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Original Research

Influence and Countermeasures of Geological Factors in Urban Environmental Design

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Abstract

Conducting geological hazard assessment and early warning in urban environmental design can help planners and designers better understand and respond to potential geological hazard risks. At present, the evaluation and warning of geological hazards in urban ecological design only rely on a single geological factor for analysis. They cannot integrate the many factors that cause geological hazards, forming a comprehensive and accurate geological hazard assessment method. The purpose of this article was to emphasize the importance of geological factors in urban environmental design, improve the accuracy of geological disaster assessment and early warning, and provide relevant countermeasures. This article found that the evaluation and warning of geological disasters had important guiding significance for professionals in the field of urban environmental design, which can help create safer, healthier, and more sustainable urban environments. This article used Back Propagation (BP) neural networks (NN) for risk assessment and early warning of geological disasters. With the powerful ability of NN to fuse and infer nonlinear factors, massive data is input into the NN for continuous training and evaluation, ensuring the safety of urban environmental design. This article considered the geological and geomorphological characteristics, including groundwater, slope stability, and flood control design. It fully utilizes and manages underground space, effectively utilizing limited land resources to enhance the sustainable development of cities. It also analyzed the use of engineering techniques to design urban environments, such as foundation treatment, earthquake prevention facilities, soil improvement, etc., to reduce the adverse effects of geological factors on the urban environment. To verify the effectiveness of the methods analyzed in the article, this article conducted a geological disaster assessment and early warning for towns 1–6 in H city. The highest accuracy rates for manually predicting 1–6 landslides, landslides, and mudslides in townships were 78.81%, 78.26%, and 79.44%, respectively. The highest accuracy rates for predicting 1–6 landslides, landslides, and mudslides in townships through BP NN were 83.29%, 84.25%, and 83.62%, respectively. This article highlighted the importance of geological disaster assessment and early warning for urban environmental design.

Keywords: Geological factor, back propagation, urban environment design, risk assessment, geological disaster

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Introduction

Since 1999, China has carried out geological hazard assessments on construction land to provide a scientific basis for land use and engineering construction [1]. Geological factors are crucial to urban design and affect building and infrastructure safety [2, 3]. Seismic assessment and anti-seismic measures are indispensable in urban design. In-depth studies of geological conditions and reasonable measures are of great importance to the sustainable development of cities and the lives of residents.

Urban environmental design occupies a core position in urban planning, and geological factors have a profound impact on it. China's geological environment is complicated due to its diverse climate and terrain, which makes it easy to cause geological disasters. Coupled with global climate change, extreme weather events occur frequently, and the risk of geological disasters rises. This poses a huge threat to people's lives and challenges urban environmental design. This article aims to study and explore the impact of geological factors on urban environmental design and propose corresponding countermeasures to improve the quality and sustainability of urban environmental design.

Related Work

City environment design ought to be taken into account with local economic, cultural, social, and ecological factors, scientific planning, and designing of the city environment [4, 5]. Tang Bo-Sin proposed a spatial analysis of the pedestrian accessibility of public facilities in a hilly, multi-level urban environment. The spatial database includes street terrain, physical obstacles, formal crossing points, and designated access points to assess the network distance between residential buildings and public recreation spaces. The spatial bias of land use planning policies has led to the emergence of these black spots in the shortage of recreational land. This requires urban planners to pay attention to the geographical barriers of pedestrian networks to address the issue of uneven distribution and achieve a pedestrian-friendly three-dimensional city [6]. The quality of the urban environment directly affects people's health, and understanding the real-time status of urban air quality is of great significance. Due to the current use of digital displays in air quality monitoring, it is difficult for users to intuitively determine the degree of air pollution, and the interactive way of data querying is not ideal. Chen Pengyu utilized real-time monitoring data to visualize and process air monitoring data, and interactive queries make it easier for users to query air quality. The gradually changing colors can intuitively highlight the air quality level, which is beneficial for the development of the urban environment [7]. Decision makers, planners, and investors rely on the evaluation and research of ecosystem services to promote a consensus on urban greening interventions (such as new parks, greenways, or green spaces) as a public product that brings broad benefits to all residents. Anguelovski Isabelle reflected different urban development trajectories, baseline environmental conditions, and needs through different cases of urban greening interventions. He believed that urban greening interventions are increasingly generating new trends of exclusion, polarization, isolation, and invisibility [8]. Urban environmental design should strengthen the rational utilization and management of urban land, prevent frequent geological disasters, and achieve sustainable development of the urban environment.

In urban environmental design, geological factors are one of the important factors that cannot be ignored, and the quality of geological conditions directly affects the development of the city and the quality of life of residents. Therefore, geological factors must be fully considered in urban environmental design, and cities must be scientifically and reasonably planned and designed. Zheng Qian studied the geological hazard risk assessment along the Chengdu–Kunming railway as an example. The elevation and fracture zone along the Chengdu–Kunming railway vary greatly. Due to geological disasters, the operation of the Chengdu–Kunming railway is often interrupted. He used the analytic hierarchy process (AHP) to evaluate geological disasters, and the evaluation results show that the combination of AHP can effectively predict the risk distribution of geological disasters in the study area for nearly 10 years [9]. Chen Xiao-qing used UAVs (Unmanned Aerial Vehicles), remote sensing imaging, laser rangefinders, geological radar, and cameras to conduct data analysis and field surveys on landslides, collapses, and debris flow gullies and to assess the coseismic geological disasters caused by earthquakes. The results showed that multiple landslides, collapses, and potential debris flow gullies occurred after the earthquake. Necessary monitoring and early warning can be implemented to ensure the safety of residents, workers, and tourists during the construction of urban environmental projects and the reopening of scenic spots [10]. YANG Guang selected influencing factors such as slope, undulation, strata, distance from the river, distance from the fault, land type, and vegetation coverage based on on-site data and the basic situation of the research area. He conducted a sensitivity assessment of the landslide risk in the research area, and the calculated sensitivity zoning results are relatively close to the actual situation on site. The research results have a certain reference value for geological disaster risk assessment [11]. Geological hazard assessment and early warning play an important role in urban environmental design, including but not limited to natural disasters such as earthquakes, landslides, mudslides, and land subsidence. These disasters may have serious impacts on the safety of people, the stability of infrastructure and buildings, and the health of the environment in cities.

Impact of Geological Factors on Urban Environmental Design

Geological Hazard Risk Assessment

Since the 21st century, with the acceleration of human urbanization and changes in the natural environment,

Table 1. Number of casualties and deaths caused by geological disasters in China from 2013 to 2020.

