and demand analysis, the land consolidation and ecological restoration research. Conclusion: supply an optional tool of space visual, fast, effective optimization location-allocation of emergency shelter for earthquake.

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1. INTRODUCTION

Population mobility and state dependence are enhancing in global age, " The modernity caused by the development of industrial society bring huge uncertainty to each field even to the smallest angle of human existing state" [1-3]. The economic losses causing from the uncertainty and the contingency of natural disasters, in particular, the earthquake are obvious increasing , it is an important factor that affect economic development and social stability [4], which is also bring great loss and damage to the people's life and property. While the crisis from a country or a region will inevitably produce international influence [5, 6].It is advantageous to prevent or reduce the damage from the earthquake and its secondary disasters to great extent that research on optimization location-allocation emergency shelter for earthquake , to guarantee the public life and property security, to improve the government's ability of protecting public safety and dealing with public emergency, safeguarding national security and social stability, promoting the comprehensive, coordinated and sustainable development of economic and social, thus, to better perform our responsibility for globalization obligation.

Earthquake emergency shelters (emergency shelter for earthquake disasters) is such a temporary and safe place arranged by the planning and construction, which has service facilities for emergency shelter and emergency evacuation[7].Generally speaking, the earthquake emergency shelters using for quake victims[8] (seismic shelter for evacuation) can be divided into three types , such as temporary emergency shelters, fixed emergency shelters, center emergency shelters according to the number of quake victims and comprehensive facilities.

2. PROFILE OF STUDY AREA

Yushu Tibetan autonomous prefecture (hereinafter refer to as the Yushu prefecture)is located in the southwest of Qinghai province, PRC., north adjacent to Hercynian Mongolian Tibetan autonomous prefecture, east adjacent to Goluo Tibetan autonomous prefecture, southeast adjacent to Ganzi Tibetan autonomous prefecture of Sichuan province, south and southwest northwest adjacent to Bayinguoleng Mongolian autonomous prefecture of Xinjiang Uygur autonomous adjacent to the border zone of Changdu region and Naqu prefecture of Tibet Autonomous Region, region. There are six counties of Yushu, Zaduo, Chengduo, Zhiduo, Nangqian, Qumalai. The capital of Yushu prefecture is base on JieGu town , the permanent population of the whole state is 357300 and the region's GDP totaled 2.55 billion Yuan in 2010.

There is 7.1 magnitude earthquake in Yushu county of Yushu Tibetan autonomous prefecture in Qinghai province at 7:49, on April 14, 2010.The epicenter location is 96.6 N, 33.2 E, which is located in the mountain of 4300 meters above sea level in Yushu Tibetan autonomous prefecture of Qinghai province, from which Yushu county town (Yushu prefecture and Yushu county government)is about 42 km. The depth of hypocenter is 14 km, and the highest intensity of earthquake is 9 degree, the fault zone is Yushu - Ganzi sinistral strike-slip faults, the intensity of meizoseismal area is Ⅸ degree. The affected scope is about 3 square kilometers, which causing heavy casualties and property losses.

3. DATA SOURCES AND PREPARING MAPS

The data of paper mainly is from The data of paper mainly is from the 1:50000 scale of digital elevation model of remote sensing image of Yushu county (2009), the current situation map of the overall land use planning of the central urban area of Yushu county (2010-2030), the 1:50000 scale of the current situation map of Yushu county of the second national land surveying (2009), the distribution map of geological disasters of Yushu prefecture and the distribution map of geological disaster of Yushu county (2010), the earthquake fault zone map of Yushu county (2010).

Papers take the central urban town of Yushu state and Yushu county-- Jiegu town as an example, firstly ,digitalize the current situation map of the overall land use planning of the central urban area of Yushu county (2010-2030), carry out the image registration with the 1:50000 scale of the current situation map of Yushu county of the second national land surveying (2009), extract the all community green spaces, public green spaces, the squares, stadiums, parkings etc of the central urban area of Yushu county as alternative shelters and save the figure of alternative sites as the form of the polygon file ; secondly, shape and draw the traffic polyline file and join in the road rank as the basic datum of traffic geometric network ,but strictly guarantee the polyline topology rules of the connectivity of all nodes and roads and no hanging line by all means; thirdly , extract and draw the point file of first-aid centers, fire control facilities, water sources, inflammable and explosive hazards, community residential areas, alternative sites for earthquake emergency shelters from the current situation map of the overall land use planning of the central urban area of Yushu county (2010-2030) as the basic datum of emergency facilities; fourthly, carry out the image registration among the distribution map of geological disasters of Yushu prefecture and the distribution map of geological disaster of Yushu county (2010) and the 1:50000 scale of the current situation map of Yushu county of the second national land surveying (2009) as the basic datum of safety indexes of alternative sites by way of coordinate transformation and spatial adjustment; fifthly, extract the slope from the 1:50000 scale of digital elevation model of remote sensing image of Yushu county (2009) as the basic datum of effectiveness indexes of alternative sites.

