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Value evaluation model (VEM) of ancient Chinese military settlement heritage: a case study of Liaoxi Corridor in the Ming Dynasty

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Abstract

The Ming Great Wall Military Defense System is the most complete ancient military cultural heritage in China, which is of great significance to the study of China's ancient military defense mechanism and pattern. Military settlement is an important carrier of this mechanism. The estimation and in-depth understanding of its value can further excavate the profound connotation of the military defense system and the Great Wall spatial pattern in the Ming Dynasty. This paper adopts the AHP-CRITIC weighting approach to determine the weights of the historical value, scientific value, social value, cultural value and artistic value of the settlement heritage, so as to construct the value evaluation model of military settlements, and takes 34 Ming Great Wall military settlements in the Liaoxi Corridor as an example for evaluation. The results of the evaluation identified the priority settlements for conservation and development, and also explored their relationship with historical status, urbanization processes and official policies. The evaluation model constructed in this paper has a certain universality, and can also be followed in the evaluation of other military settlements in the Ming Great Wall Defense System, so as to obtain the overall cognition of the settlement system.

Keywords Ming Great Wall, Military settlements, Value evaluation model (VEM), Heritage value, AHP-CRITIC

Introduction

The Ming Great Wall is the most famous world cultural heritage in China and the most complete Military Heritage in ancient China. It is of great significance to learn and understand the spatial law of the military defense system in ancient China. The previous knowledge was always limited to the study of the wall itself, but what really worked was the three-dimensional defense system with the wall itself as the axis in combination with various military elements, and it's the huge military settlement system that served as the basic unit to maintain the operation of the system.

In the current study, for the whole system, researchers have conducted an in-depth discussion on the spatial mode [1, 2] of the Ming Great Wall Military Defense System, macro systematic relationships, and fractal structure [3]. They divided the Ming Great Wall Military Defense System into three main levels: Core castle, low-level Bao city, and terminal military facilities [4]. It also involves various military elements in the system, such as the postal delivery transportation system [5], beacon towers, and other military facilities [6] as well as the military settlements [2]. Among them, there is not much research focusing on the military settlement heritage. As an important carrier of this defense system, the estimation and in-depth understanding of the value of military settlements is the top priority in the research field of the military defense system and spatial pattern of the Ming Great Wall.

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The Ming Great Wall is divided into nine important military towns, of which the easternmost Liaodong Town, is the only military defense area with both land defense and coastal defense systems. The Liaoxi Corridor area is located in the west of Liaodong Town. The special locational conditions brought about the birth and development of its land-sea coordinated defense mechanism. However, in the current research, less attention has been paid to the value of the military settlements from the perspective of the land-sea coordinated defense mechanism, and there is also short of a comprehensive construction method of the military settlement evaluation system. The objective recognition of the value of settlement heritage can provide a realistic basis for the research and protection of the land-sea coordinated defense mechanism and the Ming Great Wall Military Defense System.

Value assessment methods are applied in many fields. Scientific and effective value assessment can provide a reference for subsequent management and decision-making, and it also plays the same role in the field of heritage conservation. With the in-depth study of heritage conservation, researchers gradually realize the importance of sustainable development and scientific strategies for conservation and exploitation [7]. The practice has proved that to realize the sustainable development of cultural heritage and build a scientific decision-making and management mechanism, this must be based on the comprehensive assessment of heritage [8]. Therefore, the evaluation and research of the history, tourism, economy, risk, etc. for heritage have been popping up. The conservation of heritage is the most basic work in this management mechanism. Therefore, there have been many studies on the assessment of the current conservation status of heritage [9]. Such assessment is often a direct cognition of the surface conditions of heritage, while the assessment of its potential risks is more specific. A simplified risk assessment framework was proposed to determine the expected level of damage for structures. This method can be used for preliminary screening of potential risks for a large number of cultural heritages [10]. Further risk assessment is mainly based on climate, geography, heritage data, and GIS technology to clarify the natural disaster risk and types of heritage [11, 12]. In addition to the impact of the natural environment on heritage, there are studies related to assessing the impact on the natural environment in the life cycle of heritage [13, 14]. The above research helps to understand the relationship between heritage and the natural environment to achieve sustainable development of heritage through subsequent planning strategies [15].

To make the cultural heritage develop dynamically, in addition to the basic conservation and repair, it also needs long-term planning and development. To study the development and utilization of heritage, we should first establish a comprehensive understanding of the economic value and sustainability of heritage [16] and understand the motivation and behavior patterns of tourists [17, 18]. The recognition of heritage development and utilization can be reflected in the evaluation of the appropriateness of the new use for heritage based on the policy guidance, so as to formulate the adaptive utilization strategy of heritage [19]. It can also exist as a cultural tourism potential audit tool to determine the key development points of heritage and the spatial reformation strategies [20] and measure their attraction to tourists [21]. The continuous development of tourism may have a negative impact on heritage conservation. Therefore, the assessment based on the perspective of development and utilization should not only focus on the attraction of heritage to tourists but also assess the maximum tourism capacity of heritage. The World Tourism Organization (WOT) defines the capacity of heritage as "the maximum number of people who could visit a place in a given period of time, in such a way that the local environmental, physical, economic and socio-cultural characteristics are not compromised, and without reducing tourist satisfaction" [22]. The assessment of heritage capacity can also be carried out through the GIS platform with a complete database and management framework [23]. Most of the above studies assess the development and utilization value of heritage from a predictive perspective. In addition, some studies assess the adaptive value of heritage after development and utilization, using a combination of qualitative and quantitative analysis to determine whether tourism development has adverse effects on heritage, the use of functional space, and its attraction to tourists [24, 25].

