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

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## Background One

China earthquake networks Center

| 发震日期 | 发震时刻 | 纬度 (度.度) | 经度 (度.度) | 深度 (km) | 震级 | 参考地点 |
|---|---|---|---|---|---|---|
| 2015-04-25 | 14:11:26.3 | 28.2 | 84.7 | 20 | M8.1 | 尼泊尔 |
| 2014-04-02 | 07:46:47.0 | -19.6 | -70.7 | 10 | M8.1 | 智利北部沿岸近海 |
| 2013-05-24 | 13:44:49.2 | 54.9 | 153.3 | 600 | M8.2 | 鄂霍次克海 |
| 2012-04-11 | 18:43:12.4 | 0.8 | 92.4 | 20 | M8.2 | 苏门答腊北部附近海域 |
| 2012-04-11 | 16:38:36.5 | 2.3 | 93.1 | 20 | M8.6 | 苏门答腊北部附近海域 |
| 2011-03-11 | 13:46:21.0 | 38.1 | 142.6 | 20 | Mw9.0 | 日本本州东海岸附近海域 |
| 2010-02-27 | 14:34:16.4 | -35.8 | -72.7 | 33 | M8.8 | 智利 |
| 2009-09-30 | 01:48:15.3 | -15.5 | -172.2 | 33 | M8.0 | 萨摩亚群岛地区 |
| 2008-05-12 | 14:28:04.0 | 31.0 | 103.4 | 14 | M8.0 | 四川汶川县 |
| 2007-09-13 | 07:49:06.4 | -2.5 | 100.9 | 15 | M8.3 | 印尼苏门答腊南部海中 |
| 2007-09-12 | 19:10:23.9 | -4.4 | 101.5 | 15 | M8.5 | 印尼苏门答腊南部海中 |
| 2006-11-15 | 19:14:17.6 | 46.6 | 153.3 | 33 | M8.0 | 千岛群岛 |
| 2006-04-21 | 07:25:03.0 | 61.0 | 167.2 | 33 | M8.0 | 堪察加半岛东北地区 |
| 2005-06-14 | 06:44:32.2 | -19.9 | -69.2 | 96 | M8.1 | 智利北部 |
| 2005-03-29 | 00:09:34.6 | 2.2 | 97.0 | 33 | M8.5 | 苏门答腊北部 |

# Background Two

- **1989**: China international disaster reduction committee of ten years
- **1994,4**: disaster prevention and reduction ,china's agenda 21,Chapter 17,
- **1998**: disaster mitigation planning of PRC(1998-2010)
- **2005**: Rename National Disaster Reduction
- **2004**: the Emergency Regulations Regarding Emergency Public Health Incidents
- **2008,6**: The Recovery and Reconstruction Regulations of Wenchuan Earthquake

# Background Three

- To minimize losses of earthquake disaster and its accompanying disasters, to guarantee the land use requirement for post-disaster emergency response and reconstruction, and to achieve national economic smooth transition as soon as possible;
- To provide policy and decision-making reference aiming to the emergency response and reconstruction of earthquake disasters from the area of land management;
- To better improve our land use planning theory and practice;
- To better perform our responsibility for globalization obligation;


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# Theoretical Basis

- System Management
- Operations Research
- Land Use Planning Theory
- The Theory of Calamity
- Seismology

# Profile of study area

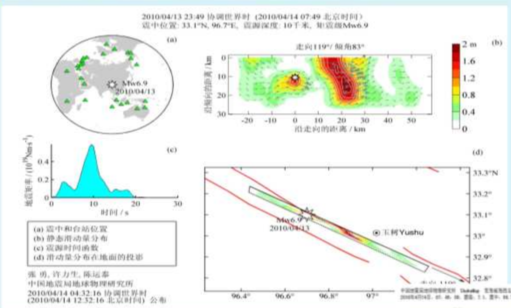
- Yushu Tibetan autonomous prefecture (hereinafter refer to as the Yushu prefecture)is located in the southwest of Qinghai province, PRC., north adjacent to Hercynian Mongolian Tibetan autonomous prefecture, east adjacent to Goluo Tibetan autonomous prefecture, southeast adjacent to Ganzi Tibetan autonomous prefecture of Sichuan province, south anc
of Changdu region and Naqu prefecture c
adjacent to Bayinguoleng Mongolian auto
Autonomous Region. There are six count
Nangqian, Qumalai. The capital of Yushu
permanent population of the whole state i
2.55 billion Yuan in 2010.

