RESEARCH ON EMERGENCY RESCUE RESPONSE IN WENCHUAN COUNTY IN CHINA BASED ON BAIDU MAP NAVIGATION DATA

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ABSTRACT:

Earthquake disasters often cause massive casualties and property losses, so it is essential to achieve rapid emergency rescue response. Although many scholars have studied the speed of emergency rescue response from different perspectives, there are still many problems in the impact of road congestion on travel paths and distances, as well as the timeliness of the road network. Therefore, this study calculated the travel distance from the rescue point to the disaster point using the path planning method based on the Baidu map navigation data, and obtained the distribution map of the emergency rescue response level in Wenchuan County, Sichuan Province, China. The results show that :(1) the path planning method based on Baidu map navigation data is more realistic and accurate than the traditional method. (2) there are apparent spatial differences in the emergency rescue response in Wenchuan County, and the emergency rescue response level in Weizhou town in the north is higher than that in Wolong and Sanjiang town in the southwest. The research results have significant reference value for planning emergency rescue routes and improving rescue speed in Wenchuan County and similar counties.

1. INTRODUCTION

Longmenshan fault zone is a high incidence area of earthquake disasters in China (Ran et al., 2010). The Wenchuan earthquake, with a magnitude of 8.0, occurred on May 12, 2008, and the Lushan earthquake, with a magnitude of 7.0, occurred on April 20, 2013 (Zhao et al., 2020). Earthquake disasters not only seriously threaten the safety of the people, but also have a massive impact on the local economic development. Therefore, to reduce casualties and property losses, improving the response speed of emergency rescue is essential (Tang et al., 2018). The response speed of emergency rescue generally includes two critical time points (Xiao and Tian, 2009): First, the time from the occurrence of the earthquake to the departure of the emergency rescue team, which is mainly affected by disaster warning and notification speed. Second, the time from the rescue team to the point of disaster is primarily influenced by the rescue team's velocity, travel path, and road congestion on the way.

At present, domestic and foreign scholars have carried out a lot of research on emergency rescue response. Wen et al. believed that the arrival time of emergency rescue vehicles in the disaster area was affected by the traffic path (Wen et al., 2019). By analyzing the uncertain factors (such as dynamic traffic environment and traffic congestion), the path planning method is used to select the optimal path to ensure that rescue personnel and materials arrive at the fastest speed and ensure the safety of people's lives and property (Shi et al., 2022). Tang et al. established the shortest path calculation model based on GIS network analysis, analyzed and calculated the railway network data set, and obtained the shortest distance from emergency rescue point to disaster point, which provided a reference for the selection of emergency rescue path of railway emergencies (Tang et al., 2019). Xu et al. proposed an improved A-star algorithm to realize the rapid planning of the emergency rescue path of moving objects in a roadless environment (Xu et al., 2022). Wen et al. proposed a co-evolutionary optimization algorithm to solve the low efficiency of urban road congestion emergency rescue, which realized the co-evolution of sub-path weight function and future environmental dynamics (Wen et al., 2020). Long et al. believed that the focus of emergency rescue was the timeliness and accuracy of transportation tasks and proposed using online GIS to coordinate emergency transportation tasks (Long, 2021). Huang et al. believed that the formulation of social emergency rescue rules significantly influenced social emergency rescue activities. They constructed a static and dynamic game model between government and enterprises in emergency management and improved the advancement of emergency rescue technology products (Huang and Gao, 2020). Tang et al. established an emergency rescue decision-making system, re-planning the rescue points based on costs and needs, reducing the total weighted rescue time, and improving the coverage rate of rescue services (Tang and Sun, 2018). Li et al. optimized the emergency logistics network, accelerated the logistics process, and reduced the rescue time in response to the impact of secondary disasters in emergency rescue work (Li et al., 2021). The above research mainly obtains the shortest path from rescue point to disaster point by constructing GIS network and Euclidean distance, coordinates emergency transportation tasks, and accelerates the emergency rescue response speed. However, the timeliness and accuracy still cannot meet the actual needs. Therefore, it is urgent to conduct relevant research to solve the above problems.