Year	Casualties	Death toll
2013	929	482
2014	637	360
2015	422	266
2016	593	362
2017	523	329
2018	185	105
2019	299	211
2020	297	117

various geological disasters have become increasingly frequent. Once disasters occur in cities with frequent human activities, the damage caused is also enormous. Therefore, traditional disaster assessment and early warning methods cannot meet the growing need for disaster prevention and reduction. Therefore, conducting geological hazard risk assessment in cities has become a trend [12–14]. It can evaluate the degree and possibility of damage and loss caused by geological disasters in each region to humans and provide scientific basis and guidance for urban disaster prevention and reduction deployment and environmental design. Therefore, it has important theoretical significance and application space. The harm caused by geological disasters to humanity has always been a common concern of countries around the world.

The statistics of casualties and deaths caused by geological disasters in China from 2013 to 2020 are shown in Table 1:

As shown in Table 1, the number of casualties and deaths in 2013 were 929 and 482, respectively. The number of casualties and deaths in 2020 was 297 and 117, respectively.

(1) Geological disaster data analysis

Accurately assessing the risk of urban geological disasters is one of the key tasks to ensure urban environmental safety and sustainable development. BP NN is a widely used artificial intelligence method for pattern recognition and prediction that can be used to assess the risk of urban geological disasters, including the potential impact of earthquakes, landslides, mudslides, and other geological disasters and their requirements for urban environmental design. Compared to traditional artificial NN, BP NN can learn and adapt to the mapping relationship between input and output by training samples. It adjusts the connection weights between neurons, enabling the network to automatically optimize and adjust, gradually improving the accuracy of predicting unknown data [15]. For urban geological hazard risk assessment, it is necessary to collect and organize relevant multi-source data, such as geology and earthquakes, and then train through BP NN to obtain a model that can accurately assess geological hazard risk [16].

In this study, the data sources of the BP neural network include historical geological disaster records, geological survey data, and topographic features. These data are rigorously screened and pre-processed to ensure the accuracy of the analysis and the effectiveness of the model training.

In 2017, a 7.0 magnitude earthquake occurred near H city, and the main types of geological disasters in towns and villages before and after the 1–6 earthquake in H city were collapses, landslides, and mudslides. The number of different types of geological disasters before and after the earthquake is shown in Fig. 1 (the horizontal axis in Fig. 1 represents 6 townships, and the vertical axis represents the number of disasters occurring):

As shown in Fig. 1, the number of collapses, landslides, and mudslides in Township 1 before the earthquake in Fig. 1 (a) was 2, 1, and 18, respectively. The number of collapses, landslides, and mudslides in Township 3 was 3, 2, and 7, respectively. The number of collapses, landslides, and mudslides in Township 6 was 4, 0, and 8, respectively.

The number of collapses, landslides, and mudslides in Township 1 after the earthquake in Fig. 1 (b) was 33, 19, and 20, respectively. The number of collapses, landslides, and mudslides in Township 3 was 2, 3, and 7, respectively. The number of collapses, landslides, and mudslides in Township 6 was 11, 5, and 9, respectively.

For earthquake risk assessment, by collecting historical earthquake data, this article uses BP NN for training and prediction to evaluate earthquake risk. Based on the evaluation results, determine the requirements for urban environmental design, such as strengthening the seismic performance of buildings and improving land use planning. The evaluation of geological disasters requires data analysis to lay the foundation for training NN models.

(2) Evaluation based on BP NN

The occurrence and impact of geological disasters are comprehensively influenced by multiple factors, and there may be complex nonlinear relationships between these factors. It is difficult to accurately capture these nonlinear

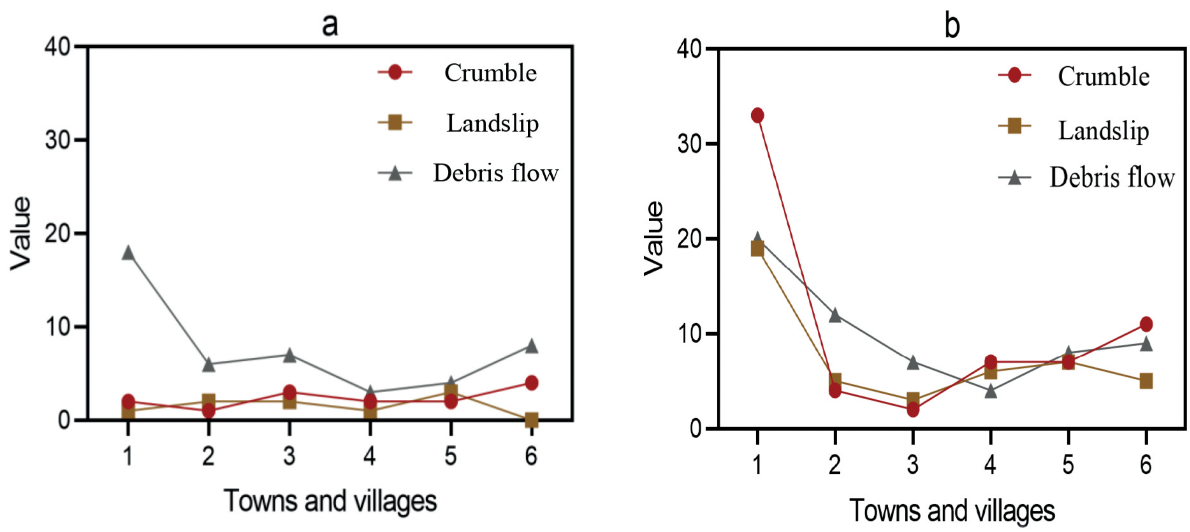

Fig. 1. Number of different types of geological hazards before and after earthquakes
(a) Number of different types of geological hazards before the earthquake
(b) Number of different types of geological hazards after the earthquake

relationships using traditional statistical methods. BP NN, as a powerful nonlinear model, can better handle nonlinear relationships and analyze the interactions between various complex factors. The data related to geological disasters often have incompleteness and noise, such as missing data. However, BP NN has strong fault tolerance and robustness, which can handle these problems and to some extent ignore the impact of noise.

The multi-level structure of BP NN can extract a significant amount of information from incoming data to execute challenging tasks. Assuming there are A input neural parameters, they are represented $[x_1, x_A]$ in matrix form. As a result, the input data for the input layer also applies to the network as a whole, as seen in the following example:

$$P_t = [x_1, x_A] \tag{1}$$

The output information of the input layer I is:

$$Q_I = [x_1, x_I] \tag{2}$$

The input of the b th neuron node in the hidden layer can be represented as the weighted sum of the output V of the input layer and the sum of the bias parameter:

$$P_H^b = \sum_{a=1}^{A} W_{ab} \cdot Q_I^a + K \tag{3}$$

Assessing the risk of urban geological disasters is an important task in ensuring urban safety and sustainable development. The potential impact of geological disasters such as earthquakes, landslides, and mudslides on the urban environment is enormous [17]. Therefore, evaluating the potential impact of these geological disasters and proposing requirements for urban environmental design based on the evaluation results is crucial for ensuring the safety and development of cities [18].