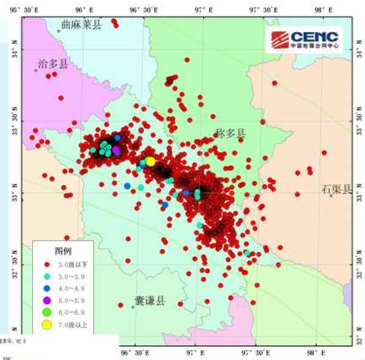
# Profile of study area

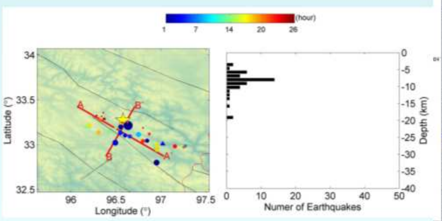
There is 7.1 magnitude earthquake in Yushu county of Yushu Tibetan autonomous prefecture in Qinghai province at 7:49, on April 14, 2010.The epicenter location is 96.6 N, 33.2 E, which is located in the mountain of 4300 meters above sea level in Yushu Tibetan autonomous prefecture of Qinghai province, from which Yushu county town (Yushu prefecture and Yushu county government)is about 42 km.

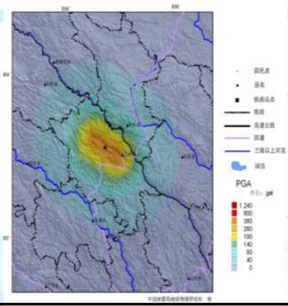
The depth of hypocenter is 14 km, and the highest intensity of earthquake is 9 degree, the fault zone is Yushu - Ganzi sinistral strike-slip faults, the intensity of meizoseismal area is Ⅸ degree. The affected scope is about 3 square kilometers, which causing heavy casualties and property losses.

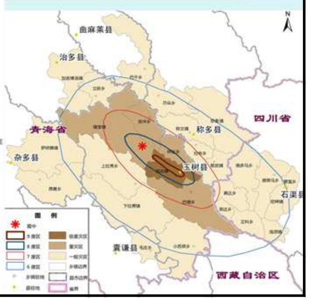
# Profile of study area











# Conception

- 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 capacity of quake victims and comprehensive facilities.

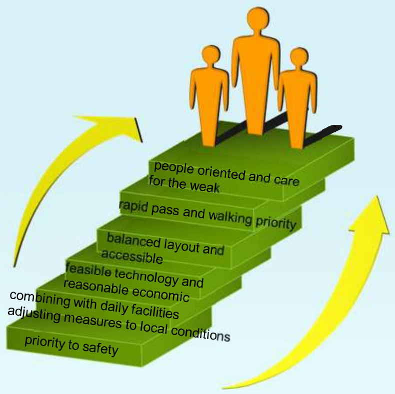
**temporary emergency shelters——basic facilities——10d**
**fixed emergency shelters——basic facilities——10-30d**
**center emergency shelters ——comprehensive facilities ——30dmore**

# Requirements

| Requirements | temporary emergency shelters | fixed emergency shelters | center emergency shelters |
|---|---|---|---|
| Safe distance from secondary disasters hazard(m) | 30m Fire safety belt，1000m safe distance | | |
| The average effective evacuation area(m2) | 1 | 2 | / |
| Sites areas（hm2） | 0.1 | 1 | 50 |
| Service radius(km)/(min) | 0.5/10 | 2-3/60 | / |
| Aisle width（m） | 4 | 7 | 15 |

# The principles of location-allocation

## System coordination tool , Main function include




**Safety** Premise

- unified planning, combine with daily facilities
- adjust measures to local conditions comprehensive utilization
- the nearest evacuation, security and accessible

# Geographical Spatial Geometric Network

- Geometric Network Model[117] can be interpreted as: A network is set by the node (the node) and the connecting arc [arc, or (branch)], expressed by symbols (N, A), hereinto, N is the set of nodes, A is the set of arcs.
- geographical spatial geometric network analysis[118] is that human activities always tend to be in a certain target selection to achieve the best effect of space position. The simulation of the network status and situation analysis shows the requirements of path analysis and network analysis, to assist in the visualization analysis of path problem (path finding), resource allocation problem (resource allocation), tracking problem (trace), spatial interaction (spatial interaction), the distance matrix computation (short for the matrix calculation) and location - configuration (the location allocation)

# location-allocation optimizing strategy

## P-median

设 $S = \{S_i | i = 1, 2, \cdots, m\}$：应急点的集合

$F = \{F_j | j = 1, 2, \cdots, n\}$：候选服务设施点的集合

$w_i$：应急点 $S_i$ 的权重；

$d_{ij}$：从应急点 $S_i$ 到候选服务设施点 $F_j$ 的距离；

p：可以建立的应急服务设施的总数（$p \le n$）；

$$x_j = \begin{cases} 1, & \text{若候选服务设施点} F_i \text{被选中} \\ 0, & \text{否则} \end{cases}$$

$$y_{ij} = \begin{cases} 1, & \text{若应急点} S_i \text{由候选服务设施点} F_i \text{来提供服务} \\ 0, & \text{否则} \end{cases}$$