In summary, taking the emergency rescue response in Wenchuan County, Sichuan Province, China .as an example, based on Baidu map navigation data, this study uses the path planning method to accurately obtain the travel distance from the rescue point to the disaster point and obtains the distribution map of emergency rescue response level in Wenchuan County, which improves the efficiency of emergency rescue. These findings can provide data support and reference for site selection, command, and dispatch

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of emergency rescue planning in Wenchuan County. (Cao et al., 2018; Dong and Cui, 2021; Guo et al., 2021; Wang et al., 2021).

2. STUDY AREA AND DATA SOURCES

2.1 Overview of the study area

Wenchuan is a county under Aba Tibetan and Qiang Autonomous Prefecture in Sichuan Province, China. It is northwest of Sichuan Province and on the southeastern edge of the Qinghai-Tibet Plateau. It is named after the Minjiang River. There are Duwen Expressway and National Highway 213 and 350 in the territory, and nine towns under its jurisdiction. According to the seventh census data, the permanent population is more than 80,000. The geographic coordinates are between 30° 45′~31°43′N and 102°51′~103°44′E. The county is 84 kilometres wide from east to west, 105 kilometres long from north to south, and covers an area of 4084 square kilometres. The terrain in Wenchuan County is inclined from northwest to southeast, and the west is mostly distributed in the mountains above 3,000 meters above sea level, while the exit of the Minjiang River in the south-eastern Xuankou County is only 780 meters above sea level. The schematic diagram of the study area is shown in Figure 1.

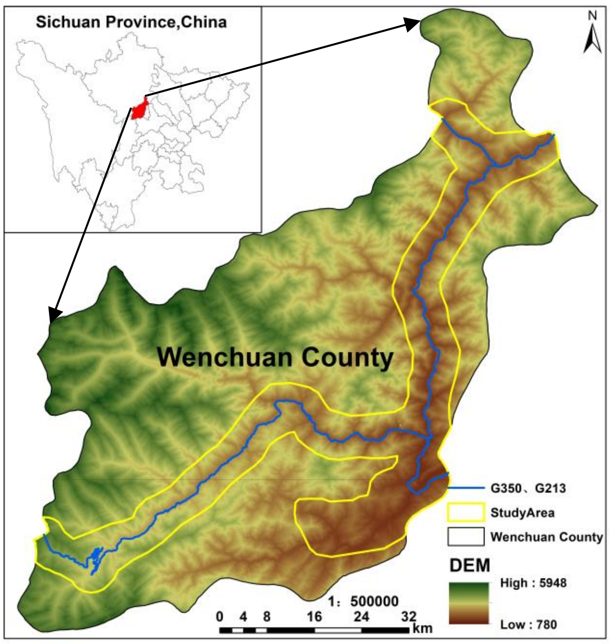

Figure 1. The study area: Wenchuan County.

2.2 Data sources

The main data of this study include Sichuan Province road network data, Baidu map navigation data and Wenchuan County POI (Point of Interest) data. More than 2300 residential points were collected, as shown in Table 1, and these are all distributed near G213 and G350. Therefore, to cover all residential points in the study area, this study establishes a 3km buffer zone with G213 and G350 as the center and extends to Sanjiang Town to include all residential points data.

Num	Lon	Lat	POI_ID
0	103.58135	31.46998	1105183
1	103.58076	31.47355	1112402
2	103.58391	31.48018	1123119
…	…	…	…
2315	103.49782	31.18375	9563542
2316	103.48448	31.3335	9563543
2317	103.58596	31.48062	96316780

Table 1. Examples of residential points.