In addition, cultural heritage is a social product, and the social, cultural, economic, ecological and other values derived from it are gradually taken into account [17]. Researchers pay attention to the relationship between culture and nature of rural heritage, which together constitute the integrity of rural heritage [26]. Moreover, the military facilities heritage is often combined with natural ecology and social and cultural values [27]. In addition, some researchers regard cultural heritage as the carrier of cultural and economic value [28], and some economic methods have also been introduced into heritage value assessment, such as The Contingent Valuation Method (CVM) [29], Travel Cost Method (TCM) [30], and The Willingness to Pay (WTP), etc. The participation of a large number of data and algorithms makes the value assessment more objective and accurate, and also makes the composition of heritage value gradually diversified. The comprehensive assessment of heritage usually reflects the role of external policies, management

and social impacts in the protection and development process [31]. However, the above methods have focused mainly on the social and economic benefits of heritage, with little coverage of other types of heritage values.

Therefore, compared with the assessment in a single field, the current more common research is the comprehensive judgment of the value of all aspects of heritage, that is, the multi criteria analysis of heritage value. One of the simplified studies uses the method of subjective scoring of decision makers to comprehensively evaluate the intrinsic value, heritage value and heritage potential value [32]. Considering the different importance of indicators, there are also studies of simple weighting through subjective decision [33]. This kind of method reflects the subjective opinions of decision makers, but it is relatively simple to judge the importance of indicators. To consider the weight comparison between indicators, it is necessary to introduce a new weighting method for calculation. The weighting method can be divided into subjective weighting method and objective weighting method. The Analytic Hierarchy Process (AHP) [34] is one of the more common methods in the subjective weighting method. By comparing and judging the importance of the two indicators, the weight of evaluation indicators can be determined. AHP method is often used in combination with other weighting methods to judge the comprehensive value of heritage [35, 36]. Generally speaking, the combination of questionnaire method, interview method and Delphi method for evaluation can form an effective group decision evaluation method [37]. Many studies persist in exploring more accurate subjective weighting methods, such as the combination of AHP and fuzzy sets to construct the evaluation indicator system of industrial heritage and translate the fuzzy indicator evaluation to enhance the accuracy [38]. The advantage of AHP method is its simplicity and efficiency. However, the subjective weighting method often has some subjective randomness and lacks judgment on the repeatability between evaluation indicators.

Objective weighting methods include principal component analysis, entropy method, CRITIC weighting method, etc. CRITIC (Criteria Importance Through Inter Criteria Correlation) is an objective weighting method proposed by Diakoulaki [39] in 1995, which is more scientific and accurate than the other methods. It was initially applied in multi criteria decision making in the field of enterprise finance. By analyzing the contrast strength of single indicators and the conflict between indicators, so as to determine the objective weight without the influence of decision makers. After a series of improvements [40], CRITIC method is commonly used to evaluate multiple objective indices that can detect the relationship between indicators. In the research, CRITIC can also be combined with other methods to evaluate the value of all aspects, so as to provide decision-makers with decision-making reference [41, 42]. The CRITIC method plays an important role in modeling the assessment of urban resilience and offers opportunities for urban research [43]. This method has also been used in the field of heritage conservation. For example, it was used to measure the extent of spatial damage in historic sites [44]. The objective weighting method is based on the statistical analysis of data but it ignores the role of people as the evaluation subject. Therefore, the results inevitably differ from the actual situation.

In order to solve the problems of various weighting methods, researchers began to focus on composite weighting methods, such as CRITIC-GRA methods [45] and CV-CRITIC methods [46]. For the evaluation model in this paper, the composition of indicators is relatively complex. The AHP method is used as the most common subjective allocation method because some of the indicators require expert judgment and decision making. In addition, there is a correlation between indicators and it is impossible to judge the degree of correlation. In order to eliminate the bias in weight calculation caused by duplicate indicators, the CRITIC method based on conflicts between indicators is preferred. Therefore, this paper selects the AHP-CRITIC composite weighting method to build the evaluation model of military settlements. The AHP-CRITIC composite weighting method is conducive to determining the indicator weight more comprehensively, so as to build a composite value evaluation model suitable for military heritage.

Materials and methods

Methods

AHP analytic hierarchy method

Analytic Hierarchy Process (AHP), proposed by Saaty [34], is one of the most widely used subjective weighting methods at present, and is widely used in many fields such as economics, sociology and so on.

(1) Construction of AHP matrix and weight calculation

A paired comparison judgment matrix A is established to compare the importance of two indicators, and aij is used to represent the comparison result of the importance of wi indicator relative to wj indicator.

$$A = \begin{bmatrix} w_1 : w_1 & \cdots & w_1 : w_n \\ \vdots & \ddots & \vdots \\ w_n : w_1 & \cdots & w_n : w_n \end{bmatrix}. \quad (1)$$

The eigenvector w is obtained through comparison and calculation, that is, the weight values of n indicators.

Scale	Pairwise comparison
1	Factor i is as important as factor j, or i, j compared with themselves
3	Factor i is slightly more important than factor j
5	Factor i is obviously more important than factor j
7	Factor i is greatly more important than factor j
9	Factor i is extremely more important than factor j
2, 4, 6, 8	The importance of pairwise comparison is between the above scales

(2) Consistency test

Since the analytic hierarchy process is based on people's subjective judgment, in order to prove the accuracy of the weight obtained, it is also necessary to test the consistency of the results.

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(Aw)_i}{w_i}, \tag{2}$$

where A_{max} refers to the maximum eigenvalue of the judgment matrix, and $(Aw)_i$ refers to the ith element of the vector A_w. The deviation consistency indicator CI is calculated according to the A_{max}.

$$CI = \frac{\lambda_{max} - n}{n-1}. \tag{3}$$

The average consistency indicator RI can be obtained by mathematical statistics. See the table below for RI value of judgment matrix of order 1–9.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Finally, the relative consistency indicator CR of the judgment matrix is calculated according to the deviation consistency indicator CI and the average consistency indicator RI.

$$CR = \frac{CI}{RI}. \tag{4}$$

The calculated matrix CR value must conform to $CR \leq 0.1$. The smaller the CR value, the higher the consistency of the judgment matrix; If $CR > 0.1$, it needs to be corrected again until the requirements are met.

