



# Suitability evaluation of underground space development in the construction planning area of Tangshan City

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**Abstract.** The evaluation of underground space development suitability is a crucial initiative for the multidimensional development of cities. It serves as the primary foundation and basis for formulating scientific and rational underground space utilization plans and land use regulations. Recent domestic research has predominantly focused on plain urban areas with simple geological conditions. This study selects the construction planning zone of Tangshan City, characterized by complex geological conditions and abundant mineral resources, as the research subject. Utilizing high-precision comprehensive geological survey data, we established an evaluation index system for underground space development suitability. By employing the Analytic Hierarchy Process (AHP), we constructed both structural and evaluation models, and assessed the suitability of underground space development across different stratigraphic depths. The results indicate that the Tangshan construction planning zone generally demonstrates favorable conditions for underground space development, with all strata within the 0-80m depth range being suitable for development. Specifically: 0-10m depth: Suitable areas account for 91.65% of the total, while moderately suitable areas comprise 8.35%; 10-30m depth: Suitable areas represent 97.22%, with moderately suitable areas at 2.78%; 30-80m depth: Suitable areas cover 96.25%, and moderately suitable areas 3.75%. Key controlling factors for suitability include: Distribution of faults and fracture zones; Seismic acceleration parameters; Water inflow characteristics. The relative importance of other evaluation indicators varies across different stratigraphic layers. These findings provide fundamental data and technical support for formulating underground space development plans in Tangshan's construction planning zone.

**Keywords:** First Keyword, Second Keyword, Third Keyword.

## 1 Introduction

With the continuous development of urbanization, the development of urban underground space has received increasing attention from urban planners and managers <sup>[1-5]</sup>. The development of urban underground space first originated in the UK in the 1860s.

After the 20th century, the United States, Japan, and other developed countries or regions in Europe gradually began to develop urban underground space. In China, the development of urban underground space started relatively late, beginning in the 1980s. Before the implementation of urban underground space development projects, one of the important steps is to conduct an evaluation of the suitability of underground space development [6].

Scholars at home and abroad have carried out a large amount of research work on the evaluation of the suitability of underground space development, with the research focus mainly on the construction of evaluation index systems and evaluation methods [7-12]. The construction of the evaluation index system mainly focuses on the above - and below - ground conditions of the geological body on which the underground space depends (including topography and geomorphology, basic geology, regional stability, engineering geology, hydrogeology, environmental geological problems, etc.). Key indicators include the activity of fault structures, foundation bearing capacity, groundwater depth, etc. There are many evaluation methods for the suitability of underground space development, mainly including: linear weighted function method, fuzzy mathematics method, grey evaluation method, entropy weight method, expert scoring method, analytic hierarchy process (AHP), etc. [13-19]. Each method has its own advantages and disadvantages, and a relatively standardized or standard evaluation method system has not been formed yet. At present, during the development of urban underground space, the analytic hierarchy process is a widely used method for evaluating the suitability of underground space development.

Tangshan is an important economic city in Hebei Province, China. The limitations of urban above - ground space have severely restricted the development of the social economy. The development of underground space will effectively relieve the pressure on the control of the use of urban land and space. However, the geological conditions in Tangshan are complex, and the development of underground space must be carried out with extreme caution. Accurately evaluating and fully demonstrating the suitability of underground space development is a crucial link. This paper selects the urban construction planning area of Tangshan as the research object. Based on the results of detailed comprehensive geological surveys, the analytic hierarchy process is used to evaluate the suitability of underground space development in the construction planning area of Tangshan, providing basic technical support and reference for the urban underground space planning and development of Tangshan.