It is important to ascertain the correction of the weight value corresponding to the network parameters by the loss function after getting the network's loss function. Calculate the gradient $\frac{\partial E}{\partial W_{bc}}$ of the loss function to the weight value through gradient descent, and adjust the weight value along the opposite direction of the gradient:

$$\Delta W_{bc} = -\eta \frac{\partial E}{\partial W_{bc}} \tag{4}$$

η is the learning rate. The entire process is more complex because the local gradient calculation must employ the local gradient determined in the preceding step when altering the weights between the input layer and the hidden layer, that is, the local gradient between the hidden layer and the output layer, as the hidden layer is not visible. Therefore, the BP NN can only perform the weight adjustment process in the reverse direction. After the weight of the network is adjusted and updated once, the forward propagation of the input data for the following round of weight modification yields a new error function. The network error can be continuously reduced through repeated iterations. It continuously approximates the functional relationship between input and output, thereby achieving network functionality for classification or prediction purposes. BP NN helps geologists and decision-makers understand the results of risk assessment and develop corresponding response measures.

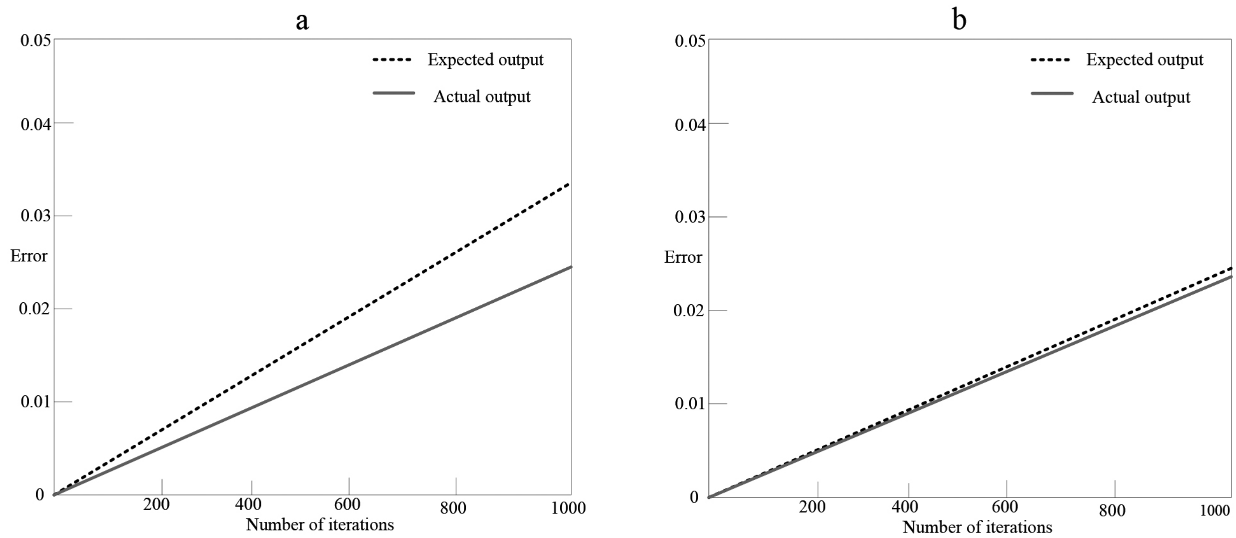

Fig. 2. Error of different hidden layers
(a) Error when the hidden layer is 6
(b) Error when the hidden layer is 8

(3) Training of BP NN model

Geological disasters are an issue that cannot be ignored in urban environmental design. The occurrence of disasters can pose a huge threat to the development of cities and the lives of residents. Therefore, monitoring and prevention of geological disasters must be considered in urban environmental design [19, 20]. Assessing the risk of urban geological disasters is a complex task. BP NN can be used for model training. The input matrix of the BP NN includes various influencing factors for urban geological hazard risk assessment, such as geological conditions, earthquake history, land use, etc. The dimensions of the input matrix are determined by specific problems, expressed as:

$$X = [x_1, x_2, ..., x_n] \tag{5}$$

x_n represents the n influencing factor and the hidden layer in the BP NN converts the linear combination of the input layer into the nonlinear output through the activation function. The output of the hidden layer can be represented as:

$$H = f(W_H * X) \tag{6}$$

Among them, W_H is the weight matrix of the hidden layer, and the output layer is the last layer of the BP NN, used to represent the evaluation results of geological disaster risk. The output of the output layer can be represented as:

$$Y = f(W_Y * X) \tag{7}$$

W_Y is the weight matrix of the output layer. The error calculation formula is used to evaluate the difference between the output results of the NN and the actual results. Common error calculation methods include square error, cross-entropy, etc. The square error formula can be expressed as:

$$E = \frac{1}{2} * (Y - T)^2 \tag{8}$$

Among them, T represents the actual results, and the BP NN adjusts the weights through BP to make the network evaluation results closer to the actual results. The weight update formula can be expressed as:

$$W(t+1) = W(t) - \eta * \Delta W \tag{9}$$

Among them, $W(t)$ represents the weight after the t iteration, and ΔW represents the updated amount of the weight. The updated formula of the learning rate can be expressed as:

$$\eta(t+1) = \eta(t) * \sigma \tag{10}$$

$\eta(t)$ represents the learning rate after the t iteration. σ is a constant of less than 1, which is used to control the attenuation of learning rate. The output results of the BP NN need to be interpreted and analyzed to assess the risk of urban geological disasters. The risk formula can be expressed as:

$$Risk = R(Y) \tag{11}$$

Among them, *Risk* converts the output results of the NN into specific risk levels or ratings.

The BP NN model can evaluate the potential impact of urban geological disasters and the requirements for urban environmental design by inputting various influencing factors. The number of iterations is 1000, and the errors of different hidden layers are shown in Fig. 2 (the horizontal axis in Fig. 2 represents the number of iterations, and the vertical axis represents the error):

As shown in Fig. 2, it can be seen from Fig. 2 (a) that when the number of iterations was 1000, the NN prediction error of the six hidden layers exceeded 0.03.

Fig. 2 (b) shows that when the number of iterations was 1000, the NN prediction error of the 8-layer hidden layer was within 0.03. The number of hidden layers and the number of neurons in each layer of the NN together determined the capacity and expression ability of the network. Deeper networks usually have higher capacity and stronger expression ability and can learn more complex and abstract features and patterns. This enables deep networks to better capture the nonlinear relationships of data when dealing with complex tasks, thereby improving the accuracy of predictions.

Accurate assessment of urban geological disaster risk through BP NN can provide scientific basis and decision support, helping urban planners and decision-makers make reasonable urban environmental design and management decisions. Of course, the evaluation results are only for reference, and it is necessary to combine specific geological and geomorphological conditions and engineering techniques to develop urban environmental design plans that meet practical needs.

Based on the above analysis, geological factors such as groundwater level, slope stability, and flood control design have a significant impact on urban environmental design. The combined effect of these factors requires planners to take comprehensive considerations and countermeasures in the design process.