CRITIC weight method

The CRITIC weight method (Criteria Importance Though Intercrieria Correlation, CRITIC) is an objective weight method proposed by Diakoulaki [39]. CRITIC weighting method focuses on the analysis of existing data, so as to weight the evaluation indicator. Its weighting method is mainly based on two principles: (1) contrast intensity, that is, the value difference of the same indicator in each evaluation object. (2) The conflict of evaluation indicators, that is, the correlation degree between the values of two indicators. The calculation process of CRITIC weight method is as follows:

(1) Data normalization processing

Because the order of magnitude of different indicators is not the same, they cannot be measured by a unified standard, which will affect the accuracy of weight calculation. Therefore, it is necessary to normalize all evaluation data first. For positive indicators (i.e., the higher the numerical value, the higher the value),

$$x'_{ij} = \frac{x_{ij} - \min x_j}{\max x_j - \min x_j}, \tag{5}$$

and for reverse indicators (i.e., the higher the numerical value, the lower the value),

$$x'_{ij} = \frac{\max x_j - x_{ij}}{\max x_j - \min x_j}, \tag{6}$$

then all indicator data are unified within the interval of [0,1] for subsequent calculation.

(2) Calculation of data contrast strength

The contrast strength of the data is usually presented by the standard deviation of each group of indicator data. The larger the standard deviation, the greater the internal fluctuation of the group of data, which can more clearly reflect the differences between the evaluation objects.

$$S_j = \sqrt{\frac{\sum_{i=1}^{m}(x_{ij} - \bar{x_j})^2}{n-1}}, \tag{7}$$

where S_j represents the standard deviation of the jth indicator and x_j represents the average value of the jth group of indicator data.

(3) Calculation of indicator conflict

The conflict between the indicators can be expressed by calculating the correlation coefficient of the two groups of data. Rij represents the correlation coefficient of group i and group j data. When the correlation coefficient is larger, the more content that

represents the repeated expression of the two indicators, the smaller the weight in the evaluation system.

$$R_j = \sum_{i=1}^{n}(1 - r_j), \tag{8}$$

then the conflicting data R_j of the jth indicator can be obtained.

(4) Calculation of objective weight of indicators

The information C_j of the indicator is calculated according to the standard deviation S_j and the indicator conflict data R_j. The more information an indicator has, the more it can not only reflect the differences among the evaluation objects, but also play an irreplaceable role in the evaluation system compared with other indicators. Therefore, the weight W_j of the jth indicator can be obtained as:

$$C_j = R_j \times S_j, \tag{9}$$

$$W_j = \frac{C_j}{\sum_{j=1}^{n} C_j}. \tag{10}$$

AHP-CRITIC composite weight method

This paper uses the AHP-CRITIC composite weight method as the evaluation method, and uses the subjective weight method to get the weight value α_j and weight value obtained by objective weighting method β_j.

$$W_j = \frac{\alpha_j \beta_j}{\sum_{j=1}^{n} \alpha_j \beta_j}, \tag{11}$$

and the final indicator weight is obtained by compound calculation according to the equation, so as to build a complete evaluation indicator system.

Study area

In the Ming Great Wall Military Defense System, the Liaoxi Corridor region usually refers to the narrow coastal plain between Shanhaiguan and Jinzhou, which is the only way to the capital and plays an extremely important military role in the war of the Ming and Qing Dynasties. In addition, because of its special geographical location, it gave birth to the only military defense zone in the Great Wall System of the Ming Dynasty with both land defense and coastal defense. The land defense settlements are closely combined with the Ming Great Wall to form a tight border defense line, while the coastal settlements give consideration to both land and coastal defense affairs, forming a unique land-coastal coordinated defense mechanism.

However, in the current research, the role of land-coastal coordinated defense mechanism in the composition of military settlement pattern is rarely involved, and the value of military settlement under this mechanism is also lack of attention, resulting in the lack of regional characteristics of the Military Heritage conservation in this area. Therefore, this paper aims to explore a construction method of evaluation system combining qualitative and quantitative research, and objectively recognize the value of military settlement in such three aspects as history, protection and development, so as to provide a theoretical basis for the follow-up research and protection work.

There were a large number of military settlements in Liaoxi Corridor of the Ming Dynasty. However, due to the long history, some low-grade settlements were not only lack of data, but also did not leave any tangible relics, so it was impossible to evaluate objectively. Therefore, by comparing the tangible relics, historical military status and other factors, and based on the field survey, this paper finally selects 34 major military settlements in Liaoxi Corridor for evaluation. According to the defense level from high to low in the Ming Dynasty, military settlements can be divided into five levels of settlements: Zhen (5)—Lu (4)—Wei (3)—Suo (2)—Bao (1). For ease of understanding, the following figures are used to distinguish the Settlement defense levels. Therefore, there are 1 settlement (level 4), 2 settlements (level 3), 6 settlements (level 2) and 25 settlements (level 1) in this evaluation, including 25 land defense settlements and 9 land-coastal defense settlements, as shown in Fig. 1. Numbers are also used instead of settlement names in the following text.

Results

Selection of evaluation indicators

The evaluation of the military settlement heritage in the Liaoxi Corridor region is mainly carried out from five dimensions: historical, scientific, social, cultural and artistic value. Based on these aspects, this paper subdivided into a number of indicators according to the actual situation of the Liaoxi Corridor, and finally formed an evaluation indicator system.