4. RESEARCH METHODS

Based on arcgis, according to the principles and requirements of location-allocation of earthquake emergency shelter, paper select the accessibility, safety, effectiveness indicators, by means of P - center model of the location - allocation optimization model constructing geographical space geometric network model. Firstly, paper calculate the shortest route from alternative shelter sites to emergency facilities as the indicators of accessibility through the shortest route and the facilities analysis of arcgis geospatial analysis based on Dijkstra algorithm; secondly, measure Euclidean distance from alternative shelter sites to the points of earthquake disasters and its secondary disasters as the indexes of safety through the neighborhood analysis of arcgis geospatial analysis; thirdly, select the effective area and the slope of alternative shelter sites as the effectiveness indexes; fourthly, with the methods of the linear effect function unifying dimension of each indicator and calculating utility, based on the analytic hierarchy process (AHP) determining the weights of evaluation indexes, the thesis ultimately calculate location-allocation of earthquake emergency shelters site through the weighted average methods.

4.1 Establish Index System

Seismic refuges must abide by the principles as follows： "unified planning, combine with daily facilities, adjust measures to local conditions, comprehensive utilization, the nearest evacuation, security and accessible"[9].The article summarized as the accessibility, safety, effectiveness indicators.

(1) the principle of priority to safety
Alternative sites selection should avoid where is the seismic active fault, the Karst subsidence, the mining goaf and the site prone to serious liquefaction, the flammable and explosive hazard and important secondary disaster. So it choose the Euclidean distance from the alternative sites to the earthquake fault zones and its secondary geological hazard, the flammable and explosive hazards resources as the safety indexes.

(2) the principle of combining with daily facilities and adjusting measures to local conditions
Combining with the space distribution and the evacuation requirements of victims , the certain scale of parks, green spaces, sports venues (school playgrounds) which has the function of emergency refuge are arranged and chosen. Effective area of the emergency refuge shelter is one of the important factors to measure the necessity and cost of construction and relocation, therefore, it's necessary to consider the effective area of alternative shelter sites.

(3) the principle of feasible technology and reasonable economic
Site selection should be available for reconstruction in technology area. The flat, open, no ponding, below 7 degrees slope places will be suitable and easy to build temporary buildings or tent for the activities of disaster relief, therefore, the slop extracting from the digital elevation model will better reflect the effectiveness of technical and economic.

(4) the principle of balanced layout and accessible
It's significant to guarantee the shortest route from the alternative sites to community residential areas, the medical emergency centers, fire-fighting facilities and water sources. However, the rescue and escape is to rely on the premise of the existing road network instead of the straight line buffer distance.

(5) the principle of rapid pass and walking priority

Emergency shelters should fully consider the evacuation time of the road network, therefore, transit-time can be as the road network weight of quantitative analysis through the calculation of the designed speed and the road length of the highway.

(6) the principle of people oriented and care for the weak
Paper increase the weight of the validity area index of the alternative sites, so that they can give more conveniences and attention in infrastructure and green channel. Through scientific and rational selection, index standardization evaluation, combining with data availability, the evaluation index system are shown below in table 4-1.

4.2 Build Traffic Geometric Network and Geographical Spatial Data System

4.2.1 Build traffic geometric network data set

(1) the preparation of element data sets
Firstly, add attribute field "road level" to the vector data of roads. Road level can be divided into national highway, provincial highway, trunk highway and general road. According to the speed limit level, classified highway is respectively assigned to the corresponding speed level, such as: the rate-limiting of national highway is 120.7 km/h, the rate-limiting of provincial highway is 104.61 km/h, the rate-limiting of trunk highway is 88.51 km/h and the rate-limiting of general road is 64.37 km/h. Secondly, add attribute field "time" to the vector data of roads. According to the length of road and speed limit level, the transit time of each road can be calculate d as the weight of traffic network data set.