Consideration of Geological and Geomorphological Characteristics

Considering the geological and geomorphic characteristics of the city, such as terrain, soil type, groundwater, etc., the urban environmental design shall be reasonably arranged and planned to ensure the stability and sustainable development of the city. The following are some factors related to geological and geomorphic characteristics.

(1) Topographical features

Considering the undulation, slope, and height difference of the terrain where the city is located, it is necessary to avoid building in areas prone to geological disasters, such as landslides, collapses, and earthquake hazards [21, 22]. Based on terrain features, land use planning should be carried out, and the layout of residential, commercial, and industrial areas should be reasonably arranged to avoid unnecessary impacts on the geological environment. Considering the stability and bearing capacity of the soil type where the city is located, to ensure the safety of buildings and infrastructure, the soil type that is easy to liquefy needs to take corresponding reinforcement measures, such as foundation reinforcement or deep foundation pit engineering technology [23].

(2) Groundwater

By understanding the groundwater level and flow conditions around the city, to avoid construction in areas where groundwater gushes out and prevent the impact of groundwater on buildings and infrastructure, it is necessary to plan the urban drainage system reasonably to ensure smooth drainage and reduce problems caused by rising groundwater levels. The development and utilization of groundwater resources must be planned reasonably to ensure the supply of water resources and environmental protection in cities. In the development and utilization of groundwater resources, it is necessary to consider the sustainability of groundwater resources, prevent excessive exploitation from leading to the depletion of groundwater resources, and also strengthen the protection of groundwater resources to prevent pollution of the groundwater environment.

(3) Slope stability

Based on the geological characteristics of the slopes around the city, a reasonable evaluation should be conducted to avoid the damage caused by urban development to the slopes. When constructing slope areas, it is necessary to carry out land management, terrace construction, or adopt appropriate engineering measures to ensure the stability of the slopes. Considering the seismic activity and intensity of the seismic zone where the city is located, corresponding design and construction measures shall be taken to ensure the seismic safety of buildings and infrastructure. Preparing relevant emergency rescue plans can improve the earthquake resistance and emergency response capabilities of cities [24, 25].

(4) Flood control

Considering the flood risks of rivers, lakes, and coastlines around the city, flood control engineering measures such as building embankments, sluices, and drainage systems should be taken to reduce the losses caused by floods to the city. In the process of urban environmental design, attention can be paid to ecological protection, environmental sustainability, and the rational utilization of natural resources. This can reduce the damage to the environment, make use of geological and geomorphic features, such as river valleys, hills, wetlands, and other natural landscapes, create urban parks and green spaces, and provide air quality improvement and ecosystem services. Through reasonable planning and design, the risk of geological disasters can be reduced, the sustainability of cities can be improved, and the quality of life of residents can be improved.

Utilization and Management of Underground Space

Fully utilizing underground space and planning and managing underground pipelines, parking lots, and facilities is one of the important directions for the development of modern urban environmental design. At the same time, it is also necessary to fully consider geological factors to avoid potential risks that underground spaces may face [26, 27].

For the planning and management of underground pipelines, geological factors are one of the important factors that must be considered. Geological factors include underground water level, seismic activity, etc. [28]. When planning underground pipelines, it is necessary to know the soil type and bearing capacity of the area to ensure the safety and stability of pipelines. If the underground soil is prone to liquefaction or has low bearing capacity, corresponding reinforcement measures need to be taken, such as improving the soil and increasing pipeline support. In addition, the level of groundwater can also affect the design and layout of underground pipelines. It is necessary to arrange the burial depth and waterproof measures of pipelines reasonably to avoid adverse effects of water pressure on pipelines. In seismically active areas, seismic design is required. Materials and structures with good seismic performance can be selected to ensure the safety of underground pipelines during earthquakes, and bearing capacity indicators need to be used.

The bearing capacity is used to calculate the maximum load that an underground space can withstand to ensure the safe operation of underground facilities or parking lots. By determining the bearing capacity coefficient and contact area of the soil, the load can be limited to an acceptable range to avoid exceeding the load-bearing capacity of the underground space. The formula for calculating bearing capacity is:

$$LC = C \times Z \times N \tag{12}$$

Among them, C is the soil-bearing capacity coefficient; Z which represents the contact area of the underground space; and N, which represents the design load.

The planning and management of underground parking lots also need to consider geological factors. When planning underground parking lots, geological surveys need to be conducted to understand the stability and bearing capacity of the underground soil layer to ensure that the foundation of the parking lot can withstand vehicle loads [29, 30]. If the underground soil layer is unstable or prone to liquefaction, corresponding foundation reinforcement measures need to be taken, such as pile foundations, reinforcement plates, etc. Waterproofing and ventilation of underground parking lots are also important considerations. A reasonable waterproof system and ventilation equipment can ensure smooth drainage and vehicle safety in the parking lot, prevent corrosion and damage to the parking lot facilities caused by groundwater and humid environments, and use groundwater flow indicators at this time.

In the planning and management of underground pipelines, groundwater flow can be used to determine the appropriate pipeline size and drainage capacity to ensure smooth water flow and drainage effectiveness.

The formula for calculating groundwater flow:

$$Q = K \times A \times \left(\frac{d_h}{d_i} \right) \tag{13}$$

Among them, Q represents groundwater flow rate; K represents the permeability coefficient; $\frac{d_h}{d_i}$ and represents the hydraulic gradient per unit length.

For the planning and management of underground facilities, geological factors also need to be fully considered, including underground commercial areas, underground transportation hubs, underground public facilities, etc. The seismic design of underground facilities is used to evaluate the seismic performance of underground facilities during earthquakes. The seismic design formula for underground facilities:

$$S_a = S_d \times C_s \times C_t \times C_d \tag{14}$$

Among them, S_a represents the seismic design of underground facilities; S_d represents the design reference acceleration spectrum; C_s represents the site category coefficient; C_t represents the period coefficient; C_d and represents the seismic design coefficient. By using these formulas, scientific basis and technical support can be provided in underground space planning and management to ensure the safety and sustainability of underground pipelines, parking lots, and facilities. At the same time, it can also avoid the potential risks and adverse effects of geological factors on underground space.

Fully utilizing underground space for planning and management of underground pipelines, parking lots, and facilities can effectively improve the efficiency and sustainability of urban spatial utilization. However, in the planning and management process, geological factors must be fully considered; geological surveys and risk assessments must be conducted; and corresponding design, construction, and maintenance measures must be taken to avoid potential risks and adverse effects of geological factors on urban underground space. Only through scientific planning, careful design, and strengthened monitoring and maintenance can the stability and safety of underground spaces be ensured, providing support for the sustainable development of cities.

This section analyzes in detail the independent and integrated effects of geological factors on urban environmental design. Key elements such as water table, slope stability, flood risk, and soil conditions have been identified and analyzed in depth to reveal their contribution to the safety and sustainability of the urban environment. At the same time, the importance of comprehensive consideration of these factors in the design process and the necessity of reducing geological risks through scientific planning and design are emphasized.