3. RESEARCH METHODS

This study uses Baidu map navigation data, POI data, and road network data to conduct emergency rescue response research. Firstly, according to the distribution of POI on the road network, the POI data is processed to remove redundant data and reduce the amount of calculation. Secondly, to obtain the traffic factor, the path planning is established using Baidu map navigation data, taking Wenchuan County Comprehensive Emergency Rescue Center as the origin and the processed residential points as the destinations. Finally, the traffic factor is normalized to reduce the influence between different dimensions. The spatial quantification of the traffic factor is carried out by the kriging interpolation method, and the distribution of emergency rescue response level in the whole study area is obtained. The study technology route is shown in Figure 2.

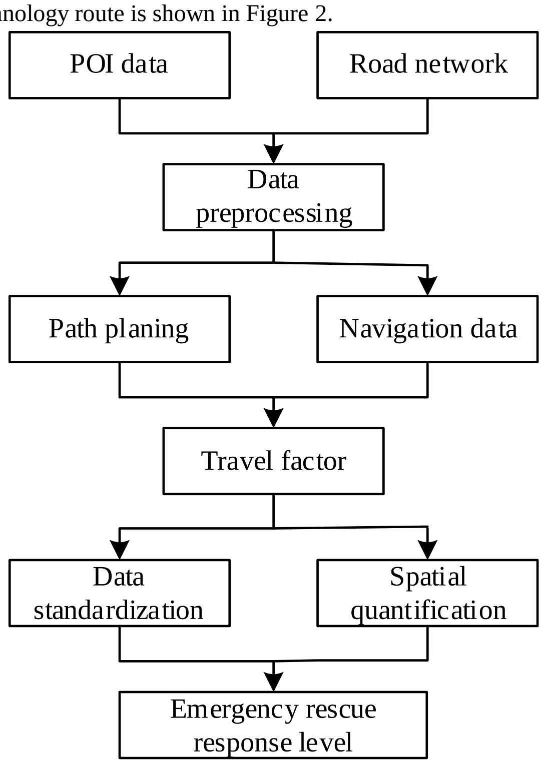

Figure 2. Technology route.

3.1 POI data processing

In this study, more than 2300 residential points were collected. Due to some residential points' geographical overlap or close distance, the emergency rescue response distance is almost the same. The repeated calculation of closely connected residential areas will cause too much calculation. Therefore, it is necessary to preprocess the POI data first.
Preprocessing principles:
(1) If the distance between two residential points is less than 50 meters, they should be considered one point.

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(2) If the distance between two residential points is less than 50 meters, but they are not on the same straight road, or there are residential points at the corner of the road, they should be retained.

3.2 Travel factor calculation

The travel factor is the actual travel distance from the origin to the destination, calculated based on processed POI data. This study established the path planning using Baidu map navigation data, taking Wenchuan County Comprehensive Emergency Rescue Center as the origin and the residential points as the destinations. According to the traffic conditions in the study area, there are generally multiple paths. However, traffic congestion may occur during morning and evening rush hours at different times. Therefore, the distance of the optimal path can be calculated using Baidu map navigation data as the travel factor.

3.3 Data normalization

After getting the travel factor of residential points in the study area, it is necessary to normalize the data. Data normalization is to scale the data proportionally so that it can fall into a small specific interval, remove the limitation of data units, and convert them into pure dimensionless values, which is convenient for the comparison and weighting indicators of different units or orders of magnitude. Data normalization can accelerate the gradient decline and improve the speed and accuracy of solving the optimal solution. Because the travel factor values are relatively concentrated, and the min-max method can well retain this feature, this study uses the min-max method for normalization. The formula is shown in (1):

$$x^* = \frac{x - min}{max - min} \tag{1}$$

where x^* is the normalized result, max is the maximum value of the data, and min is the minimum value of the data.