(2) the construction of network database and network data set
By means of network analyst tool of ArcGIS, local network database is built in the catalog, which is named city.mdb or city.ldb. And network data set "city" is set in this database.

(3) the input of the polyline file of roads and the location points of medical emergency facilities, etc
Input the polyline file of roads to the data set "city" of "city.mdb or city.ldb", and then the location points of those emergency facilities, such as the medical emergency centers, fire-fighting equipments, water sources, community residential areas are inputted into "city " data set.

(4) the construction of geometry traffic network
By means of network analyst tool of ArcGIS, right-click the "city" data set, choose the limit. "Time" field is chosen as the weight value of geometry traffic network, any node is chosen as the connecting node of the geometric network, and finally produce two new element classes: city_net (geometric network class) and city_net_Junctions (connecting node class) , and set the connecting rules of geometric network : Edge - Egde rules (figure 4-1).

4.2.2 Geospatial data processing

(1) to analyze nearest facilities and the shortest route of facilities by creating network analysis layer

Respectively add the points of the medical emergency centers, fire-fighting equipments, water sources, community residential areas to the geometry traffic network "Facilities", alternative sites are as the event "Incidents". Calculate respectively the distance from alternative sites to nearest facilities to get the shortest route distinguishing the weight of access time as the indexes of site accessibility.

(2) to calculate the Euclidean distance of hazard resources through the neighborhood analysis
Based on the analysis of near tool of arcgis, measure Euclidean distance among the alternative sites , earthquake fault zones, geological hazard points and flammable and explosive hazard points as the indexes of site safety.

(3) to extract the slope by way of the surface analysis of digital elevation model
Extract the slope of the alternative sites through the surface analysis of the DEM as a measure of the terrain and topography indicator. Then, statistic the average gradient of each raster sites through the spatial overlay analysis, so that evaluate gradient values of each alternative site as one of the indexes of site effectiveness.

(4) to calculate the effective areas of alternative sites
Considering the collapse of buildings, paper use 70% of the area of alternative sites as effective site area. According to the area standard of the fixed refuge shelter(2 meters per person), effective site area divide the area standard of the fixed refuge shelter is effective refuge population as the other of the indexes of site effectiveness.

4.3 Quantitative Evaluation Indexes

The study use the methods of the linear utility function uniform index dimension.

$$UA(a_i)=\begin{cases}\dfrac{x_i-b_i}{a_i-b_i} & UA(a_i)\ \text{positive} \qquad (i=1,2,3,\cdots\cdots,n)\\[2ex] \dfrac{b_i-x_i}{b_i-a_i} & UA(a_i)\ \text{negative} \qquad (i=1,2,3,\cdots\cdots,n)\end{cases}$$

（Formula 4-1）

The variable values of the evaluation index Ui (i = 1, 2, 3,..., n)is Xi (I = 1, 2, 3,..., n); ai and bi, respectively, is the upper and lower of critical point of the system index; Xi ,orderly efficacy UA (ai), can be determined by formula (i): UA (ai) is as the index utility of Ui; A is the interval of the value of evaluation indexes; namely (ai, bi), the upper threshold ai is the maximum of Euclidean distance or the minimum of route distance; The lower threshold bi is the minimum of Euclidean distance or the maximum of route distance.

4.4 Determine the Weight of Indexes

Paper adopt the analytic hierarchy process (AHP) [131] as a method of weight determination. Mathematical model [10] : suppose a hypothesis goal U, the influence factors have Pi (I = 1, 2,..., n), the total is n, and the weight of Pi respectively is (i = 1, 2,..., n),n > 0:

$$U = W_1P_1 + W_2P_2 + \cdots + w_n\ p_n = \sum_{i=1}^{n} w_i * p_i \qquad \text{(Formula 4-2)}$$

Here, introduce the soft of EXPERT CHOICE to create the weight , which working principle is based on the principle of analytic hierarchy process (AHP). The comparison results from the exporters is input computer, and computer automatically operated and generated the weights. The table of weight index is shown as follows.