## 2 Geological Overview and Evaluation Methods

### 2.1 Overview of the Construction Planning Area

The construction planning area of Tangshan City is located on the west side of Tangshan City (Figure 1), including the Jingtang Smart Port area and the Tangshan New City planning area, with a total area of 99.28 km<sup>2</sup> (including 16.83 km<sup>2</sup> of Jingtang Smart Port planning area and 82.45 km<sup>2</sup> of Tangshan New City planning area). The construction planning area is located in the central part of the Jidong alluvial plain in the North China Plain, south of the Yanshan Mountains and north of the Bohai Sea,

adjacent to the center of Tangshan city. It is 118 kilometers southwest of Tianjin city and 164 kilometers northwest of Beijing city. The overall terrain of the construction planning area is low in the south and high in the north, mainly consisting of artificial landforms, hills, and alluvial plains. It belongs to a warm temperate semi humid monsoon climate, with abundant mineral resources and developed economic industries. The area is crisscrossed by highways and railways, including the Jingshan Railway, Jinqin High speed Railway, Zhangtang Railway, Jingqin Intercity Railway, Changshen Expressway, and Tanglang Expressway, providing convenient transportation conditions.

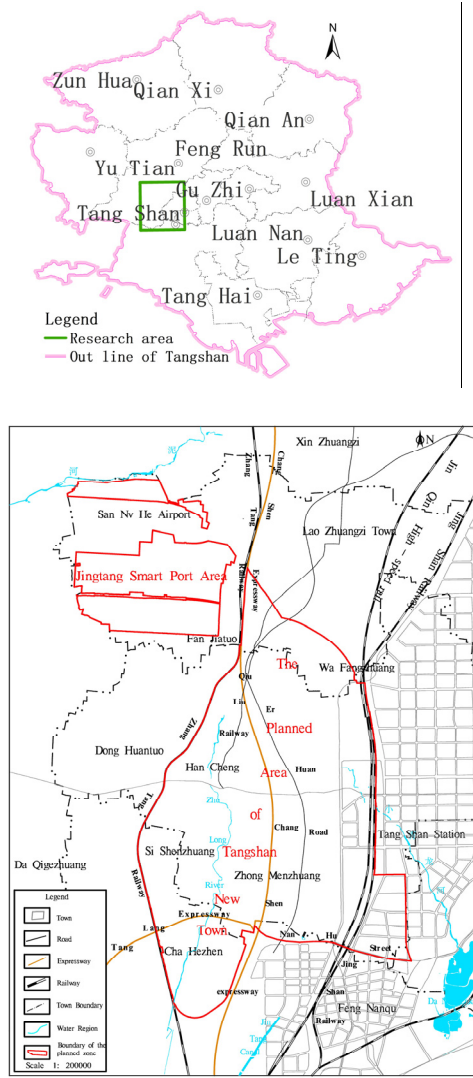


Fig. 1. Location map of the research area

## 2.2 Regional Geological Survey

In 2021-2022, high-precision comprehensive geological surveys were carried out to fully investigate and grasp the geological conditions of the planned construction area in Tangshan City, mainly including basic geological surveys (1:25000), hydrogeological surveys (1:25000), engineering geological surveys (1:10000), geological hazard surveys (1:10000), shallow geothermal energy surveys (1:25000), land quality surveys (1:10000), earthquake safety evaluations (hole spacing of 700m), and surveys and evaluations of overlying mineral resources. The data used for the suitability evaluation of underground space development mainly comes from various thematic achievement maps and reports formed through high-precision comprehensive geological surveys.

## 2.3 Suitability Evaluation Method

Adopting Analytic Hierarchy Process <sup>[20]</sup>to evaluate the suitability of underground space development in the construction planning area of Tangshan City. This method is a decision analysis approach that combines quantitative and qualitative methods. It mainly divides the problem into different sub objectives based on the overall goal to be solved, and then forms a multi-layer structure according to the logical relationship between the objectives. The sub objectives are compared pairwise to determine their importance, and a judgment matrix is used to determine the importance of the lower level objectives to the upper level criteria. Finally, the importance of the sub objectives to the overall goal is determined. The Analytic Hierarchy Process (AHP) has unique advantages in the comparative study of multiple factors. It can effectively break down and subdivide complex problems with multiple factors. Through scientific and effective mathematical calculations and rigorous analysis, the optimal solution can be found and effective scientific basis can be provided.