数学模型为：

$$\min z = \sum_{i=1}^{m} \sum_{j=1}^{n} w_i d_{ij} y_{ij} \quad \text{（公式 4-1）}$$

$$s.t. \quad \sum_{j=1}^{n} y_{ij} = 1, \quad i = 1, 2, \cdots, m \quad \text{（公式 4-2）}$$

$$y_{ij} - x_j \le 0, \quad i = 1, 2, \cdots, m; j = 1, 2, \cdots, n \quad \text{（公式 4-3）}$$

$$\sum_{j=1}^{n} x_j = p \quad \text{（公式 4-4）}$$

$$y_{ij}, x_j \in \{0, 1\}, \quad i = 1, 2, \cdots, m; j = 1, 2, \cdots, n \quad \text{（公式 4-5）}$$

## P-center

设 $S = \{S_i | i = 1, 2, \cdots, m\}$：应急点的集合

$F = \{F_j | j = 1, 2, \cdots, n\}$：候选服务设施点的集合

D:为应急点到已设定的候选服务设施的最大距离；

p：可以建立的应急服务设施的总数（$p \le n$）；

$$x_j = \begin{cases} 1, & \text{若候选服务设施点} F_i \text{被选中} \\ 0, & \text{否则} \end{cases}$$

$$y_{ij} = \begin{cases} 1, & \text{若应急点} S_i \text{由候选服务设施点} F_i \text{来提供服务} \\ 0, & \text{否则} \end{cases}$$

数学模型为：

$$\min D \quad \text{（公式 4-6）}$$

$$s.t. \quad \sum_{j=1}^{n} y_{ij} = 1, \quad i = 1, 2, \cdots, m \quad \text{（公式 4-7）}$$

$$y_{ir} - x_j \le 0, \quad i = 1, 2, \cdots, m; j = 1, 2, \cdots, n \quad \text{（公式 4-8）}$$

$$\sum_{j=1}^{n} x_j = p \quad \text{（公式 4-9）}$$

$$D - \sum_{j=1}^{n} d_{ij} y_{ij} \ge 0, \quad i = 1, 2, \cdots, m \quad \text{（公式 4-10）}$$

$$y_{ij}, x_j \in \{0, 1\}, \quad i = 1, 2, \cdots, m; j = 1, 2, \cdots, n \quad \text{（公式 4-11）}$$

# location-allocation optimizing strategy

## LSCP

（ Set covering location model ）

$$\min z = \sum_{j=1}^{n} x_j \quad \text{（公式 4-12）}$$

$$s.t. \quad \sum_{j=1}^{N_i} x_j \ge 1 \quad \forall i \in I \quad \text{（公式 4-13）}$$

$$x_j = 0 \vee 1 \quad \forall j \in J \quad \text{（公式 4-14）}$$

## MCLP

（Maximum set covering location model ）

$$\max z = \sum_{i=1} a_i y_i \quad \text{（公式 4-15）}$$

$$s.t. \quad \sum_{j=1}^{N_i} x_j \ge y_i, \quad 1 \le i \le n$$

$$\sum_{j=1}^{n} x_j = p$$

$$x_j = 0 \vee 1 \quad \forall j$$

$$y_i = 0 \vee 1 \quad \forall i$$

# location-allocation optimizing strategy

**BACOP1**

（ Backup coverage model ）

BACOP1

$$\max imize \sum_{i \in V} d_i u_i$$

Subject to

$$\sum_{j \in \pi_i} x_j = p$$

$$0 \le u_i \le 1 (i \in V)$$

$$x_j \ge 0 (i \in V)$$

**BACOP2**

（ Backup coverage model ）

BACOP2

$$\max imize \theta \sum_{i \in V} d_i y_i + (1 - \theta) \sum_{i \in V} d_i u_i$$