Urban Environmental Design Strategies to Address Geological Factors

Application of Engineering Technical Means

The subsequent strategies can be implemented to mitigate the negative effects of geological elements on the urban setting.

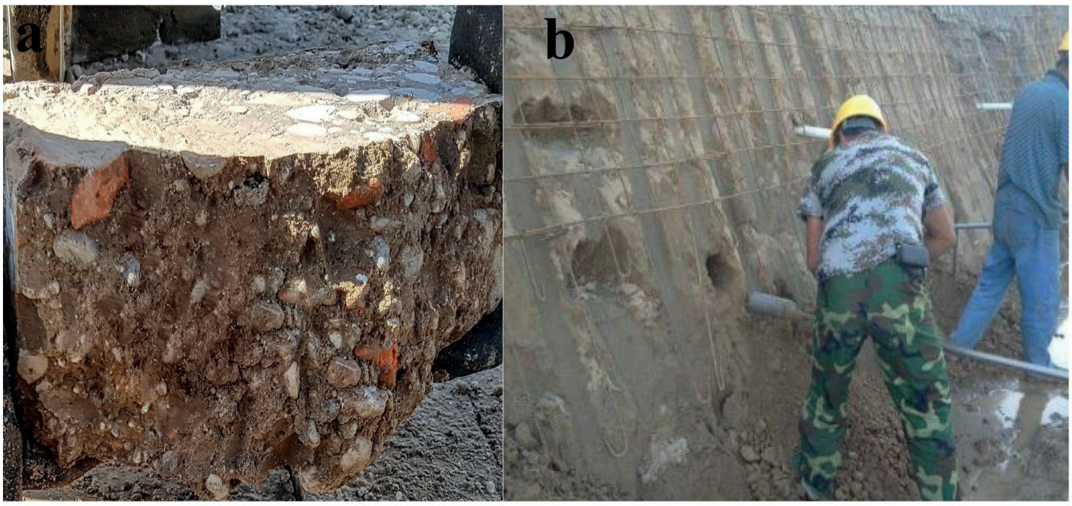

Fig. 3. Deep gravel column and prestressed anchor rod

(1) Foundation treatment

Foundation treatment refers to the reinforcement and improvement of underground soil to enhance its bearing capacity and stability. Common foundation treatment methods include grouting reinforcement, compaction reinforcement, retaining wall reinforcement, etc., used to treat areas with poor geological conditions and reduce the impact of foundation settlement and deformation.

(2) Soil improvement

Soil improvement is a commonly used engineering technique that can reduce the adverse effects of geological factors on the urban environment. By improving soil properties and enhancing soil mechanical properties, the stability of the foundation can be enhanced, drainage conditions can be improved, and the risk of geological disasters can be reduced. Common soil improvement methods include deep gravel columns, prestressed anchor rods, etc., which can improve soil stability in areas with poor geological conditions. Deep gravel columns can increase the shear strength and compressive performance of the soil and improve the bearing capacity and stability of the foundation. Prestressed anchor rods are commonly used in areas with poor geological conditions, such as slopes, to prevent soil sliding and collapse. The deep gravel column and prestressed anchor rod are shown in Fig. 3:

As shown in Fig. 3, a deep gravel column (a in Fig. 3) is a method of improving soil properties by injecting mixed materials such as cement and lime into the soil. The prestressed anchor rod (b in Fig. 3) is a method of fixing steel bars or steel strands in the soil and applying prestressing force to enhance the tensile strength and sliding stability of the soil.

In addition to deep gravel columns and prestressed anchor rods, there are also soil reinforcement piles, soil, and plant root system technologies. Soil reinforcement pile is a method of nailing reinforced concrete or fiber-reinforced materials into the soil to increase the compressive strength and improve drainage performance and stability of the soil. This method is suitable for the treatment of weak soil layers and liquefied soil layers. A soil improvement technology uses substances such as curing agents and binders to react with the soil to optimize its characteristics and improve its impermeability, corrosion resistance, and load-bearing capacity. The application of plant roots, the selection of plants suitable for the local environment, through its roots to enhance soil stability, improve erosion resistance, slow down water flow, and effectively prevent soil loss and landslides.

(3) Geotechnical measures

In response to geotechnical instability and landslide tendencies, geotechnical measures such as slope protection, vegetation cover, and retaining walls can be implemented to maintain topographic stability. The water table can be stabilized using well control and reservoir regulation. Improve basic conditions, reduce the risk of geological disasters, and ensure urban safety and sustainable development. In the planning and design stage, it is very important to fully consider geological factors and take corresponding measures.

These foundation treatment and soil improvement techniques are a direct response to geological instability and disaster risk. These methods are particularly suitable for geologically fragile areas and aim to enhance the overall stability of the urban environment by enhancing the soil carrying capacity and improving drainage conditions.

Disaster Risk Management and Early Warning

It is possible to conduct early warning analysis on the distribution of geological disasters, delineate the scope and degree of danger zones, and then control the speed of population development within the danger zone [31, 32]. The most reliable method to reduce the risk of geological disasters is to formulate and strictly implement relevant

Table 2. Classification of actual risk levels

Towns and villages	Area (Square meter)	Area ratio (%)	Risk level
1	801.16	8.1%	Low risk
2	721.61	7.3%	Low risk
3	590.06	6.0%	Medium risk
4	322.90	3.3%	Medium risk
5	425.70	4.3%	High risk
6	197.49	2.0%	High risk

policy measures to transfer population and property within severe, medium, and high-risk areas. Analyzing geological disaster risks includes measures such as disaster warnings to reduce the damage of geological disasters to the urban environment. The total area of H city is 9875.63 square meters, and the actual risk level classification is shown in Table 2.

As shown in Table 2, the proportion of townships 1–6 to the total area was 8.1%, 7.3%, 6.0%, 3.3%, 4.3%, and 2.0%, respectively; the risk levels were respectively low risk, low risk, medium risk, medium risk, high risk, and high risk.

When the BP NN predicts without error, E_{PA} indicates that the predicted and observed values are the same after normalizing their mean and standard deviation:

$$E_{PA} = \frac{\sum_{i=1}^{N}\left[\left(y_i - y_m\right)\times\left(\bar{y}_i - \bar{y}_m\right)\right]}{\left(N-1\right)S_y} \tag{15}$$

$\bar{y}_i - \bar{y}_m$ reflects the degree of deviation of predicted data from the mean of observed data.