The evaluation process of underground space development using Analytic Hierarchy Process can be summarized as follows: firstly, understanding the overview of the construction planning area, mastering the regional geological survey data, and conducting suitability analysis of influencing factors; Then, by screening geological element indicators and combining them with standardized criteria for indicator grading, a suitability evaluation index system for underground space development is constructed. Based on the comprehensive screening of indicators and grading, an evaluation hierarchy model is constructed; By constructing the Analytic Hierarchy Process judgment matrix  $T$ , the weights of suitability evaluation indicators are obtained, and the importance ranking of each evaluation factor is obtained. Then, the weight matrix of suitability evaluation indicators for underground space development is derived; By using the comprehensive index evaluation method combined with the weights of various evaluation factors, the suitability evaluation models and comprehensive evaluation models for underground space development in different depths of strata are obtained, and the suitability evaluation results for underground space development are finally derived.

### 3 Geological Condition Analysis

#### 3.1 Basic Geology

The research area is located in a sloping alluvial plain, which is a middle late Pleistocene alluvial fan of the Luan River. The ground is flat, with a slope of generally 0.5-1.5%, and locally up to 2-3%; The strata are based on metamorphic rocks from the Precambrian period, with sedimentary cover layers developed from the Middle Upper Proterozoic to the Cenozoic period. The thickness of the Quaternary period is about 100-300m, with no exposed bedrock; The main distribution includes Fengtai Yejituo Fault, FL10-5 Fault, Beiziyuan Fengnan Fault, etc.

#### 3.2 Engineering Geology

The research area is mainly distributed with cohesive soil, silt, sand, gravel soil, and fill soil. Among them, cohesive soil, silt, and sand are widely distributed with thicknesses of about 0.40-28.80m, 0.40-10.90m, and 0.40-22.20m, respectively; Gravel soil is mainly distributed within a burial depth range of 25-200m, with a layer thickness of 0.50-44.80m; The thickness of the fill soil varies from 1 to 4 meters. According to the geomorphic features, the study area can be divided into alluvial engineering geological zone, lacustrine engineering geological zone, and lacustrine engineering geological zone. The main engineering geological problems include soil erosion and locally scattered poor foundation soil.

#### 3.3 Hydrogeology

The shallow groundwater in the research area is mainly composed of pore water in loose rocks of the Cenozoic era. The shallow groundwater floor in the Tangshan New City planning area is buried at a depth of 60-90m, with an aquifer thickness of 40-70m. The water level is generally buried at a depth of 5-30m, gradually deepening from south to north; The shallow groundwater floor in the Jingtang Smart Port area is buried at a depth of 60-140m, with an aquifer thickness of 45-100m. The water level generally deepens from northwest to southeast at a depth of 5-30m.

#### 3.4 Geological Hazards

There are mainly geological disasters such as goaf collapse and ground subsidence in the research area. The impact of goaf collapse mainly comes from Donghuantuo Mine and Tangshan Mine, located in the northwest and southeast corners of Tangshan New City Planning Area, respectively; Ground subsidence is distributed in the southwest and is mainly affected by groundwater extraction. In recent years, its development has shown a slowing trend. According to the requirements of the Code for Seismic Design of Buildings<sup>[21]</sup>, the equivalent shear wave velocity of the 20m soil layer in most areas of the study area is 250-300m/s, indicating good site stability.

### 3.5 Geothermal Energy and Overburden Mineral Resources

The burial depth of the constant temperature layer in the research area is generally 20~30m, with an average depth of 25m. The temperature is about 12.5~15.5 °C, and the overall temperature gradient does not change much, generally less than 2.0 °C/100m. The temperature of the constant temperature layer in the Jingtang Smart Port area is 12.5-13.5 °C, and the ground temperature gradient is generally 1.0-1.5 °C/100m. Only the southern part of Huanghuagang has a temperature greater than 13.5 °C and a ground temperature gradient greater than 1.5 °C/100m. The temperature of the constant temperature layer in Tangshan New City area is generally higher than that in Jingtang Smart Port area, ranging from 13.0 to 15.5 °C; The temperature gradient is generally 1.0~1.5 °C/100m, with only the Hancheng Yuanjiazhuang Liugezhuang line, Lijiazhuang, and Liguantun areas having a temperature gradient greater than 1.5 °C/100m, and the highest value reaching 2.75 °C/100m.