3.4 Spatial Quantization

To get the distribution of emergency rescue response level in the study area, the normalized data need to be quantified spatially. This study uses the Kriging interpolation method for spatial quantization (Kleijnen and van Beers, 2022; Meng, 2021). This interpolation method has the following two advantages:
(1) In the process of data gridding, the spatial correlation property of the description object is considered, which makes the interpolation result more scientific and closer to the actual situation.
(2) This method can give the interpolation error, that is, Kriging variance, so that the interpolation results are precise.
Kriging interpolation method is shown in (2):

$$\hat{z}_0 = \sum_{i=1}^{n} \lambda_i z_i \tag{2}$$

Where $\hat{z}_0$ is the estimated value at point (x_0, y_0), and $z_0 = z(x_0, y_0)$. λ_i is the weight coefficient, which is also the weighted sum of all known points in space to estimate the values of unknown points. However, the weight coefficient is not the reciprocal of distance, but a set of optimal coefficients that can meet the minimum difference between the estimated value $\hat{z}_0$ and the actual value z_0 at the point (x_0, y_0), as shown in (3):

$$\lambda_i = \min[Var(\hat{z}_0 - z_0)] \tag{3}$$

At the same time, the spatial quantization result $\hat{z}_0$ needs to meet the conditions of unbiased estimation, as shown in (4):

$$E(\hat{z}_0 - z_0) = 0 \tag{4}$$

4. RESULTS ANALYSIS

4.1 Comparative analysis of different methods

4.1.1 Euclidean distance method. Euclidean distance is the most common distance metric, which measures the absolute distance between two points in a multidimensional space. In the Euclidean distance method, the distance is generally calculated from the Cartesian coordinates of these points using the Pythagorean theorem. In geography, considering the influence of the curvature of the earth, the longitude and latitude coordinates of two points are generally used to calculate the shortest distance along the surface of the earth between two points. The formula is shown in (5):

$$\mathrm{d} = 2r \cdot \arcsin\left(\sqrt{\sin^2\left(\frac{\phi_2 - \phi_1}{2}\right) + \cos(\phi_1)\cos(\phi_2)\sin^2\left(\frac{\lambda_2 - \lambda_1}{2}\right)}\right) \cdot \frac{\pi}{180} \tag{5}$$

Where d is the Euclidean distance from point 1 to point 2, r is the radius of the earth, (λ_1, ϕ_1) and (λ_2, ϕ_2) are the longitude and latitude coordinates of point 1 and point 2, respectively. The Euclidean distance method ignores the spatial obstacles, cannot consider the road network and traffic conditions, and can only obtain the spatial straight-line distance between the two points.

4.1.2 GIS Network Analysis method. GIS network analysis based on road network data can be realized with ArcGIS software, and the shortest path can be obtained from the origin to the destination. The method first loads the road network data of the study area and reconstructs the topological structure of the road network data to obtain the road network data set. Then, according to the functional properties of the road, the roads that cannot be driven (such as pedestrian streets, trestle roads, and other non-vehicle roads) are removed. The length of each section is calculated, and the stop points, obstacle points, and road impedance are set. Among them, the obstacle points are generally inaccessible sections or locations caused by road maintenance. Road impedance refers to the average travel time, distance, and cost of vehicles passing through the road to indicate the traffic difficulty of the road section or the whole road network. Because some nodes in the road network data do not fall directly on some lines in the road network, or the road network data is not clear, it does not cover some nodes. Therefore, before calculating the shortest path, we need to do neighborhood analysis on these nodes and connect them to the actual road with the shortest vertical distance. Finally, the shortest path and travel distance of the origin and destination are obtained using ArcGIS software's path analysis function.
After practical verification, there are some problems with the GIS network analysis method: (1) It is difficult to obtain accurate road network data in remote areas, and the update speed of road network information is slow. (2) The obstacle points and road

impedance in GIS network analysis method need to be manually set according to the actual road conditions. When the road information changes, this method dramatically reduces analysis efficiency. (3) If the origin and destination are within the apartment complexes, only using the neighborhood analysis method is no longer applicable, and it is also necessary to identify the entrance to assist the calculation.

4.1.3 Comparative analysis. this study compares and analyzes each research method based on travel distance to study the differences among Euclidean distance, GIS network analysis and path planning based on Baidu map navigation data. As shown in Figure 3.