Subject to

$$\sum_{j \in W_i} x_j - y_i - u_i \ge 0 (i \in V)$$

绘图区

$$u_i - y_i \le 0 (i \in V)$$

$$\sum_{j \in w} x_i = p$$

$$0 \le u_i \le 1 (i \in V)$$

$$0 \le y_i \le 1 (i \in V)$$

$$x_j \ge 0 (i \in W)$$

# Several distance measuring geographic space

**Euclidean distance**

$$d_{12} = \sqrt{[(x_1 - x_2)^2 + (y_1 - y_2)^2]}$$

$$d_{12} = r * a\cos[\sin b * \sin d + \cos b * \cos d * \cos(c - a)]$$

**Network distance**

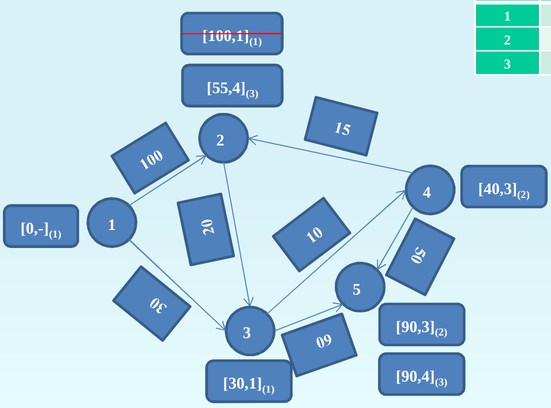
**Manhattan distance**

$$d_{12} = |x_1 - x_2| + |y_1 - y_2|$$

# Dijkstra shortest path algorithm

$$[u_j, i] = [u_i + d_{ij}, i] \qquad d_{ij} \geq 0$$

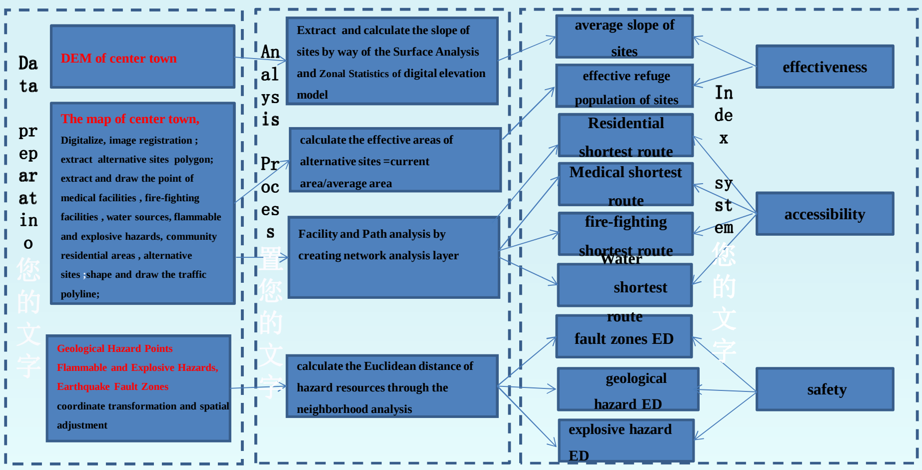
| node | mark | state |
|---|---|---|
| 1 | [0,-] | permanent |
| 2 | [0+100,1]=[100,1] | temporary |
| 3 | [0+30,1]=[30,1] | temporary |




| node | mark | state |
|---|---|---|
| 1 | [0,-] | permanent |
| 2 | [100,1] | temporary |
| 3 | [30,1] | permanent |
| 4 | [30+10,3]=[40,3] | temporary |
| 5 | [30+60,3]=[90,3] | temporary |

| node | mark | state |
|---|---|---|
| 1 | [0,-] | permanent |
| 2 | [40+15,4]=[55,4] | temporary |
| 3 | [30,1] | permanent |
| 4 | [40,3] | permanent |
| 5 | [90,3]或者[40+50,4]=[90,4] | temporary |

# Research methods



# Evaluation Indexes System

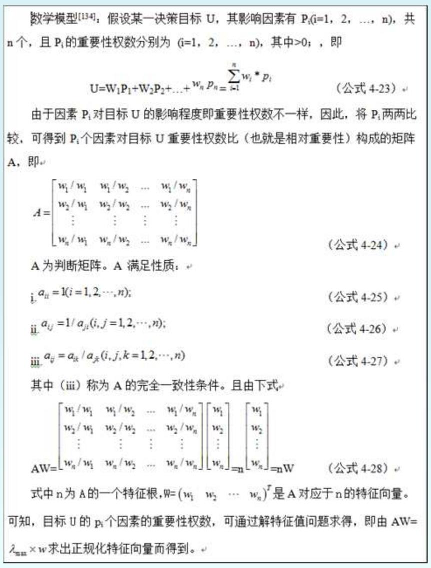
| | | | | |
|---|---|---|---|---|
| A the optimization strategy of location-allocation | B1 effectiveness | 0.2 | C11 effective refuge capacity (population) | 0.15 |
| | | | C12 the average slope of alternative sites | 0.05 |
| | B2 accessibility | 0.4 | C21 the shortest route of community residential 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 |

# Quantitative evaluation indexes

**Uniform index dimension using the linear utility function**

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

# Determine the weight of indexes



数学模型[134]，假设某一决策目标 U，其影响因素有 $P_i$(i=1，2，…，n)，共 n 个，且 $P_i$ 的重要性权数分别为 (i=1，2，…，n)，其中>0；，即

$$U=W_1P_1+W_2P_2+\ldots+w_n p_n=\sum_{i=1}^{n} w_i * p_i \quad \text{（公式 4-23）}$$