Within a 300m extension of the research area, there are 7 mining areas with overlying strata and 2 mining rights. Among them, the Jingtang Smart Port area involves one mineral deposit and one mining right; There are 6 mineral deposits and 2 mining rights in Tangshan New City. At present, mining has been stopped.

## 4 Evaluation of Suitability for Underground Space Development

### 4.1 Construction of Suitability Evaluation Index System for Underground Space Development

**Indicator screening.** Based on the analysis of geological conditions, the suitability evaluation indicators for underground space development in the research area are mainly considered from the aspects of basic geological conditions, engineering geological conditions, hydrogeological conditions, shallow geothermal energy, overlying mineral resources, geological disasters, etc. [22]. The specific situation of considering indicators, screening criteria, and whether to include them in the evaluation indicator system is shown in Table 1.

**Table 1.** Index selection for suitability assessment of underground space development

First level indicator	Secondary indicators	Screening Criteria	Whether in the indicator system
Basic geological conditions	Elevation and slope	If the slope is too steep, it will increase the development cost. If it is less than 5% in this area, this indicator can be ignored	No
Engineering geological conditions	Rock and soil type	The soil density of the stratum where the development depth is located is relatively high, the overall engineering properties are good, and there is no special distribution of rock and soil. This indicator can be ignored	No

	Foundation bearing capacity	The distribution of bearing capacity on the surface of foundations at different depths varies and needs to be considered layer by layer	Yes
	Beneficial for the proportion of development layer thickness	The distribution of rock and soil types in different depths of strata varies on the surface and needs to be considered layer by layer	Yes
	Distribution of fractures and broken zones	Mainly considering the influence within 5km and 10km on both sides of the Holocene active fault, the complex structure in the area has a significant impact on the development of underground space	Yes
	Sand liquefaction	The liquefaction of sandy soil in Yangyikou Village Moyizhuang, Xiaodaodi Village, and the southeast area of Zhongmenzhuang has a significant impact on the stability of site construction	Yes
<b>Hydrogeologic condition</b>	Ggroundwater type	The groundwater below a shallow development depth of 80 meters in the research area is mainly composed of shallow loose rock pore water, which does not have differential distribution characteristics	No
	Ggroundwater depth	The burial depth of water level gradually deepens from south to north, and the distribution on the surface has differences	Yes
	Groundwater inflow	There is no complete distribution of aquitards between the upper aquifers, which has strong infiltration recharge and water storage conditions, and has a certain impact on the development of underground space	Yes
<b>Shallow geothermal energy</b>	Shallow geothermal energy	The overall temperature gradient does not change significantly	No
<b>Overburden mineral</b>	Overburden mineral resources	There is currently no mining or planning	No
<b>Geological disaster</b>	Karst collapse	22 karst collapses have developed in the urban area of Tangshan, far away from the study area, with almost no impact	No
	Mining subsidence	The impact of goaf collapse mainly comes from Donghuantuo Mine and Tangshan Mine, located in the northwest and southeast corners of Tangshan New City in the working area, respectively	Yes

	Land subsidence	There are differences in the distribution of cumulative quantities over the past five years	Yes
	Corrosivity of soil and water	Scattered distribution of soil and water corrosion within the research scope can have a corrosive impact on underground buildings	Yes
<b>Earthquake safety</b>	Seismicity	Within a 25km radius centered on the planning area, there have been 26 earthquakes of magnitude 4.7 or above in history, and the impact of earthquakes needs to be considered	Yes

**Grading of evaluation indicators.** Referring to the "Code for Engineering Geological Survey of Urban and Rural Planning"<sup>[23]</sup>, analyze the characteristics of the adaptability evaluation indicators for underground space development and their possible impact on underground space development and utilization (underground space development mainly considers strata with a burial depth of less than 80 meters), classify and assign values to each individual indicator (Table 2). Considering the characteristics of engineering geological conditions, the two indicators of foundation bearing capacity and development layer thickness are graded and assigned values according to three different layers: 0-10m, 10-30m, and 30-80m.