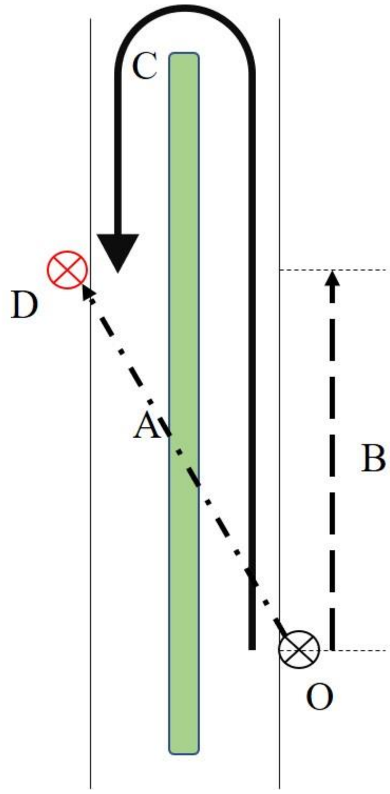

Figure 3. Schematic diagram of three methods.

In Figure 3, point O is the origin, point D is the destination, and the middle of the road is a green belt or isolation fence, which cannot be crossed. A, B and C are the distances of Euclidean distance, GIS Network analysis, and path planning based on Baidu map navigation data respectively.

As can be seen from Figure 3, the Euclidean distance only considers the straight-line distance between two points, ignoring the fact that travel should be along the road in real life; Although the method of GIS network analysis realizes driving along the road, it ignores the problem that the origin and destination are not on the same side of the road, failing to reach the actual destination. Path planning based on Baidu map navigation data can solve the above problems effectively. At the same time, Baidu map navigation data can choose the optimal path according to traffic congestion and waiting for traffic lights on different paths.

4.2 Distribution of emergency rescue response level based on Baidu map navigation data

This study uses Baidu map navigation data to establish the path planning for the integrated emergency rescue center and residential points in Wenchuan County, and obtains the travel factors of emergency rescue response in Wenchuan County, as shown in Table 2. Table 2 shows that the minimum travel factor is 68, and the maximum is 186245 in the study area.

POI_ID	Lon	Lat	Travel factor
18879896	103.59372	31.47839	68
9548805	103.58931	31.47832	536
4872695	103.58792	31.47921	580
…	…	…	…
606196328	103.13964	30.99552	105032
601196245	103.11627	30.96729	109368
92772875	102.90816	30.89604	186245

Table 2. Travel factors.

The obtained travel factors are normalized to obtain the distribution of residential points, as shown in Figure 4. The magnitude of the slope indicates the degree of clustering of residential points. The smaller the slope indicates the more concentrated the residential points, and the larger the slope indicates the more dispersed the residential points. The distribution of residential points shows the clustering phenomenon at a certain location in the study area. From Figure 4, the residential points in Wenchuan County are mainly concentrated in the travel factors of 0 to 0.2, 0.5 to 0.6, and 0.7, which is in line with the actual clustering situation.

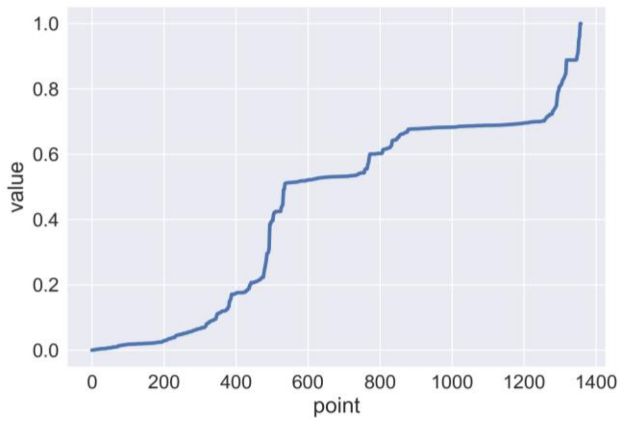

Figure 4. Distribution of travel factors normalization.