由于因素 $P_i$ 对目标 U 的影响程度即重要性权数不一样，因此，将 $P_i$ 两两比较，可得到 $P_i$ 个因素对目标 U 重要性权数比（也就是相对重要性）构成的矩阵 A，即

$$A=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \ldots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \ldots & w_2/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & \ldots & w_n/w_n \end{bmatrix} \quad \text{（公式 4-24）}$$

A 为判断矩阵。A 满足性质：

i. $a_{ii}=1(i=1,2,\cdots,n);$ （公式 4-25）

ii. $a_{ij}=1/a_{ji}(i,j=1,2,\cdots,n);$ （公式 4-26）

iii. $a_{ij}=a_{ik}/a_{jk}(i,j,k=1,2,\cdots,n)$ （公式 4-27）

其中（iii）称为 A 的完全一致性条件。且由下式

$$AW=\begin{bmatrix} w_1/w_1 & w_1/w_2 & \ldots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \ldots & w_2/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & \ldots & w_n/w_n \end{bmatrix}\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}=n\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}=nW \quad \text{（公式 4-28）}$$

式中 n 为 A 的一个特征根，$W=(w_1 \quad w_2 \quad \cdots \quad w_n)^T$ 是 A 对应于 n 的特征向量。可知，目标 U 的 $p_i$ 个因素的重要性权数，可通过解特征值问题求得，即由 $AW=\lambda_{max}\times w$ 求出正规化特征向量而得到。

- Analytic Hierarchy Process (AHP)
- Clear problem and build hierarchy analysis diagram
- Construct comparative judgment matrix
- Calculate the maximum eigenvalue and eigenvector
- Consistency check
- Range and order

# The comprehensive location-allocation model

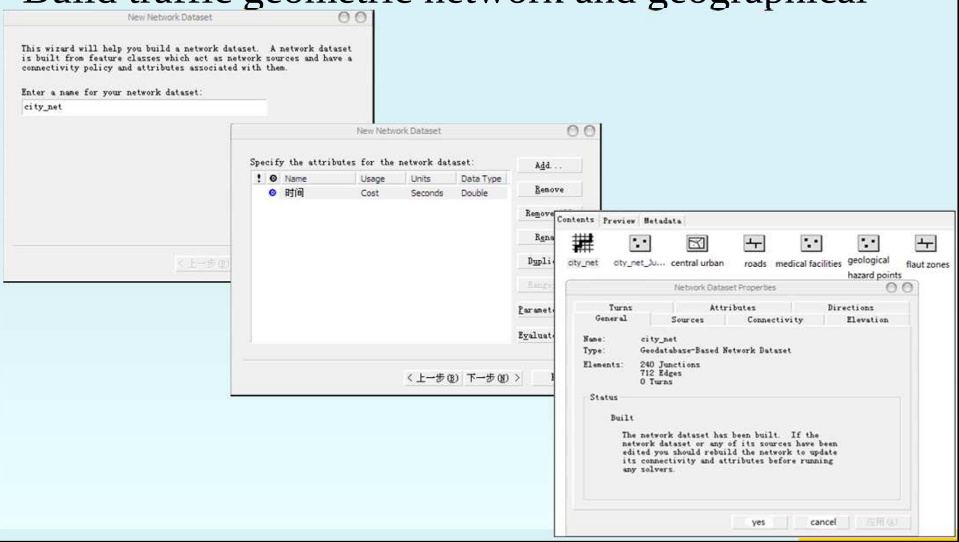
- arithmetic average method
- $C=\sum_{i=1}^{n} w_i k_i$ , hereinto， $\sum_{i=1}^{n} w_i=1$

# Range the location level

- When C≥0.5, alternative emergency shelter is the best location;
- When 0.4＜C≤0.5, alternative emergency shelter is a suboptimal scheme;
- When0.3＜C≤0.4, it means generally matching the requirements of safe, effective and accessible;
- When C＜0.3, it is not suitable for an emergency shelter.