**Table 2.** Classification and assignment of index for suitability assessment of underground space development

First level indicator	Secondary indicators	Third level indicators	Grading and assigning evaluation indicators				Burial depth
			4 points	3 points	2 points	1 point	
Suitability evaluation of underground space development	Basic geological conditions	Distribution of fractures and broken zones (Q1)	Distance from general faults>100m or active faults>500m	Distance from general fault 100-50m or active fault 250-500m	Distance from general faults<50m or active faults 50-250m	Distance from active fracture<50m	0~80m
			0~10m foundation bearing capacity (Q <sub>2</sub> )	≥200KPa	150~200	100~150	<100
	Engineering geological conditions	10~30mfoundation bearing capacity (Q <sub>3</sub> )	≥300KPa	250~300	150~250	<150	10~30 m
			30~80mfoundation bearing capacity (Q <sub>4</sub> )	≥300KPa	250~300	200~250	<200

	0~10m Beneficial for the proportion of development layer thickness (Q <sub>5</sub> )	80~100%	60~80%	40~60%	0~40%	0~10m
	10~30m Beneficial for the proportion of development layer thickness (Q <sub>6</sub> )	80~100%	60~80%	40~60%	0~40%	10~30 m
	30~80m Beneficial for the proportion of development layer thickness (Q <sub>7</sub> )	80~100%	60~80%	40~60%	0~40%	30~80 m
	Corrosivity of soil and water (Q <sub>8</sub> )	Micro corrosiveness	Weak corrosiveness	Moderate corrosiveness	Moderate to strong corrosiveness	0~80m
	Sand liquefaction (Q <sub>9</sub> )	Mild liquefaction or no liquefaction	Mild liquefaction	Moderate liquefaction	Severe liquefaction	0~80m
Hydrogeologic condition	Shallow groundwater depth (Q <sub>10</sub> )	20~30m	10~20m	5~10m	0~5m	0~80m
	Water inflow (Q <sub>11</sub> )	<1000 m <sup>3</sup> /d	1000~3000 m <sup>3</sup> /d	3000~5000 m <sup>3</sup> /d	>5000 m <sup>3</sup> /d	0~80m
Geological disaster	Annual average subsidence of ground subsidence (Q <sub>12</sub> )	<10 mm/a	10~30 mm/a	30~50 mm/a	>50 mm/a	0~80m
	Mining subsidence (Q <sub>13</sub> )	No goaf collapse	The impact of goaf collapse is relatively small	The impact of goaf collapse is significant	Mining subsidence area	0~80m

Earth-quake safety	Seismic ac-celeration (Q <sub>14</sub> )	0.14~0.19g	0.19~0.28g	0.28~0.38g	0.38~0.75g	0~80m
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### 4.2 Hierarchical Structure Model for Suitability Evaluation of Underground Space Development

**Establishment of hierarchical structure model for suitability evaluation of underground space development.** Based on the basic principles of Analytic Hierarchy Process and the screening results of suitability evaluation indicators for underground space development (Tables 1 and 2), a hierarchical structure model for suitability evaluation of underground space development in the construction planning area of Tangshan City was established (Figure 2.).