4.5 The Comprehensive Location-Allocation Model

The method of arithmetic average is used as the optimization strategy of location-allocation.

$$C = \sum_{i=1}^{n} w_i k_i, \quad \text{hereinto} \quad \sum_{i=1}^{n} w_i = 1 \qquad \text{(Formula 4-3)}$$

C is the comprehensive evaluation value of the optimization strategy of location-allocation ; Wi is weight; Ki is single index value. the higher C value is, the better the location is.

4.6 Range the Location Level

Natural breakpoint method is used to divide the level of location-allocation, 0.1 is the interval scale, the comprehensive evaluation value can be divided into the optimal, subprime, generally, unsuitable four levels.

When $C \geqslant 0.5$, alternative emergency shelter is the best location; When $0.5 < C \leqslant 0.4$, alternative emergency shelter is a suboptimal scheme; When$0.4 < C \leqslant 0.3$, it means generally matching the requirements of safe, effective and accessible; When $C < 0.3$, it is not appropriate as an emergency shelter.

5. RESULTS

5.1 The Effective Refuge Capacity of Earthquake Emergency Shelters

Select green spaces, squares, parking lots and parks and statistic area and code the location. Green spaces are coding form 101 to113, squares are 201-206 , parks are 301-302, parking lots are 401-412. Alternate emergency shelters are totally 33. Effective shelter area, effective refuge population and effective refuge capacity of alternative site are as shown in figure 5-1:

5.2 The Average Slope of Earthquake Emergency Shelters

Overlay the slope degree map and the alternative sites to statistic the average gradient of each alternative site(figure 5-2).

5.3 The Shortest Route from Alternative Sites to Community Residential Areas

Assuming the emergency shelter sites as "the sites" and community residential areas as "the event", analyze the shortest route distance from 33 alternative sites to 16 community residential areas (figure 5-3).

5.4 The Shortest Route from Alternative Sites to Medical Facilities

The shortest route from alternative sites to medical facilities is shown in figure 5-4.

5.5 The Shortest Route from Alternative Sites to Fire-Fighting Facilities

The shortest route from 33 alternative sites to 2 fire-fighting facilities are shown in figure 5-5.

5.6 The Shortest Route from Alternative Sites to Water Sources

In order to prevent post-earthquake epidemics, fully considering the climatic conditions and the casualties pollutions, it is beneficial for alternative sites to near the water sources so that avoid secondary pollution and disease. The shortest route distance diagram is shown below 5-6:

5.7 The Euclidean Distance between the Alternative Sites and the Earthquake Fault Zones

In order to prevent the aftershocks and secondary geological disaster, it is one of the location principles of earthquake emergency shelters to avoid the tectonic fault zones. Earthquake, however, is not affected by roads network but is transferred by seismic wave, Euclidean distance is a good way to measure the shortest linear distance between 33 emergency shelters and earthquake fault zones(figure 5-7).

5.8 The Euclidean Distance between the Alternative Sites and Geological Hazard Points

Geological hazard is one of the potential hazards causing from geological structure. It's necessary to avoid and reduce the likelihood of occurrence, the results are shown in figure 5-8.

5.9 The Euclidean Distance between the Alternative Sites and the Flammable and Explosive Hazards

The alternative sites should be far away from the equipment of the gas stations, power plants and oil depots to avoid the flammable and explosive hazards (figure 5-9).

5.10 The Optimal Strategy of Emergency Shelter Sites

The linear function is the relative order of the maximum and the minimum. The further the distance is, the better the positive linear function reflects. While the nearer the distance is, the better the negative linear function reflects.

The comprehensive optimal strategy of emergency shelter sites are shown below in figure 5-

10 and table 5-1 Location 16 people's park, Location12 King Gesar plaza and location32 MinZhu Village are the best emergency shelters. Actually, Location12 and Location16 had been used as the headquarters office of earthquake relief, while location32 MinZhu Village is actually used as a refugee resettlement site, location 25 wetland park is actually as temporary construction site.

6. RESEARCH CONCLUSIONS

There are lots of researches on the allocation-location of emergency shelter sites , however, many of them are about scientific algorithm and mathematical formulae. It is too abstract and indirectly for solving practical problems. Therefore, the visual analysis and fast location is the characteristic of this research. The study firstly definite what kind of site should be selected and know the basic conditions of an emergency shelter site, and then put forward to the location allocation strategy， that is to say, based on the principles of effectiveness, accessibility, safety . The study calculate the Euclidean distance and the shortest route by way of geographical spatial geometric network. Evaluation indexes and weights fully shows the principles of location-allocation.