The reverse recursion of the network from the output layer to the input layer reveals that the weight adjustment method for the r layer is:

$$\varepsilon_{pk}^{(r)} = \sigma_r^{'}\left(h\right)_{pk}^{(r)} \cdot \sum_{i=1}^{n-1} \varepsilon_{pk}^{(r-1)} w_{ip}^{(r-1)} \tag{16}$$

The local error of the output depends on the output error and the partial derivative of the layer. During the entire calculation process, local errors are mapped and propagated from back to front. In the prediction of geological disasters, different numbers of hidden layers can be selected based on the type of selection factors. Excessive hidden layers make it easier for the algorithm to enter the local minimum. The number of nodes in the hidden layer follows the following formula:

$$J = \sqrt{U + P} + a \tag{17}$$

J and P respectively represent the number of nodes in the hidden layer and the number of input nodes. The evaluation of geological disasters involves many factors and can be adjusted and optimized for different regions in the model construction based on effectiveness.

In the practical operation of geological disaster early warning management, it is often necessary to address both the root cause and root cause, take a multi-pronged approach, and take comprehensive measures to reduce and transfer risks. In short, geological disaster warning requires the investment and coordination of individuals and groups. It is a model led by national governments, participated by local governments, funded by international organizations and institutions, supported by the scientific and academic communities, and coordinated by other groups and individuals.

Based on the early warning analysis of the distribution of geological disasters, the scope and extent of dangerous areas can be effectively defined. These measures complement each other and provide a more accurate risk management framework for urban environmental design.

Application of Smart City Technology

The technology can integrate and collect multi-source geological data, including geological surveys, geological exploration, satellite remote sensing, and other data, to form a comprehensive geological information database. Such a database can provide accurate geological basic data for urban planning and construction and support data sharing and collaboration among different departments. By comprehensively analyzing geological hazards such as underground geological conditions, seismic activity, landslides, and ground subsidence, potential geological risks can be identified early and corresponding disaster prevention measures can be taken in advance.

By combining smart city technologies such as remote sensing and geographic information systems, real-time monitoring and analysis of geological factors can be achieved, which can provide accurate information support for urban environmental design. The following are some applications of technologies in geological factor monitoring and analysis:

Remote sensing technology utilizes remote sensing technologies such as satellites and drones to obtain information on surface topography and vegetation cover.

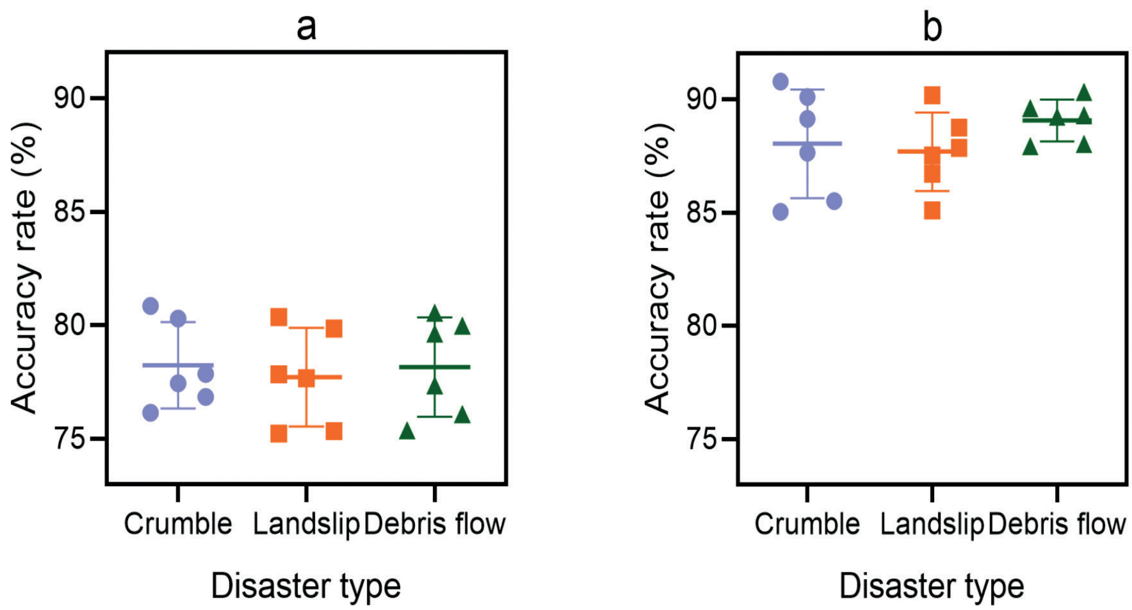

Fig. 4. Accuracy of artificial experience assessment and BP NN in disaster assessment
(a) Accuracy of manual experience evaluation
(b) Accuracy of BP NN evaluation

These data can provide information on geological structure, land use types, green space coverage, and other aspects, which can provide basic data for urban environmental design.

Geographic information system: through the integration of geospatial data, including geological, geomorphological, groundwater level, seismic activity, and other data, a geographic information database can be built and geographical spatial analysis can be carried out. With the help of geographic information system technology, real-time monitoring of changes in geological factors, such as surface subsidence and groundwater level fluctuations, can be carried out, and these data can be visualized and comprehensively analyzed.

The integrated geological information system and remote sensing technology provide a scientific basis for real-time monitoring and analysis of geological factors. The application of these technologies allows for dynamic tracking and timely updating of risks assessed through BP neural networks.

Evaluation and Early Warning BP NN

BP NN Evaluation Effect

(1) Evaluate accuracy

The experimental data in this article is collected from the historical disasters that occurred in H city. The risk assessment of geological disasters needs to consider multiple factors, such as geological conditions. BP NN has strong parallel processing ability, which can simultaneously consider multiple factors and integrate them for evaluation. This ability enables the BP NN to analyze the impact of various factors on geological disasters more comprehensively, providing more accurate risk assessment results.

The accuracy of artificial experience assessment and BP NN in disaster assessment is shown in Fig. 4 (the horizontal axis in Fig. 4 represents the type of disaster, including collapse, landslide, and debris flow, while the vertical axis represents the accuracy):

As shown in Fig. 4, the accuracy rates of evaluating the occurrence of collapse in townships 1–6 through manual experience in Fig. 4 (a) were 80.29%, 77.44%, 76.15%, 76.84%, 80.84%, and 77.85%, respectively. The accuracy rates for evaluating the occurrence of landslides in townships 1–6 were 75.34%, 79.85%, 77.83%, 77.67%, 75.22%, and 80.36%, respectively. The accuracy rates for evaluating the occurrence of debris flows in townships 1–6 were 79.97%, 75.37%, 79.62%, 76.08%, 77.35%, and 80.55%, respectively.

Fig. 4 (b) shows that the lowest and highest accuracy rates for evaluating the occurrence of landslides in townships 1–6 using BP NN were 85.02% and 90.78%, respectively. The lowest and highest accuracy rates for evaluating the occurrence of landslides in townships 1–6 were 85.09% and 90.17%, respectively. The lowest and highest accuracy rates for evaluating the occurrence of debris flows in townships 1–6 were 87.92% and 90.31%, respectively.