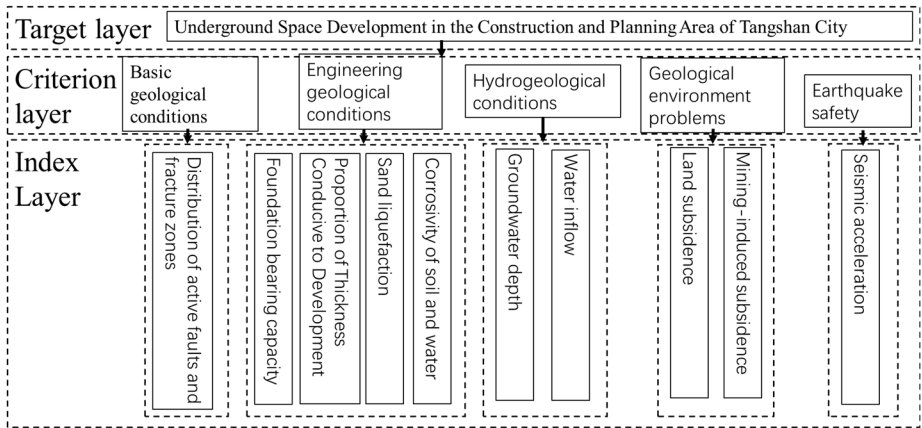


Fig. 2. Construction of hierarchical structure model

**Determination of Weight for Suitability Evaluation Indicators of Underground Space Development.** Using Satty1-9 scales (Table 3), compare the importance of each indicator pairwise to form a judgment matrix T (Equation (1)).

Table 3. Identification and meaning of judging matrix in the expert analytic hierarchy weighting Process

Scale	Meaning
1	Indicates that two factors have equal importance compared to each other
3	Compared to two factors, one factor is slightly more important than the other
5	Indicates that one factor is significantly more important than the other compared to two other factors
7	Compared to two factors, one factor is more important than the other
9	Indicates that one factor is extremely important compared to the other

2,4,6,8 The median of the two adjacent judgments mentioned above represents the transitional period between the importance judgments

Reciprocal Comparing factor xi with xj yields a judgment of uij; On the contrary, comparing factor xj with xi yields the judgment that uji=1/uij

Construct a judgment matrix T based on this:

$$T = \begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1m} \\ u_{21} & u_{22} & \cdots & u_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ u_{m1} & u_{m2} & \cdots & u_{mm} \end{bmatrix} \quad \text{Equation (1)}$$

In the formula, U={u1, u2,..., um} is the evaluation factor vector, and Uij represents the relative importance value of Ui to Uj.

According to the judgment matrix, calculate the maximum eigenvalue of T and its corresponding eigenvector. The obtained eigenvector is the importance ranking of each evaluation factor. After consistency testing, obtain the weights of each factor. Table 4 shows the weight matrix of the final suitability evaluation indicators for underground space development.

**Table 4.** Weight matrix of index for suitability assessment of underground space development

Serial Number	Criterion layer	Indicator layer	Indicator layer weight		
			0~10m	10~30 m	30~80 m
1	Basic geological conditions	Distribution of fractures and broken zones ractures and broken zones	0.15	0.26	0.30
		0~10m Foundation bearing capacity	0.13	—	—
		10~30 m Foundation bearing capacity	—	0.05	—
		30~80 m Foundation bearing capacity	—	—	0.02
2	Engineering geological conditions	0~10m Beneficial for the proportion of development layer thickness	0.05	—	—
		10~30m Beneficial for the proportion of development layer thickness	—	0.10	—
		30~80m Beneficial for the proportion of development layer thickness	—	—	0.06
		Sand liquefaction	0.05	0.06	0.03
		Corrosivity of soil and water	0.03	0.05	0.05
3	hydrogeologic condition	Groundwater depth	0.06	0.07	0.08
		Water inflow	0.03	0.07	0.22
4	Geological hazards Geological hazards	Land subsidence	0.03	0.02	0.01
		Mining subsidence	0.05	0.06	0.07
5	Earthquake safety	Ground motion acceleration	0.42	0.26	0.16

### 4.3 Comprehensive Evaluation Model for Suitability Assessment of Underground Space Development

Using the comprehensive index evaluation method (Equation 2), evaluate the suitability of groundwater spatial development.

$$F = \sum_{i=1}^n Q_i \cdot w_i \quad \text{Equation (2)}$$

In the formula: F is the comprehensive index for evaluating the suitability of underground space development; N is the number of evaluation factors; Q (i) is the value assigned to the i-th evaluation factor (Table 3); W (i) is the weight of the i-th evaluation factor (Table 4).