The core of geometric network is to ensure the connectivity of network, therefore, the strict topology relationship is the key for the shortest route algorithm. The analysis of "the facility" "and "the route" can be realized by geographical spatial geometric network ,which has the obvious advantage in the aspect of emergency rescue.

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BIOGRAPHICAL NOTES

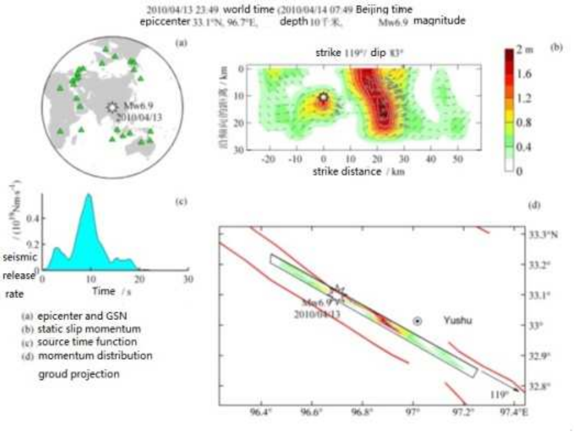


Figure 2-1 profile of Yushu earthquake

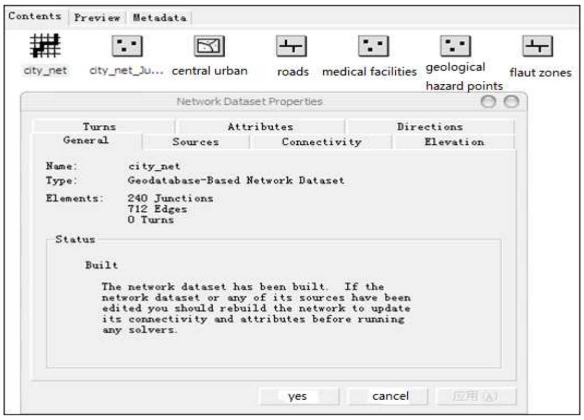


Figure 4-1 geographic traffic geometric network data

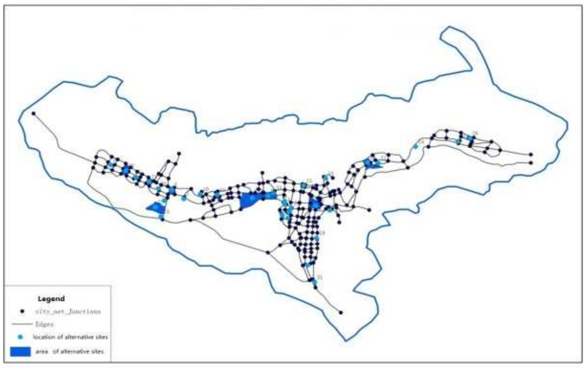


Figure 5-1 effective shelter area and address coding

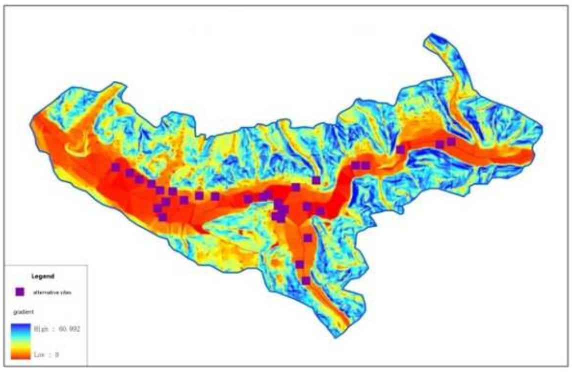


Figure 5-2 the slope degree

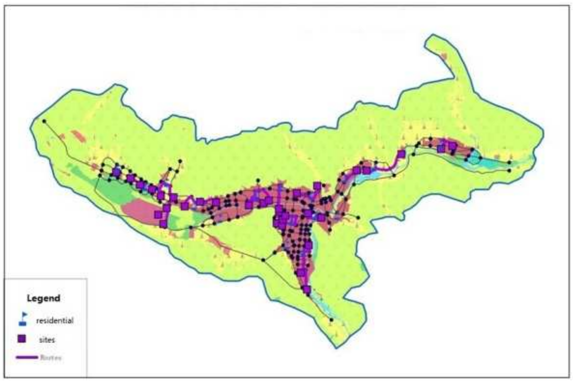


Figure 5-3 the shortest route from emergency shelter sites to community residential areas