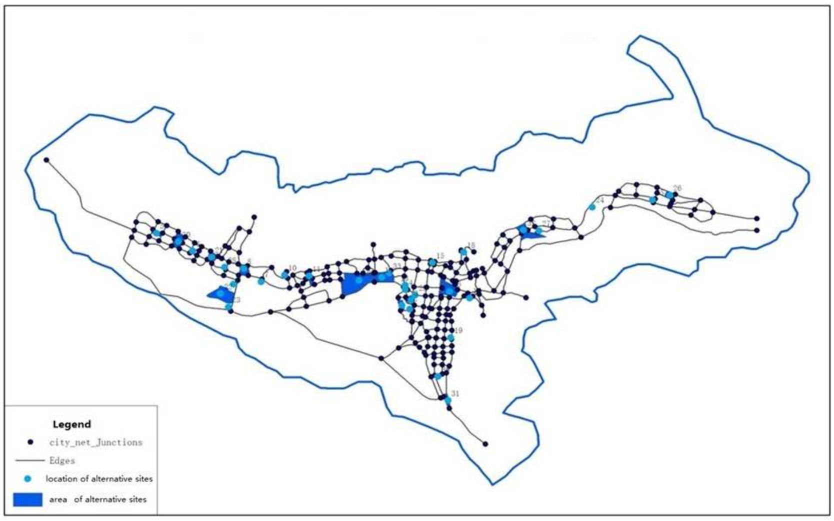
# Demonstration

- Build traffic geometric network and geographical



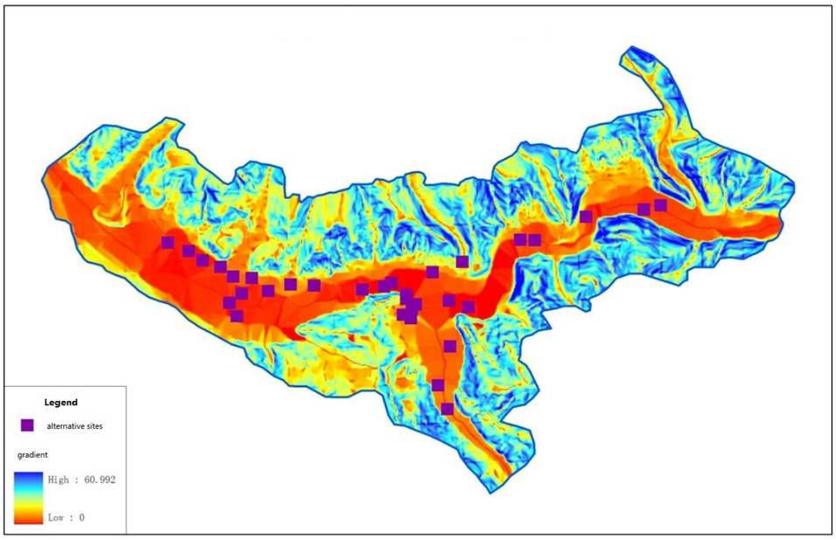
## The effective refuge capacity

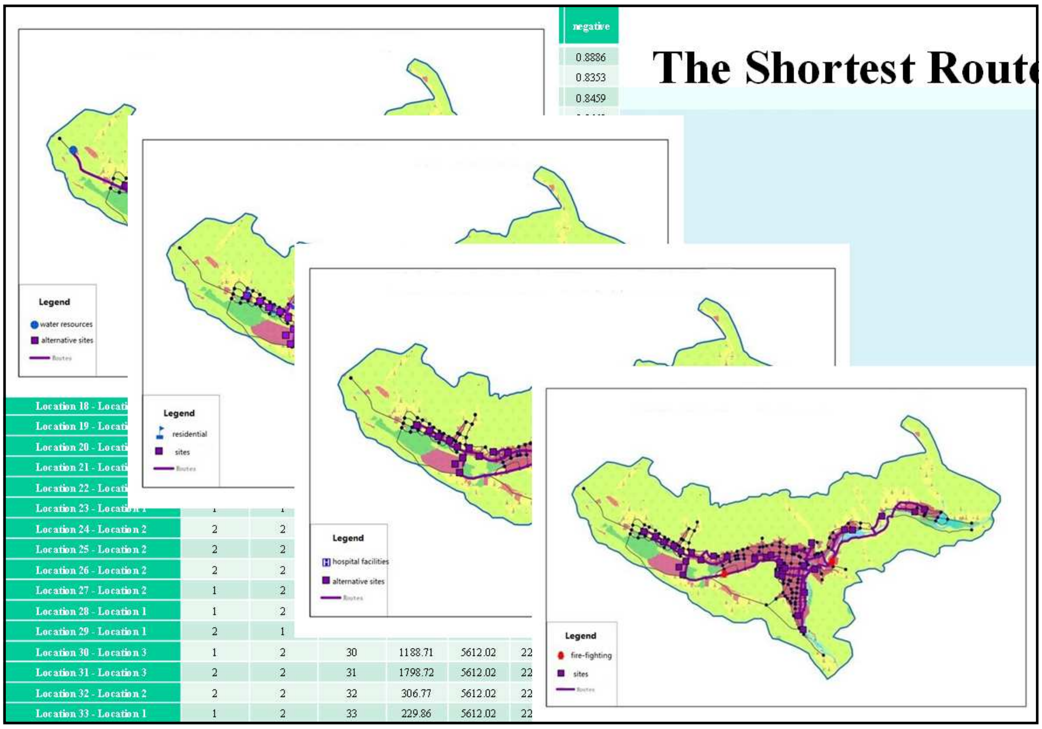
| FID | Id | sites | SHAPE_Area | effective refuge areas | effective refuge population | upper | lower | positive |
|---|---|---|---|---|---|---|---|---|
| Location 1 | 201 | 广场 | 21840.22 | 15288.15 | 7644 | 58185.19 | 893.82 | 0.1178 |
| Location 2 | 202 | 广场 | 3876.20 | 2713.34 | 1357 | 58185.19 | 893.82 | 0.0081 |
| Location 3 | 203 | 广场 | 30054.14 | 21037.90 | 10519 | 58185.19 | 893.82 | 0.1680 |
| Location 4 | 206 | 广场 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| Location 5 | 101 | 绿地 | | | | | | |
| Location 6 | 104 | 绿地 | | | | | | |
| Location 7 | 402 | 停车场 | | | | | | |
| Location 8 | 103 | 绿地 | | | | | | |
| Location 9 | 401 | 停车场 | | | | | | |