The suitability evaluation model for underground space development at different depths is shown in equations 3-5:

(1) Suitability evaluation model for underground space development in 0-10m strata

$$F = 0.15 \cdot Q_1 + 0.13 \cdot Q_2 + 0.05 \cdot Q_5 + 0.05 \cdot Q_8 + 0.03 \cdot Q_9 + 0.06 \cdot Q_{10} + 0.03 \cdot Q_{11} + 0.03 \cdot Q_{12} + 0.05 \cdot Q_{13} + 0.42 \cdot Q_{14} \quad \text{Equation(3)}$$

(2) Suitability evaluation model for underground space development in 10-30m strata

$$F = 0.26 \cdot Q_1 + 0.05 \cdot Q_3 + 0.10 \cdot Q_6 + 0.06 \cdot Q_8 + 0.05 \cdot Q_9 + 0.07 \cdot Q_{10} + 0.07 \cdot Q_{11} + 0.02 \cdot Q_{12} + 0.06 \cdot Q_{13} + 0.26 \cdot Q_{14} \quad \text{Equation (4)}$$

(2) Suitability evaluation model for underground space development in 30-80m strata

$$F = 0.30 \cdot Q_1 + 0.02 \cdot Q_4 + 0.06 \cdot Q_7 + 0.03 \cdot Q_8 + 0.05 \cdot Q_9 + 0.08 \cdot Q_{10} + 0.22 \cdot Q_{11} + 0.01 \cdot Q_{12} + 0.07 \cdot Q_{13} + 0.16 \cdot Q_{14} \quad \text{Equation (5)}$$

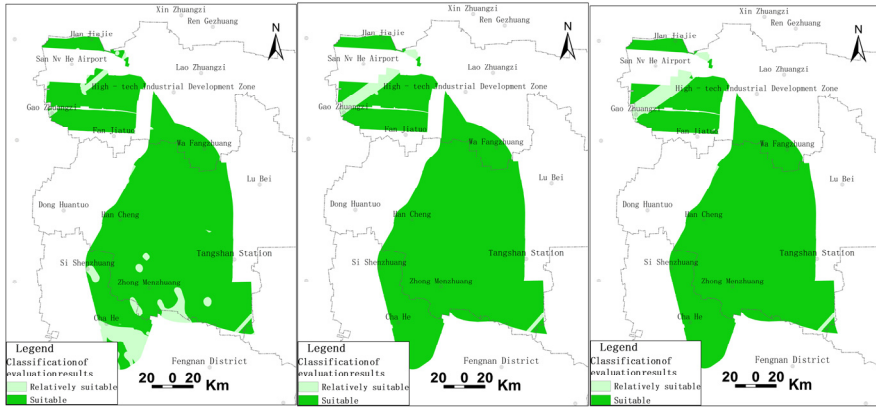
### 4.4 Evaluation Results of Suitability for Underground Space Development

Based on the single indicator grading and assignment (Table 3) and the suitability evaluation results of underground space development, the suitability of underground space development is divided into three levels: suitable, relatively suitable, and generally suitable (Table5).

**Table 5.** Classification of Comprehensive Evaluation Index for Suitability of Underground Space Development

Grade	Suitable	Good suitability	Generally suitable	Poor suitability
Index Range	$4 \geq F > 3$	$3 \geq F > 2$	$2 \geq F > 1.5$	$1.5 \geq F \geq 1$

According to Table 5, the results of the suitability evaluation for underground space development were normalized to obtain the suitability evaluation results for underground space development at different depths of 0-10m, 10-30m, and 30-80m (Figure 3).



**Fig. 3** Suitability classification chart Left: 0-10m stratigraphy, center: 10-30m stratigraphy, right: 30-80m stratigraphy)

According to the statistical results in Figure 3, the suitable area for underground space development in the strata with a burial depth of 0-10m is approximately 90.99 km<sup>2</sup>, accounting for 91.65% of the total planned area; The area of the more suitable region is about 8.29 km<sup>2</sup>, accounting for 8.38% of the total planned area, mainly scattered in local areas such as Gaozhuangzi Village and south of Chahe Town. In the strata with a burial depth of 10-30m, the suitable area for underground space development is approximately 95.62km<sup>2</sup>, accounting for 97.22% of the total planned area; The area of the more suitable area is about 2.76km<sup>2</sup>, accounting for 2.78% of the total planned area, mainly scattered along the northeast direction from Gaozhuangzi Village in Jingtang Smart Port and the southeast corner of Tangshan New City planning area. In the strata with a burial depth of 30-80m, the suitable area for underground space development is approximately 95.56km<sup>2</sup>, accounting for 96.25% of the total planned area; The suitable area is about 3.72km<sup>2</sup>, accounting for 3.75% of the total planned area, mainly distributed along the northeast direction from Gaozhuangzi Village in Jingtang Smart Port and the southeast corner of Tangshan New City planning area. Overall, the suitability for underground space development in shallow strata with a burial depth of 80m is relatively good, with the best suitability for underground space development in strata with a burial depth of 10-30m, followed by strata with a burial depth of 30-80m, and relatively poorer in strata with a burial depth of 0-10m.