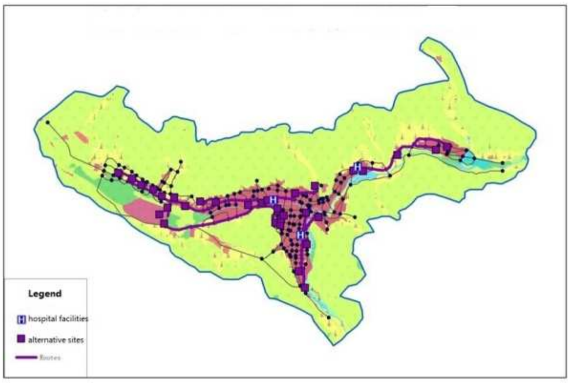
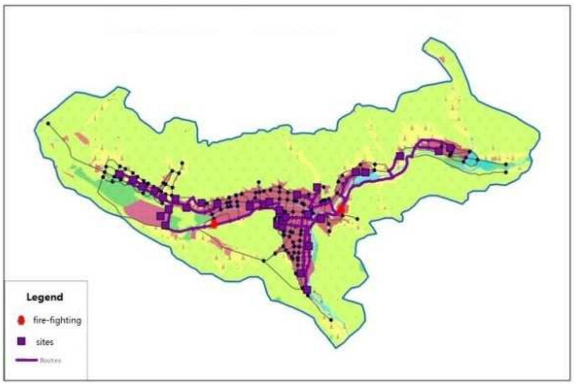


Figure 5-4 the shortest route from emergency shelter sites to medical facilities



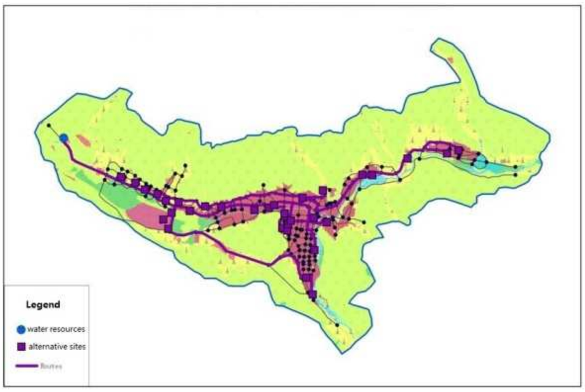
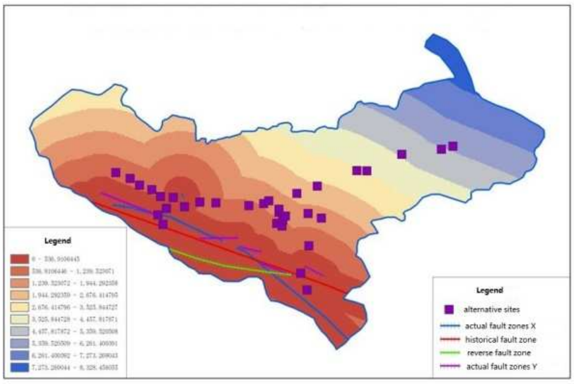


Figure 5-5 the shortest route from emergency shelter sites to fire-fighting facilities

Figure 5-6 the shortest route from emergency shelters sites to water sources



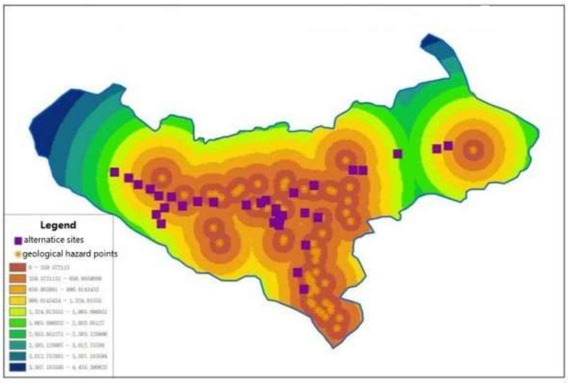


Figure 5-7 Euclidean distance between emergency shelter sites and earthquake fault zones