The historical value mainly refers to the historical status and military significance of specific settlements. The settlement development in Liaoxi Corridor is guided by military and political factors, showing an obvious hierarchy, which is one of the characteristics that is very different from the natural evolution of the urban system. Based on this feature, there is a significant gap between the military settlements in terms of scale, defense level, etc. The higher the status of the military settlements is, and the more significant the research is on the overall defense system of the Ming Great Wall, which thus lead

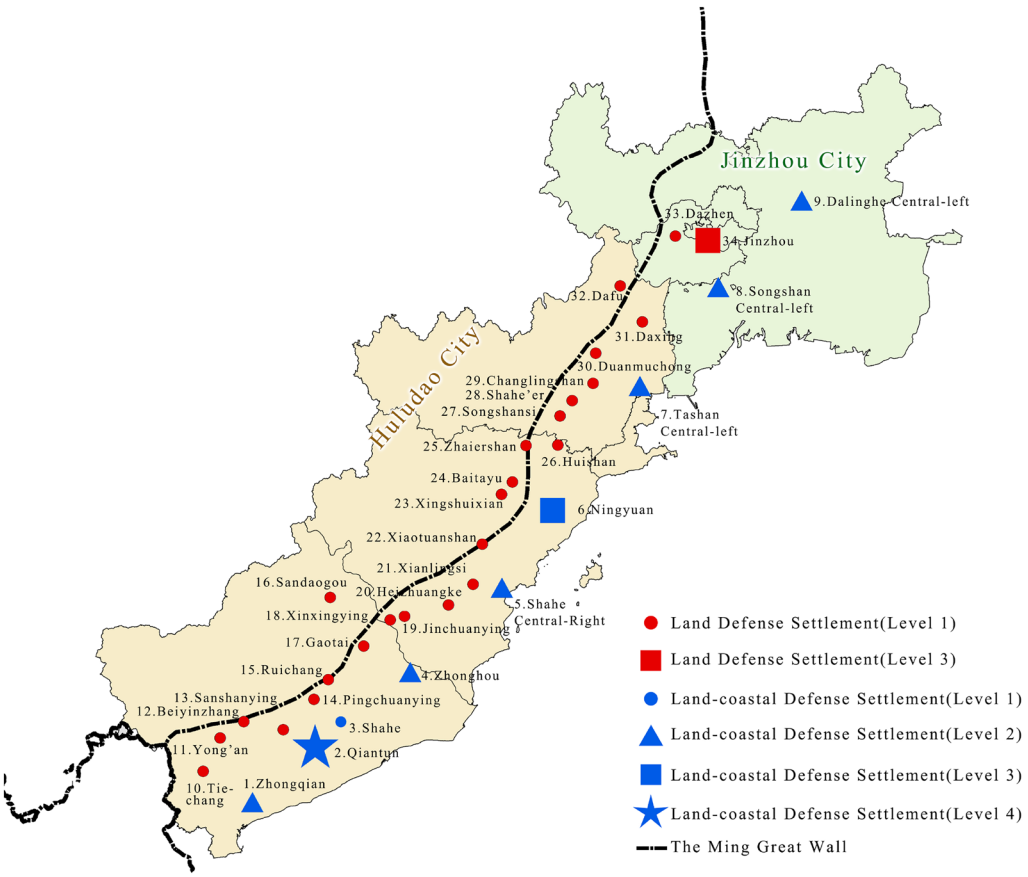

Fig. 1 Major military settlements distribution in Liaoxi Corridor

to more prominent historical value. This paper selects settlement area, defense level, troop size, and the number of ancillary military facilities as the evaluation indicators of historical value to measure the importance of each settlement.

The scientific value mainly refers to the construction techniques and conservation significance of military settlements. In general, the earlier the settlement was built, the more important it was. The construction techniques of military settlements varied depending on factors such as the defense level, military significance, etc. Preservation varies, as does the protection level provided by local governments. This paper evaluates the protection of the settlement by such indicators as the build time, the protection level of cultural relics and tangible historical remains.

The social value refers to the development prospects and socio-economic value of military settlements as cultural heritage attractions. In this area, the vast majority of settlements are not only lack of overall planning, but also lack of tourism infrastructure. Therefore, the evaluation of its social value mainly focuses on its potential value. The accessibility of settlements is one of the important factors in the utilization of heritage. The site selection of military settlements in Liaoxi Corridor falls into two regions: coastal plain and hilly land. Elevation and terrain have an important impact on its accessibility. In addition, the utilization of the whole area also need to consider the spatial relationship between settlements and other heritage. In this regard, the military settlement emphasis of land defense and land-sea coordinated defense is different. Land-sea coordinated defense needs to consider not only the Wall itself, but also the locational relationship between the wall and the coastline. Therefore, in terms of social value, it is mainly evaluated by such indicators as elevation, distance from the Ming Great Wall or coastline, current locational conditions and land use types.

The cultural value refers to the cultural continuity and intangible remains of military settlements as cultural heritage. On the one hand, the cultural value is highly correlated with the extent to which the settlement is mentioned in historical sources. On the other hand, intangible remains and other cultural heritage are also one of the important evaluation indicators. Therefore, this paper selects intangible relics, historical events and cultural continuity as indicators of cultural value.