## 5 Discussion

The suitability evaluation of underground space development is a relatively complex and exploratory research stage, and there is currently no relatively unified or standardized indicator system and method system. This article adopts high-precision comprehensive geological survey results and evaluates the adaptability of underground space development from different depths, laying a good foundation for the accuracy and reliability of evaluation results. However, it should be pointed out that there are still some

shortcomings, mainly manifested in: (1) there is a large subjectivity in the selection of indicator systems and evaluation methods; (2) In indicator systems of different depths, some indicators can achieve hierarchical processing, while others do not.

## 6 Conclusion

On the basis of fully collecting and analyzing high-precision comprehensive geological survey results such as basic geology, engineering geology, hydrogeology, and geological hazards, this article establishes a suitability evaluation index system for underground space development in the construction planning area of Tangshan City, which makes up for the research work on suitability evaluation of underground space development in areas with complex geological conditions in China; Using the Analytic Hierarchy Process, a structural model and an evaluation model were established to assess the suitability of underground space development in the region. The main conclusions are as follows:

(1) In areas with complex geological conditions and seismic impact, as long as the geological survey work covers comprehensively and the work accuracy is high enough, the general underground space development suitability evaluation method is also applicable;

(2) The suitability evaluation index system for underground space development mainly includes 5 secondary indicators and 10 tertiary indicators. Among them, in different depths of strata such as 0-10m, 10-30m, and 30-80m, the distribution of faults and fracture zones and the weight of seismic acceleration are relatively large, which are the main control indicators affecting the development of underground space. In addition, in the strata with a burial depth of 0-10m, the secondary indicators that affect the development of underground space are in descending order of importance, including foundation bearing capacity, groundwater level burial depth, proportion of favorable development layer thickness, sand liquefaction, and goaf collapse. Other indicators have a relatively small impact; In the strata with a burial depth of 10-30m, the secondary indicators are, in order, the proportion of favorable development layer thickness, groundwater level burial depth, water inflow, sand liquefaction, goaf collapse, and soil erosion, while other indicators have a relatively small impact; In the strata with a burial depth of 30-80m, the main control indicators also include water inflow, and the secondary indicators are groundwater level burial depth, goaf collapse, proportion of favorable development layer thickness, and soil erosion. Other indicators have a relatively small impact.

(3) The evaluation results show that the overall suitability of underground space development in the construction planning area of Tangshan City is good, and the strata with a burial depth of 0-80m are suitable for underground space development. In the strata with a burial depth of 0-10m, the suitable area for underground space development accounts for 91.65% of the total area, and the relatively suitable area accounts for 8.35%; In the strata with a burial depth of 10-30m, the suitable area for underground space development accounts for 97.22% of the total area, and the relatively suitable area accounts for 2.78%; In the strata with a burial depth of 30-80m, the suitable area

for underground space development accounts for 96.25% of the total area, and the relatively suitable area accounts for 3.75%.

(4) The suitability evaluation of underground space development is an important basis for formulating underground space development plans and engineering construction designs. In the process of underground space development, further investigation and evaluation based on larger scale geological work are needed for specific underground space development and construction projects or purposes, in order to avoid major engineering problems and reduce the geological safety risks that may arise from underground space development.

## Acknowledgement

This research is supported by the Research on Evaluation System of Suitability of Underground Space development and Utilization in Typical Cities-Tangshan City Planning Area as an Example (Grant No. 13000024P00329410267M)

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