Figure 5-8 Euclidean distance between emergency shelter sites and geological hazard points

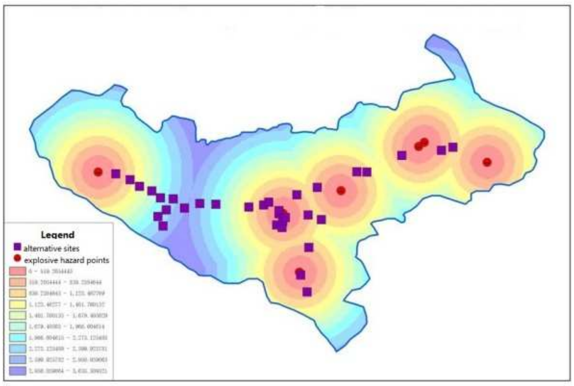


Figure 5-9 Euclidean distance between emergency sites and flammable and explosive hazards

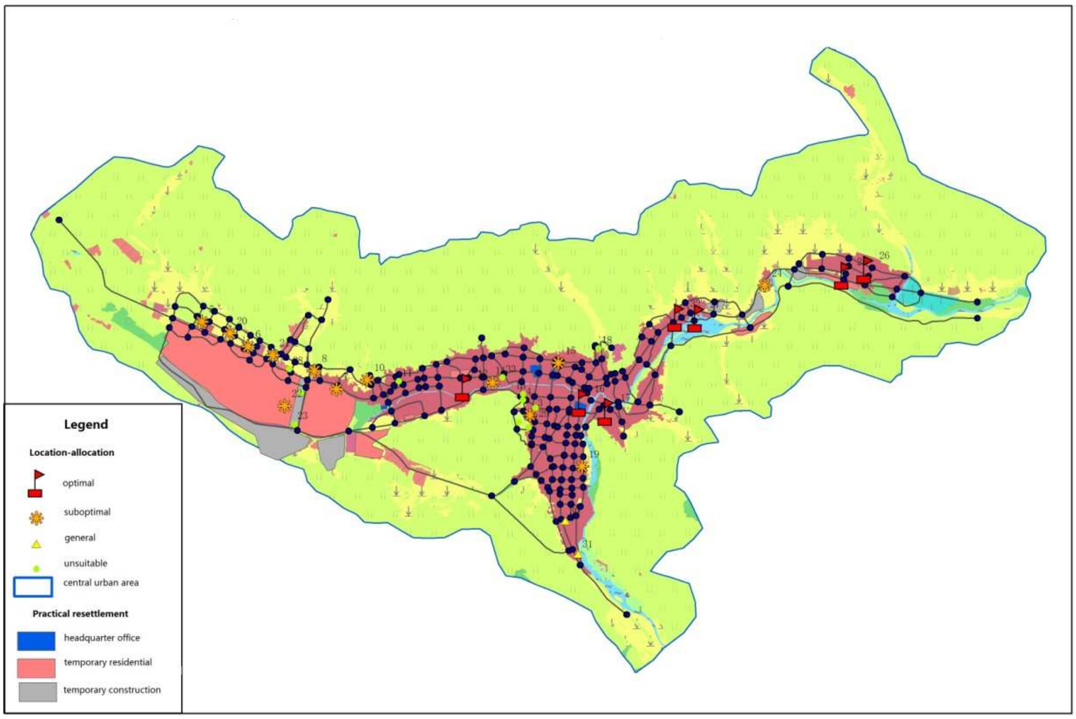


Figure 5-10 the optimal strategy of emergency shelter sites

Table 4-1 the weight of evaluation indexes of location-allocation

A the optimization strategy of location-allocation	B1 effectiveness	0.2	C11 effective refuge capacity (population)	0.15
			C12 the slope of alternative sites	0.05
	B2 accessibility	0.4	C21 the shortest route of community residential areas	0.20
			C22 the shortest route of medical facilities	0.10
			C23the shortest route of fire-fighting facilities	0.05
			C24 the shortest route of water sources	0.05
	B3 safety	0.4	C31 Euclidean distance of the earthquake fault zones	0.20
			C32 Euclidean distance of geological hazard points	0.10
			C33 Euclidean distance of the flammable and explosive hazards points	0.10