Table 1 Evaluation indicator system of military settlement heritage in Liaoxi Corridor

Value type	Evaluation indicator	Scoring criteria
Historical value	Settlement area/m^2	The actual area of each settlement
	Defense level	Zhen city (10), Lu city (8), Wei city (6), Suo city (4), Bao city (2)
	Troop size/person	The number of soldiers stationed in each settlement
	Number of nearby military facilities	The number of military facilities near each settlement is obtained through GIS neighbor analysis
Scientific value	Build time	Hongwu–Xuande period (1368–1435) (10), Zhengtong–Tianshun period (1436–1521) (8), Jiajing–Chongzhen period (1522–1644), (6) others (4)
	Cultural relics protection level	National (10), provincial (8), municipal (6), county (4), none (2)
	Tangible relics	Many tangible relics and in good condition (10), some relics in general condition (8), Few tangible relics, but well preserved (6), poor preservation (4), almost no relics (2)
Social value	Elevation	The elevation values of each settlement
	Horizontal distance from the Ming Great Wall or coastline	The horizontal distance from the Ming Great Wall (Land defense), the average horizontal distance from the Ming Great Wall and the coastline (Land-coastal defense)
	Current location conditions	Municipal (10), county (8), town (6), village (4), other (2)
	Land use type	Forest land (10), grass land (8), wetland (6), cultivated land (4), construction land and others (2)
Cultural value	Intangible relics	Many intangible relics and in good condition (10), some relics in general condition (8), few relics, but well preserved (6), poor preservation (4), almost no relics (2)
	Historical events	The importance and the number of historical events
	Cultural continuity	The preservation of traditional cultural
Artistic value	Architectural forms	The preservation of architectural forms
	Materials	The use of traditional materials
	Decorations	The preservation of architectural decoration

The artistic value mainly refers to the art of construction and decoration of military settlements. In this study area, the traditionally architectural forms and building materials preserved in the settlements are a reflection of their artistic value. In addition, some of the settlements also possess monumental inscriptions and memorial archways that show the traditional carving techniques. Thus, architectural forms, materials and decorations are determined to evaluate artistic value.

Based on the actual situation of the study area, the evaluation indicator system of military settlement heritage in Liaoxi Corridor, as shown in Table 1, is constructed through the optimization of the above five aspects and the formulation of scoring standards.

Calculation of AHP subjective weight

Based on the construction of the evaluation model, the paper was sent to 30 experts in the fields of heritage, history, architecture and urban planning. The questionnaire included a background introduction to the study and a comparison of the importance between two indicators. The received response will first undergo AHP consistency check in the yahhp software to ensure logical consistency. After the software check and negotiation with experts, a total of 17 valid questionnaires passed the consistency test, with an effective rate of 56.7%. The geometric mean method is used to ensure the validity of the data and to minimize the influence of extreme data All expert questionnaires are presented in an Additional file 1.

The evaluation indicator matrix is established, and the subjective indicator weight is calculated finally based on AHP weighting method according to the comparison of the importance between the two indicators, as shown in Table 2.

Calculation of CRITIC objective weight

Firstly, the evaluation indicators are scored and normalized to obtain the original data of the evaluation indicators, and then the contrast strength and conflict of the indicator data are calculated according to the Eqs. 7, 8. Finally, the weight of the objective indicators is as shown in Table 3.

Calculation of AHP-CRITIC composite weight

Based on the results of AHP subjective weighting method and CRITIC objective weighting method, the final CRITIC composite weight is calculated according to Eq. 11. On the basis of the weight values of the five value types calculated by AHP weighting method, a complete evaluation system of military settlement's heritage value can be constructed, as shown in Table 4.

Value evaluation

Because there are objective data items with different orders of magnitude in the evaluation indicators, the

Table 2 Indicator weights based on AHP method

Indicator type	Evaluation indicator	Weight
Historical value × 0.306	Settlement area	0.190
	Defense level	0.493
	Troop size	0.189
	Number of nearby military facilities	0.128
Scientific value × 0.322	Build time	0.137
	Protection level	0.258
	Tangible relics	0.605
Social value × 0.149	Elevation	0.302
	Distance from Ming Great Wall or coastline	0.218
	Location conditions	0.315
	Land use type	0.165
Cultural value × 0.133	Intangible relics	0.371
	Historical events	0.485
	Cultural continuity	0.144
Artistic value × 0.090	Architectural forms	0.600
	Materials	0.228
	Decorations	0.172

Table 3 Indicator weights based on CRITIC method

Indicator type	Evaluation indicator	Weight
Historical value	Settlement area	0.160
	Defense level	0.133
	Troop size	0.151
	Number of nearby military facilities	0.556
Scientific value	Build time	0.215
	Protection level	0.499
	Tangible relics	0.286
Social value	Elevation	0.301
	Distance from Ming Great Wall or coastline	0.291
	Location conditions	0.217
	Land use type	0.191
Cultural value	Intangible relics	0.247
	Historical events	0.408
	Cultural continuity	0.345
Artistic value	Architectural forms	0.514
	Materials	0.340
	Decorations	0.146

Table 4 Indicator weights based on AHP-CRITIC method

Indicator type	Evaluation indicator	Weight
Historical value × 0.306	Settlement area	0.155
	Defense level	0.335
	Troop size	0.146
	Number of nearby military facilities	0.364
Scientific value × 0.322	Build time	0.088
	Protection level	0.389
	Tangible relics	0.523
Social value × 0.149	Elevation	0.358
	Distance from Ming Great Wall or coastline	0.249
	Location conditions	0.269
	Land use type	0.124
Cultural value × 0.133	Intangible relics	0.270
	Historical events	0.583
	Cultural continuity	0.147
Artistic value × 0.090	Architectural forms	0.750
	Materials	0.189
	Decorations	0.061

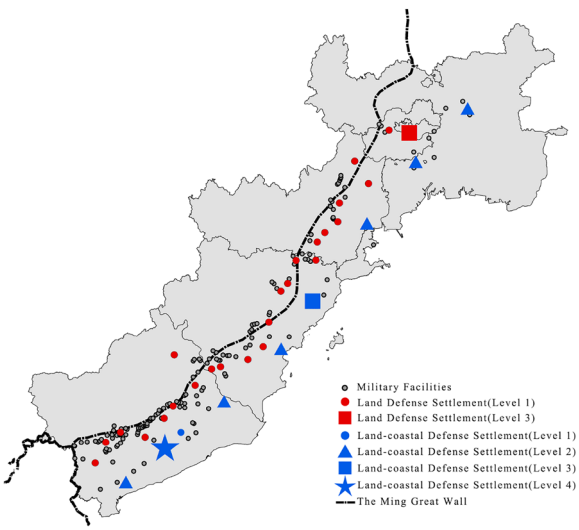

Fig. 2 Spatial distribution of military facilities and settlements

data should be normalized and all data should be unified into the interval of [0,10] before the settlement value score is calculated, so as to eliminate the impact of dimension on the value evaluation. According to the AHP-CRITIC composite weights obtained through the above steps, the scores of the five value types of settlements are calculated respectively. The Table 5. shows the settlements with top 10 evaluation scores of the five value types. The spatial distribution of some of the evaluation indicators (e.g., military facilities, elevation, land use types) is visualized by GIS, as shown in Figs. 2, 3, and 4.