| Location 10 | 102 | 绿地 | | | | | | |
| Location 11 | 106 | 绿地 | | | | | | |
| Location 12 | 302 | 公园 | | | | | | |
| Location 13 | 403 | 停车场 | | | | | | |
| Location 14 | 301 | 公园 | | | | | | |
| Location 15 | 404 | 停车场 | | | | | | |
| Location 16 | 204 | 广场 | | | | | | |
| Location 17 | 412 | 停车场 | | | | | | |
| Location 18 | 405 | 停车场 | | | | | | |
| Location 19 | 407 | 停车场 | | | | | | |
| Location 20 | 105 | 绿地 | | | | | | |
| Location 21 | 110 | 绿地 | | | | | | |
| Location 22 | 107 | 绿地 | | | | | | |
| Location 23 | 408 | 停车场 | | | | | | |
| Location 24 | 205 | 广场 | | | | | | |
| Location 25 | 409 | 停车场 | | | | | | |
| Location 26 | 113 | 绿地 | | | | | | |
| Location 27 | 111 | 绿地 | | | | | | |
| Location 28 | 112 | 绿地 | | | | | | |
| Location 29 | 410 | 停车场 | | | | | | |
| Location 30 | 411 | 停车场 | | | | | | |
| Location 31 | 108 | 绿地 | | | | | | |
| Location 32 | 109 | 绿地 | | | | | | |