Table 5-1 the optimal comprehensive strategy of emergency shelter sites (U Value)

FID	Id	C11 effective capacity	C12 the slope	C21 residential	C22 medical	C23 fire - fighting	C24 water sources	C31 fault zones	C32 geological hazard	C33 explosive hazard	U
Location 16	204	0.70	0.91	0.86	0.93	0.90	0.45	0.30	0.31	0.25	0.5991
Location 12	302	1.00	0.90	0.84	0.87	0.33	0.64	0.19	0.16	0.35	0.5900
Location 32	109	0.51	0.65	0.78	0.99	0.83	0.29	0.62	0.20	0.24	0.5869

Location 25	409	0.04	0.81	0.99	0.49	0.11	0.04	0.96	0.69	0.18	0.5789
Location 27	111	0.00	0.82	0.82	1.00	0.75	0.27	0.64	0.35	0.32	0.5516
Location 26	113	0.14	0.81	0.75	0.41	0.00	0.00	1.00	0.47	0.29	0.5283
Location 17	412	0.03	0.98	1.00	0.87	1.00	0.41	0.29	0.03	0.35	0.5080
Location 24	205	0.03	0.85	0.21	0.76	0.44	0.16	0.82	1.00	0.18	0.4775
Location 15	404	0.02	0.73	0.76	0.86	0.68	0.51	0.39	0.18	0.23	0.4566
Location 22	107	0.75	0.90	0.21	0.30	0.73	0.82	0.00	0.63	0.79	0.4490
Location 20	105	0.33	0.92	0.79	0.11	0.24	0.96	0.14	0.62	0.33	0.4472
Location 5	101	0.10	0.92	0.96	0.00	0.09	1.00	0.14	0.91	0.16	0.4423
Location 14	301	0.32	0.97	0.59	0.96	0.45	0.61	0.24	0.09	0.20	0.4413
Location 10	102	0.02	0.16	0.91	0.55	0.27	0.75	0.10	0.25	0.89	0.4320
Location 6	104	0.04	0.94	0.87	0.17	0.31	0.94	0.12	0.45	0.45	0.4207
Location 8	103	0.23	0.46	0.70	0.36	0.58	0.85	0.05	0.22	0.85	0.4195
Location 21	110	0.18	0.54	0.79	0.23	0.40	0.91	0.13	0.28	0.60	0.4132
Location 3	203	0.17	0.45	0.77	0.85	0.66	0.49	0.22	0.16	0.05	0.4116
Location 19	407	0.00	0.60	0.83	0.96	0.73	0.38	0.12	0.11	0.26	0.4095
Location 7	402	0.01	0.75	0.61	0.48	0.48	0.82	0.05	0.18	1.00	0.4013
Location 11	106	0.19	0.73	0.48	0.68	0.18	0.72	0.19	0.13	0.72	0.3952
Location 33	406	0.02	1.00	0.51	1.00	0.51	0.59	0.27	0.12	0.17	0.3930
Location 18	405	0.01	0.27	0.59	0.69	0.69	0.43	0.46	0.07	0.23	0.3796
Location 9	401	0.04	0.95	0.41	0.35	0.67	0.84	0.05	0.43	0.83	0.3796
Location 28	112	0.03	0.55	0.58	0.32	0.53	0.88	0.11	0.32	0.71	0.3744
Location 2	202	0.01	0.00	0.71	0.84	0.64	0.48	0.19	0.24	0.12	0.3586
Location 13	403	0.02	0.87	0.47	0.99	0.64	0.54	0.27	0.00	0.02	0.3550
Location 29	410	0.01	0.77	0.44	0.92	0.63	0.52	0.25	0.08	0.02	0.3375
Location 1	201	0.12	0.09	0.48	0.89	0.57	0.50	0.19	0.25	0.11	0.3354
Location 23	408	0.05	0.90	0.00	0.27	0.79	0.80	0.02	0.69	0.90	0.3221
Location 4	206	0.01	0.07	0.45	0.97	0.64	0.54	0.25	0.03	0.01	0.3046
Location 30	411	0.02	0.41	0.55	0.82	0.49	0.37	0.02	0.18	0.00	0.2809
Location 31	108	0.12	0.43	0.06	0.71	0.38	0.31	0.06	0.12	0.20	0.1994

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