The various scores are associated with the weight of indicator type and summed, then the final score of settlement value can be obtained. The top 20 settlements in the value evaluation and their detailed scores are shown in Table 6.

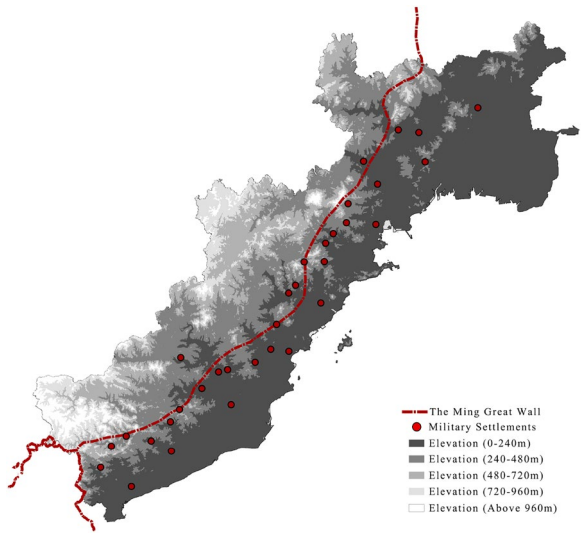

Fig. 3 Elevation distribution of military settlements

The spatial distribution of important settlements can be visualised by calculating the kernel density of the evaluation scores, as shown in Fig. 5. From the results, only 1 settlement scored 7–8, 1 settlement scored 6–7, 3 settlements scored 5–6, a total of 11 settlements scored 4–5, and a total of 18 settlements scored less than 4. The scores of the most settlements are concentrated below 5. This indicates that the settlement system is not protected well.

Comparison and verification

Calculation of indicator weights

From the AHP calculation, according to the Eqs. 2, 3, 4, CI = 0.0275, CR = 0.0305 for the weight of value type; CI = 0.0615, CR = 0.0691 for the weight of historical value; CI = 0.0170, CR = 0.0327 for the weight of scientific value; CI = 0.0522, CR = 0.0587 for the weight of social value; CI = 0.0183, CR = 0.0352 for the weight of cultural value; CI = 0.0168, CR = 0.0323 for the weight of artistic value. The relative consistency indicator of the above