The assessment of geological disasters is an important means of preventing their occurrence. By evaluating

Table 3. Classification of labor experience risk levels

Towns and villages	Actual area (Square meter)	Subdivision area (Square meter)	Error (Square meter)	Risk level
1	801.16	731.55	69.61	Medium risk
2	721.61	665.83	55.78	Medium risk
3	590.06	510.22	79.84	Medium risk
4	322.9	255.31	67.59	Low risk
5	425.7	401.59	24.11	High risk
6	197.49	133.32	64.17	Low risk

Table 4. Risk classification of BP NN

Towns and villages	Actual area (Square meter)	Subdivision area (Square meter)	Error (Square meter)	Risk level
1	801.16	781.45	19.71	Low risk
2	721.61	709.71	11.9	Low risk
3	590.06	580.3	9.76	Medium risk
4	322.9	302.45	20.45	Medium risk
5	425.7	409.53	16.17	High risk
6	197.49	153.42	44.07	High risk

geological disasters, the danger of geological disasters can be identified promptly, and corresponding preventive measures can be taken to ensure the safety of the city. Geological disasters are a necessary consideration in urban environmental design, and there are many measures to prevent geological disasters, such as reasonable planning of urban land, improving urban disaster prevention systems, and strengthening emergency command for geological disasters.

(2) Hazard level classification

The classification of risk levels based on manual experience is shown in Table 3:

As shown in Table 3, the area errors of townships 1–6 based on manual experience were 69.61 square meters, 55.78 square meters, 79.84 square meters, 67.59 square meters, 24.11 square meters, and 64.17 square meters, respectively; the grades are medium risk, medium risk, medium risk, low risk, high risk, and low risk. The error in dividing the area of townships 1 to 6 based on manual experience is significant, and its classification of risks is also inaccurate.

Risk classification based on BP NN is shown in Table 4:

As shown in Table 4, the errors for classifying townships 1–6 based on BP NN were 19.71 square meters, 11.90 square meters, 9.76 square meters, 20.45 square meters, 16.17 square meters, and 44.07 square meters, respectively; the grades were low risk, low risk, medium risk, medium risk, high risk, and high risk.

BP NN is a model with adaptive learning ability. It can automatically adjust the weight through the training process to gradually improve the accuracy of the model evaluation. In geological hazard risk assessment, there is often a large amount of data and variables, and the weights and impact degrees of some variables may not be easily determined. The use of BP NN can adapt to the characteristics of different datasets through continuous learning and optimization and provide more accurate risk assessment results. Through appropriate methods and tools, BP NN can be visualized and analyzed to better understand their results. This helps geologists and decision-makers understand the results of risk assessment and develop corresponding response measures.

BP NN Warning Effect

(1) Warning accuracy

Artificial experience often relies on historical cases and personal experience, but geological disaster events have certain spatiotemporal changes and individual differences, and different situations may occur under different geographical environments and time conditions. If the sample size of manual experience is small or the data source is insufficient, it is difficult to provide accurate and comprehensive information support, thereby affecting the accuracy of early warning. Through manual warning and BP NN warning of geological disasters in H city, the accuracy of artificial experience evaluation and BP NN

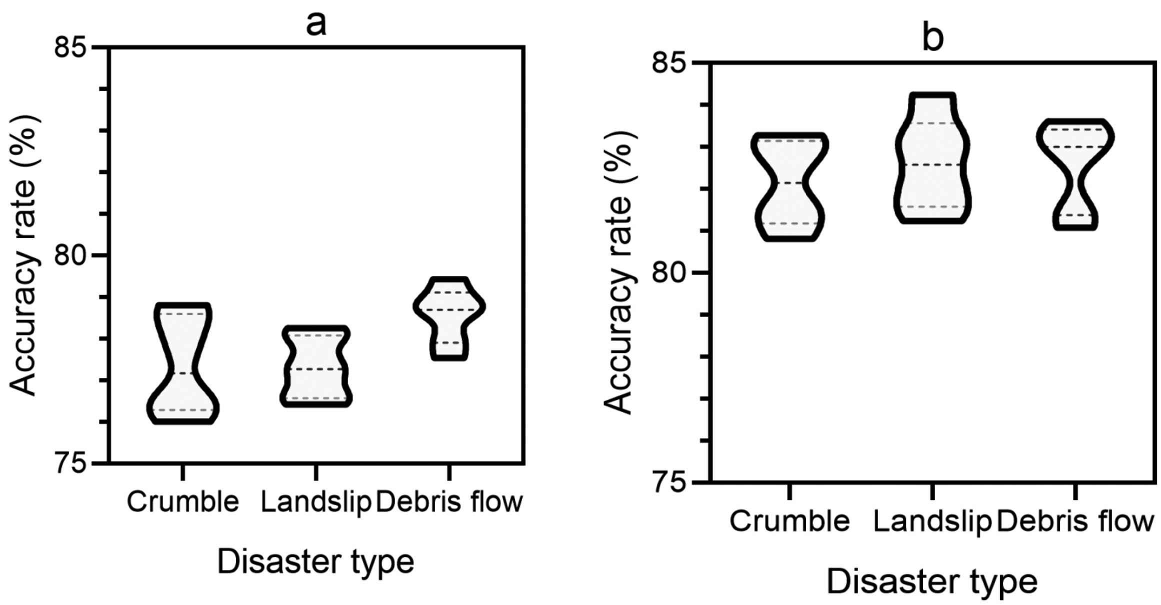

Fig. 5. Early warning accuracy of artificial experience evaluation and BP NN
(a) Accuracy of manual experience warning
(b) BP NN warning accuracy

warning is shown in Fig. 5 (the horizontal axis of Fig. 5 represents the type of disaster, including collapse, landslide, and debris flow, while the vertical axis represents the accuracy):

As shown in Fig. 5, Fig. 5 (a) shows that the highest accuracy rates for manually predicting landslides, landslides, and mudslides in townships 1–6 were 78.81%, 78.26%, and 79.44%, respectively.

Artificial experience is usually based on the accumulated knowledge and experience of individuals or experts, which is easily influenced by subjective opinions and one-sided perspectives. Geological disasters have complex characteristics and diverse influencing factors, and relying on personal subjective experience often makes it difficult to comprehensively and objectively consider and analyze various factors, resulting in low accuracy of early warning judgments. Artificial experience mostly relies on historical data and existing knowledge and may not be updated and adapted promptly when facing new situations or changes. The occurrence and evolution of geological disasters are dynamic processes that require real-time monitoring and continuous data updates to obtain the latest information and trends. If relying solely on manual experience without timely monitoring methods and data support, it would affect the accuracy of early warning.

The highest accuracy rates for predicting collapse, landslide, and debris flow in townships 1–6 through BP NN in Fig. 5 (b) were 83.29%, 84.25%, and 83.62%, respectively. BP NN has good generalization ability, that is, its adaptability to unknown data. By using appropriate training and validation methods, overfitting or underfitting problems can be avoided, and the generalization ability and accuracy of early warning models can be improved.