To further explore the aggregation of travel factors, this study counts the distribution of travel factors, and divides the traffic situation into 10 levels according to the equidistant segmentation method, as shown in Figure 5 and Figure 6. From Figure 5, the travel factors are mainly clustered around 0-0.1, 0.5-0.6, and 0.6-0.7 in Wenchuan County. There are 346 residential points with travel factors from 0 to 0.1, corresponding to Wolong Town and Xuankou Town in the southwest of Wenchuan County. There are 236 residential points with travel factors from 0.5 to 0.6, corresponding to Mianshi Town and Yinxing Town in the central part of Wenchuan County. There are 476 residential points with travel factors from 0.6 to 0.7, corresponding to Keku Town and Weizhou Town near the emergency rescue center in northern Wenchuan County. From Figure 6, the travel factors of 39% of the residential points are from 0 to 0.5, the travel factors of 61% of the residential points are from 0.5to 1.0, and the travel factors of most of the residential areas are greater than 0.5. The above results show that most of the residential points in Wenchuan County are concentrated in areas with good traffic conditions in the north, near the Wenchuan County Emergency Rescue Center, which is convenient for the rapid arrival of emergency rescue teams and the implementation of rescue operations.

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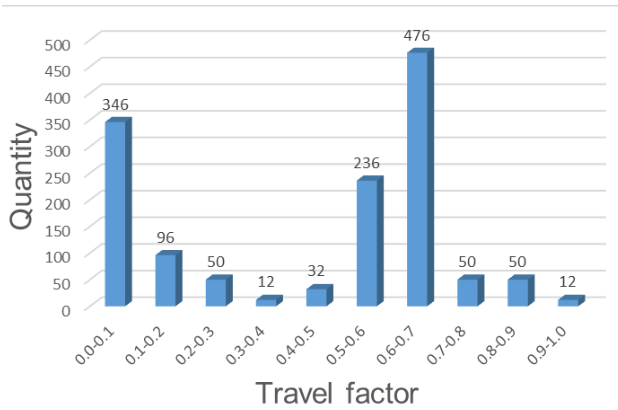

Figure 5. Travel factors statistics (10 levels).

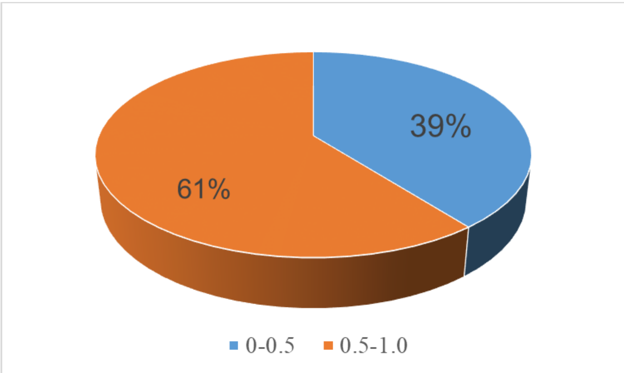

Figure 6. Traffic conditions of residential points in Wenchuan County.

Finally, the normalized data is spatially quantified to obtain the distribution of emergency rescue response level in the whole study area, as shown in Figure 7. The terrain in Wenchuan County is tilted from northwest to southeast, and the west is mainly distributed in high mountains above 3000 meters above sea level, as shown in Figure 8. The comprehensive emergency rescue center in Wenchuan County is in Weizhou Town, with flat terrain in the northeast of Wenchuan County, which is the economic development center in Wenchuan County. There are county governments and people's hospitals nearby. Wolong Town, southwest of Wenchuan County, with high altitude and steep terrain, is far from the emergency rescue center, resulting in low travel factors and the lowest emergency rescue response level. Xuankou Town in the southeast Wenchuan County has a flat terrain, but it is far from the national highways G213 and G350. The travel factor is moderate, and the emergency rescue response level is low. Through the above analysis, it can be seen that the emergency rescue response in Wenchuan County has obvious spatial distribution differences, and the emergency rescue response level shows apparent characteristics of high in the north and low in the south, high in the east, and low in the west.