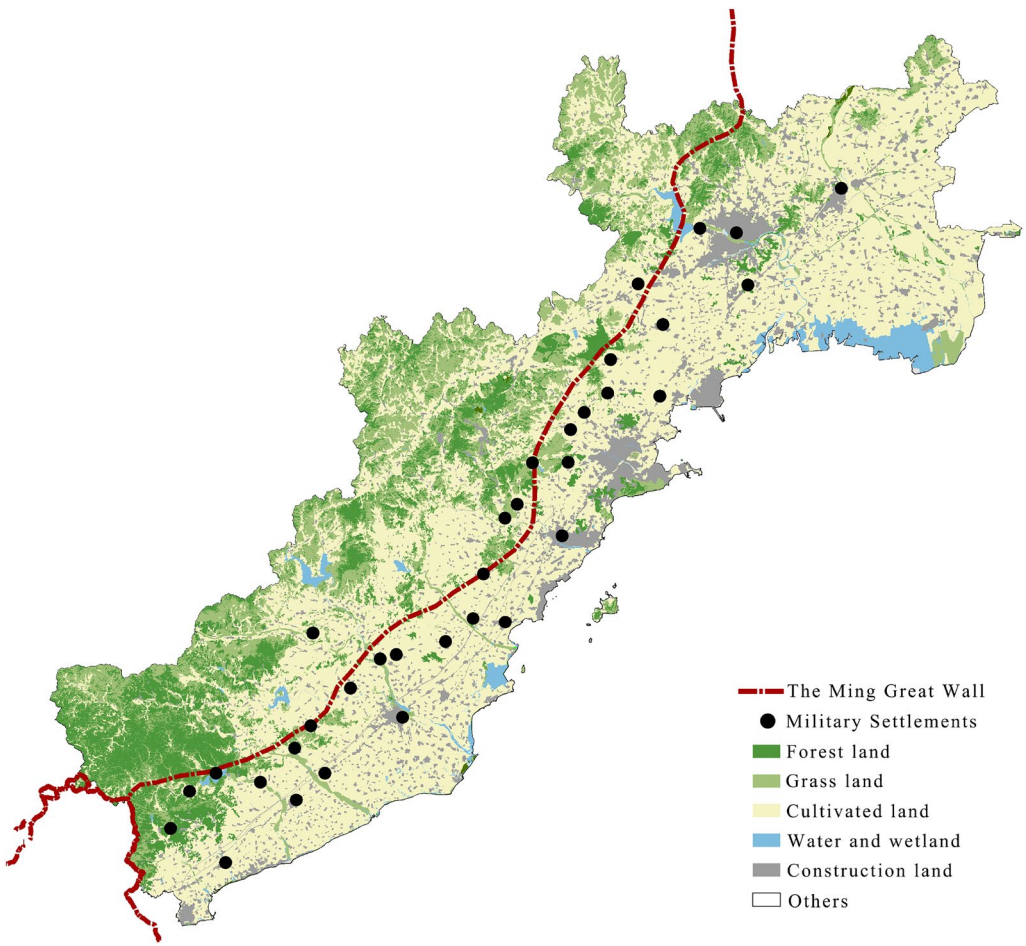

Fig. 4 Distribution of land use types in the Liaoxi Corridor¿

Table 5 Top 10 evaluation scores of the five value types

Settlement number	Historical value	Settlement number	Scientific value	Settlement number	Social value	Settlement number	Cultural value	Settlement number	Artistic value
34	5.580	6	10	6	7.791	6	8.835	6	8.880
6	4.445	1	9.222	5	7.616	34	8.289	1	7.379
12	4.377	11	8	7	7.336	1	7.754	11	5.878
13	4.123	10	6.954	1	7.157	2	7.501	7	3.878
11	4.064	13	6.954	22	6.669	5	7.501	10	3.878
2	3.711	26	6.954	33	6.558	8	7.208	13	3.501
14	3.529	14	5.908	34	6.474	7	6.041	26	3.501
19	3.488	16	5.908	18	6.244	10	5.461	32	3.501
30	3.483	20	5.908	21	6.039	4	4.920	5	2.378
17	3.216	29	5.908	15	5.971	17	4.874	34	2

Table 6 Top 20 settlements of the value evaluation

Military settlement	Score of value evaluation	Military settlement	Score of value evaluation
6. Ningyuan Wei	7.714	30. Duanmuchong Castle	4.118
1. Zhongqian Suo city	6.433	19. Jinchuanying Castle	4.104
34. Jinzhou Wei	5.500	26. Huishan Castle	4.098
11. Yong'an Castle	5.448	7. Tashan Central-left Suo	4.033
13. Sanshanying Castle	5.071	22. Xiaotuanshan Castle	4.027
10. Tiechang Castle	4.971	2. Qiantun	4.026
5. Shahe Central-Right Suo	4.482	15. Ruichang Castle	3.956
12. Beiyinzhang Castle	4.378	32. Dafu Castle	3.898
14. Pingchuanying Castle	4.366	25. Zhaiershan Castle	3.799
17. Gaotai Castle	4.212	23. Xingshuixian Castle	3.748

groups of weight data is less than 0.1, indicating that the consistency test of the indicator matrix is passed, and the weight obtained is effective.

The aim of CRITIC method is to calculate weights based on existing data. The data for each indicator was obtained from official documents and credible academic publications, such as the *Investigation Report on The Resources of Ming Great Wall of Liaoning Province* and the *Research on Defense of Liaodong Town in the Ming Dynasty*, and was verified through multi-channel comparisons. The subjective evaluation is scored by a number of experts in related fields. Subjective indicators are scored by experts in the relevant fields, and the geometric mean method is used to ensure the validity of the data.

Therefore, the AHP-CRITIC method is suitable for constructing the value evaluation model in this paper and is informative for determining the weights of indicators.

Value evaluation

Publications such as the *Investigation Report on The Resources of Ming Great Wall of Liaoning Province*, the *Research on Defense of Liaodong Town in the Ming Dynasty*, and the *Great Wall Chorography*, as well as official documents such as the Huludao and Jinzhou *National Territory Spatial Planning* and the *List of Cultural Relics Protection Units*, were used to validate the results of the value evaluation. The scores of the top ten settlements in terms of comprehensive value were compared with their defense levels, historical relics, and protection levels, as shown in Fig. 6.

It can be inferred that the trend of the results is roughly the same as that of the historical status and relics of the settlements. Some of the level-1 settlements with better preservation conditions reflect important historical features and therefore they have a high comprehensive value. However, the scores of the settlements with poor tangible relics are generally low because they can't reflect the heritage value. The value evaluation in this paper is basically in line with the actual situation, and the settlements with highest scores, such as Ningyuan Wei (level 3), Zhongqian Suo (level 2), and Yong'an Castle (level 1), will also be prioritized in the future planning of heritage tourism attractions.

In conclusion, the value evaluation model proposed in this paper is applicable to the value evaluation of military