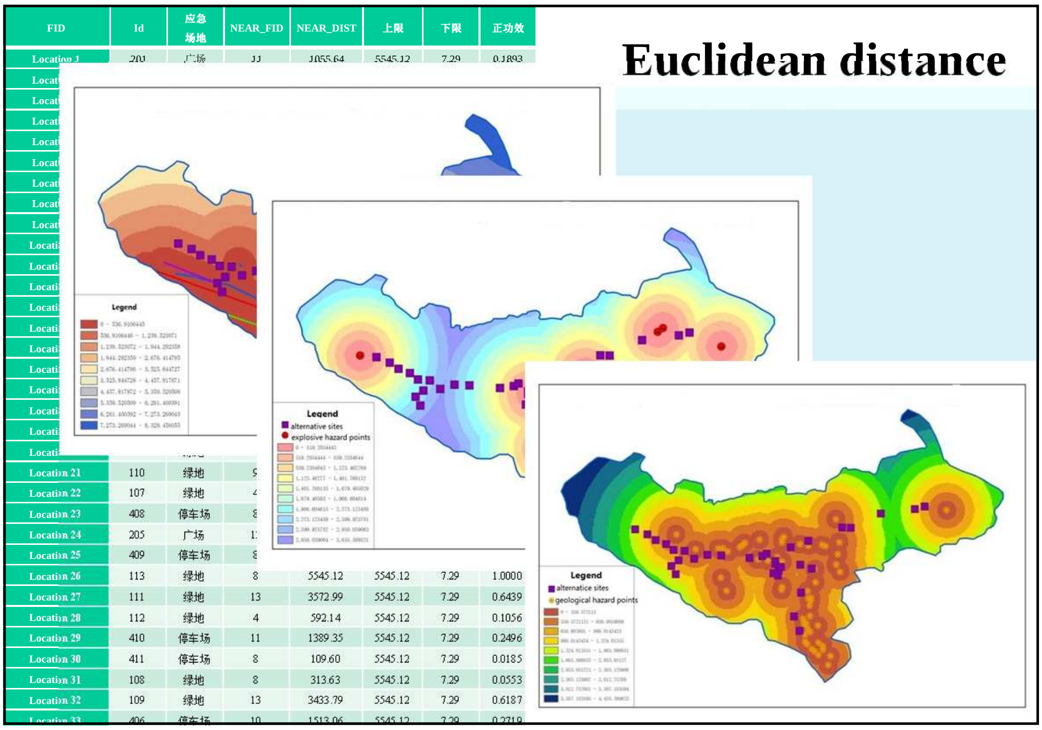



## The average slope

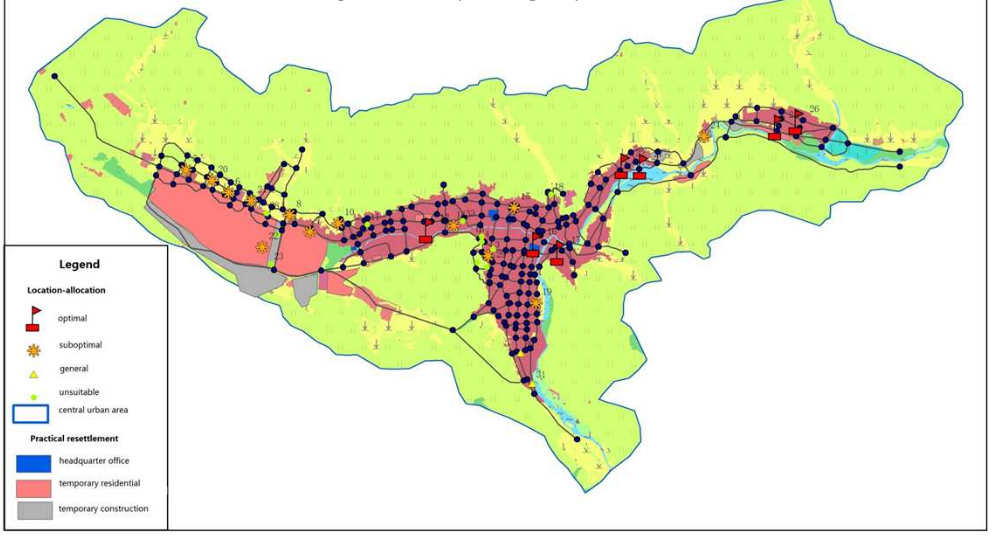
| FID | Id | sites | slope | lower | upper | negative |
|---|---|---|---|---|---|---|
| Location 1 | 201 | 广场 | 9.19 | 10.13 | 0.00 | 0.0928 |
| Location 2 | 202 | 广场 | 10.13 | 10.13 | 0.00 | 0.0000 |
| Location 3 | 203 | 广场 | 5.56 | 10.13 | 0.00 | 0.4511 |
| Location 4 | 206 | 广场 | 9.40 | 10.13 | 0.00 | 0.0721 |
| Location 5 | 101 | 绿地 | 0.85 | 10.13 | 0.00 | 0.9161 |
| Location 6 | 104 | | | | | |
| Location 7 | 402 | | | | | |
| Location 8 | 103 | | | | | |
| Location 9 | 401 | | | | | |
| Location 10 | 102 | | | | | |
| Location 11 | 106 | | | | | |
| Location 12 | 302 | | | | | |
| Location 13 | 403 | | | | | |
| Location 14 | 301 | | | | | |
| Location 15 | 404 | | | | | |
| Location 16 | 204 | | | | | |
| Location 17 | 412 | | | | | |
| Location 18 | 405 | | | | | |
| Location 19 | 407 | | | | | |
| Location 20 | 105 | | | | | |
| Location 21 | 110 | | | | | |
| Location 22 | 107 | | | | | |
| Location 23 | 408 | | | | | |
| Location 24 | 205 | | | | | |
| Location 25 | 409 | | | | | |
| Location 26 | 113 | | | | | |
| Location 27 | 111 | | | | | |
| Location 28 | 112 | | | | | |
| Location 29 | 410 | | | | | |
| Location 30 | 411 | | | | | |
| Location 31 | 108 | | | | | |
| Location 32 | 109 | | | | | |
| Location 33 | 406 | | | | | |




The Shortest Route
Legend
water resources
alternative sites
residential
sites
hospital facilities
alternative sites
fire-fighting
sites

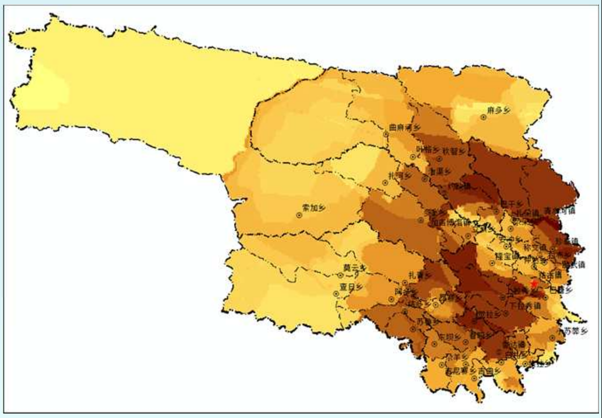

Euclidean distance
Legend
alternative sites
explosive hazard points
Legend
alternatice sites
geological hazard points

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.




# Research Prospect

- anti-seismic suitability evaluation of construction land
- disaster emergency and prevention decision-making system
- earthquake disaster evaluation based on remote-sensing image
- dynamic uncertainty location




Thanks
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