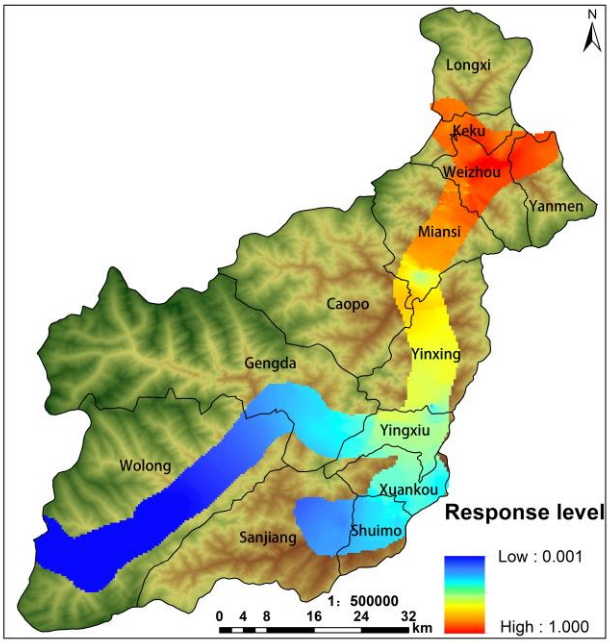

Figure 7. Distribution diagram of emergency rescue response level in Wenchuan County.

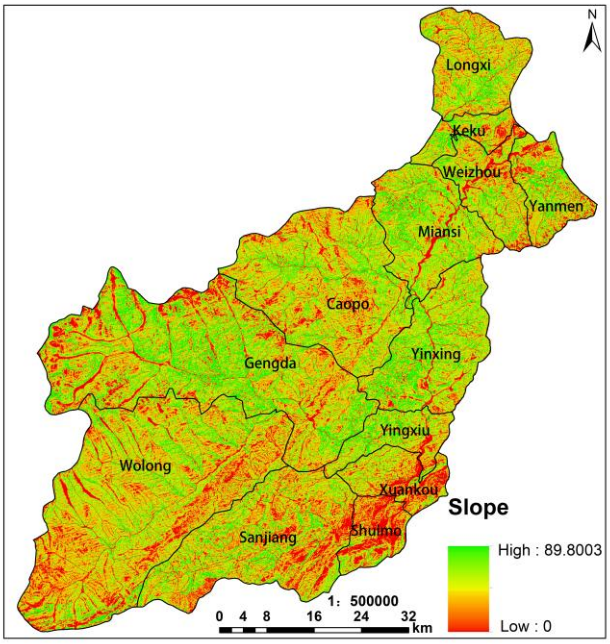

Figure 8. Slope in Wenchuan County.

5. CONCLUSION

Wenchuan County is in the Longmenshan fault zone on the eastern edge of the Qinghai-Tibet Plateau. Earthquake disasters occur frequently, and the speed of emergency rescue response is closely related to the safety of life and property. Therefore, to reduce casualties and property losses, this study uses path planning method based on Baidu map navigation data to calculate the actual travel distance from the rescue points to the disaster points, and obtains the emergency rescue response level distribution map in Wenchuan County. The main conclusions are as follows:

(1) The traditional Euclidean distance and GIS Network Analysis methods will lead to some errors in the results. In contrast, the

path planning method based on Baidu map navigation data can obtain more authentic and accurate results.
(2) There is an apparent spatial difference in the emergency rescue response level in Wenchuan County, which is high in the north and low in the south, high in the east, and low in the west. The emergency rescue response level in Weizhou Town in the north is the highest, and the emergency rescue response level in Wolong Town in the southwest is the lowest.
The proposed method in this study obtained a more accurate emergency rescue path in Wenchuan county and improved the speed of emergency rescue. However, this study only considers the single mode of driving, which may also require walking or other modes of transportation in actual rescue missions. Therefore, other transportation modes can be comprehensively considered to study the emergency rescue response from multiple dimensions, such as time and cost in the future.

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