As a nonlinear model, BP NN can capture complex relationships and nonlinear features in input data, and the occurrence of geological disasters is usually influenced by multiple variables. The relationships between these variables may be nonlinear, and BP NN can better adapt and express these complex relationships through nonlinear transformations between multiple layers of neurons, thereby improving the accuracy of early warning. BP NN can learn the mapping law between input and output by training samples. Through training with a large amount of real data, the network can gradually optimize weights and biases and improve its early warning ability for geological disasters.

(2) Warning time cost

Artificial experience warning often relies on the knowledge and experience of experts and is carried out through their evaluation and judgment. Experts need to carefully analyze and compare various data and information, combine their own experience and judgment to conduct a comprehensive evaluation and draw early warning conclusions. This process requires experts to invest a lot of time and energy in repeated research and discussion, resulting in significant time expenditure.

The manual warning time here is very long and requires investigation, unlike BP NN operating on a computer. Therefore, the time cost predicted by traditional artificial NN and BP NN will be compared here. The comparison of the time cost between traditional artificial NN warning and BP NN warning is shown in Fig. 6 (the horizontal axis in Fig. 6 represents the type of disaster, including collapse, landslide, and debris flow, while the vertical axis represents time):

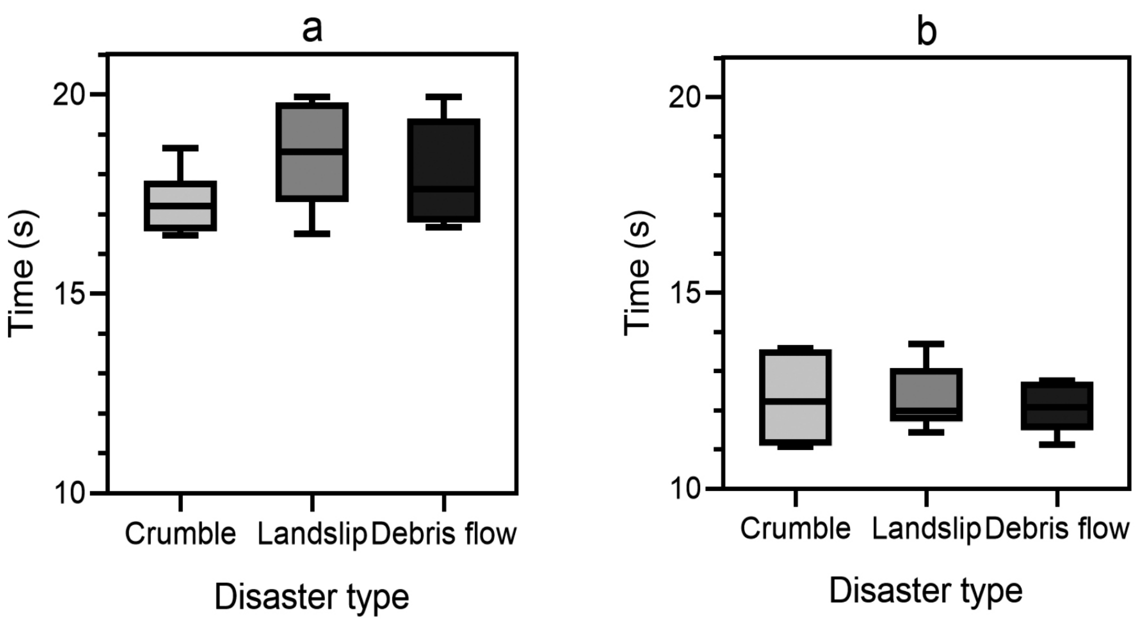

Fig. 6. Warning time of traditional artificial NN and BP NN
(a) Traditional artificial NN warning time
(b) BP NN warning time

As shown in Fig. 6, Fig. 6 (a) shows that the minimum and maximum time for warning township 1–6 collapse through traditional artificial NN were 16.48 seconds and 18.65 seconds, respectively. The minimum and maximum time for warning the 1–6 landslide in townships through traditional artificial NN were 16.50 seconds and 19.93 seconds, respectively. The minimum and maximum time for warning 1–6 debris flows in townships through traditional artificial NN were 16.67 seconds and 19.94 seconds, respectively.

Fig. 6 (b) showed that the minimum and maximum time for warning the collapse of townships 1–6 through BP NN was 11.08 seconds and 13.58 seconds, respectively. The minimum and maximum time for early warning of landslides 1–6 in townships through BP NN was 11.44 seconds and 13.69 seconds, respectively. The minimum and maximum time for warning the 1–6 debris flow in townships through BP NN was 11.12 seconds and 12.76 seconds, respectively.

Results and Discussion

In this study, through the application of the Back Propagation neural network to assess the risk of geological factors in urban environmental design, remarkable research results have been achieved. The results show that the accuracy of the BP neural network in predicting geological disasters such as landslides, collapses, and debris flow has been significantly improved compared with the traditional manual experience assessment, with the highest accuracy reaching 83.29%, 84.25%, and 83.62%, respectively. In addition, the BP neural network model can not only assess the possibility of disaster in advance but also give early warning in time, which provides strong support for the smooth progress of urban environment design. The study also emphasizes the importance of considering geological and geomorphic features in urban planning, which can provide a scientific basis for sustainable urban development through rational planning and utilization of groundwater resources, protection, and development of geological landscapes. At the same time, by adopting appropriate engineering techniques and smart city technologies, the adverse impact of geological factors on the urban environment can be reduced, and real-time monitoring and data analysis can be achieved, providing valuable information for urban planners and disaster managers. Although the BP neural network model in this study shows good adaptability and accuracy in geological hazard risk assessment, there are also certain challenges, such as the complexity of geological factors and the need for continuous data updates. Future research is needed to further optimize models and explore more efficient ways to process and analyze large amounts of geological data to improve the accuracy and efficiency of risk assessments.

Conclusions

Geological factors are one of the important factors that must be considered in urban environmental design. In urban ecological design, it is necessary to fully consider geological factors and scientifically and reasonably plan and design the city to promote the sustainable development of the city and the quality of life of residents. It is necessary to strengthen the monitoring and prevention of geological disasters, reasonably plan and utilize groundwater resources, protect and develop geological landscapes, and provide a scientific basis for the sustainable development of cities. Through geological factors, it is possible to comprehensively understand the geological background, geological disaster risks, and groundwater resources of the city, providing a scientific basis for urban environmental design. This article analyzed the impact and countermeasures of geological factors in urban ecological design, elaborated on the importance of conducting geological disaster assessment and early warning, and provided a theoretical and practical basis for the sustainable development of the urban environment. In the process of geological disaster assessment and warning, the interaction between geological factors and urban environmental design should be considered to minimize the impact of geological disasters on the urban environment as much as possible.

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Conflict of Interest

The authors have declared that no competing interests exist.

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