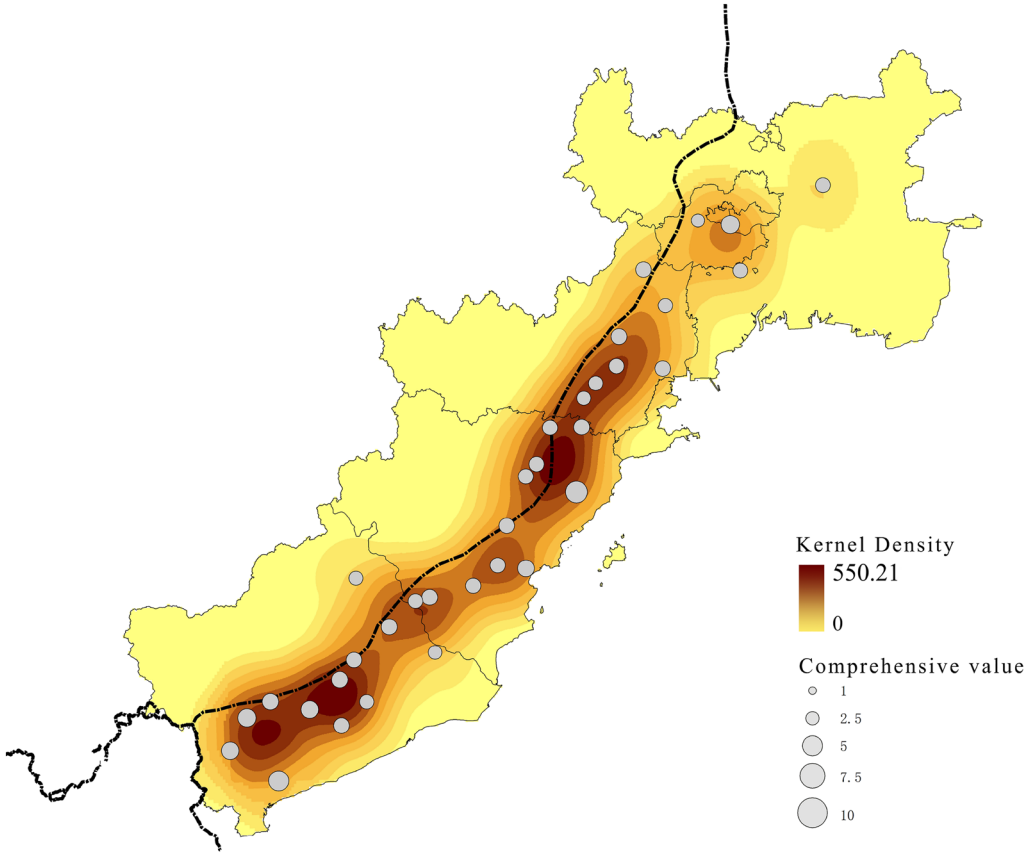

Fig. 5 Kernel density of military settlements comprehensive evaluation score

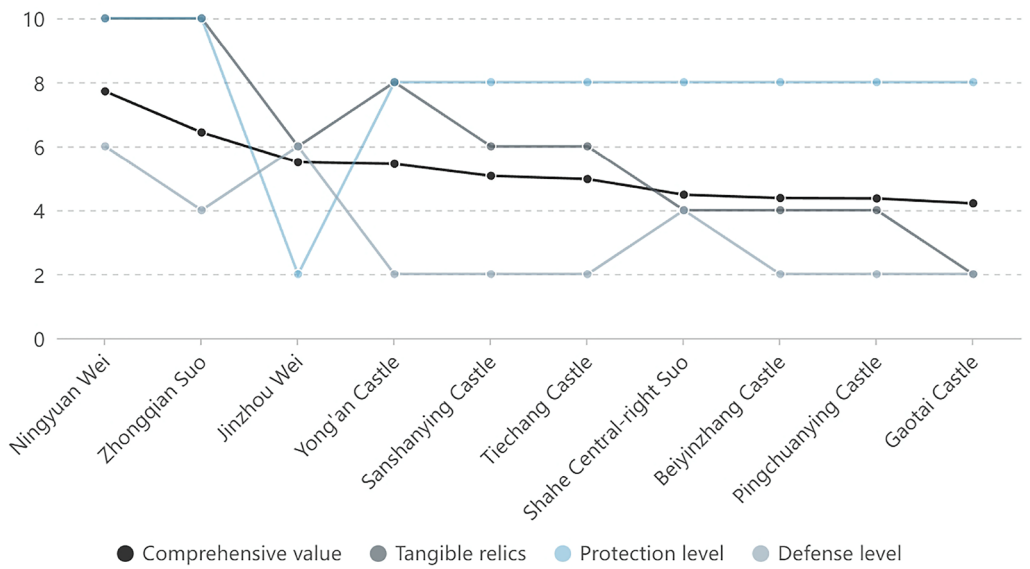

Fig. 6 Comparison between the comprehensive value and other indicators

settlements in Liaoxi Corridor with a certain degree of accuracy.

Discussions

Relationship between historic status and historical value

The historical status of the settlement refers to its defense level and military significance, which is mainly reflected in its historical value. Among the settlements with high scores of historical value, there are several level-1 settlements in addition to Jinzhou Wei (level 3), Ningyuan Wei (level 3) and Qiantun Wei (level 4), which are the focus of regional defense. The characteristics of this distribution pattern are as follows: (i) The three high-level military settlements basically exist as the focus of regional defense, with large area, large troop size and high Settlement defense level, so the historical value score is higher. However, due to the needs of convenient transportation, command and coordination in the rear, the important settlements were usually built on the coastal plains, with fewer military facilities in the vicinity, so their scores are not significantly higher than those of low-level settlements. (ii) The level-1 settlements in the top ten are located near the Ming Great Wall, which belongs to the first line of defense for external defense, and are mainly concentrated in two regions. In these two regions, beacon towers, enemy towers and other facilities are concentrated. These settlements get a high score of the historical value because of their strong spatial correlation with the surrounding facilities.

Impact of rapid urbanization on heritage values

Scientific value acts as the most important part of the weight in the whole evaluation system. The evaluation results can not only reflect the construction techniques of the settlements, but also reflect its subsequent conservation value. However, the scientific value of settlements has suffered in the context of rapid urbanization.

The scale of tangible relics has a significant influence on the comprehensive value of the settlements. In the process of urbanization, the settlements of high importance and good geographical location tend to be more seriously damaged due to their proximity to the urban area. The poor preservation instead makes the comprehensive score of these settlements lower than that of some level-1 settlements. For example, Jinzhou Wei (level 3), which had a vast urban area and a large scale of troops in history, has lost its tangible relics due to the expansion of the Jinzhou urban area. Meanwhile, there are also some level-1 settlements that were far less important than the above settlements in history. However, they were less affected by urban development, preserved more complete material remains, and were able to better reflect their original historical characteristics. Therefore, they received a higher comprehensive score. Typical examples of this type include Yong'an Castle, Tiechang Castle, and Sanshanying Castle.

Rapid urbanization brings not only damage to heritage, but also inappropriate development and utilization. For example, Ningyuan Wei, as shown in Figs. 7 and 8, had a lot of problems during the development process. Tourism infrastructure and stores are unattractive to tourists and even destroy the historical features of ancient settlements. Some of the remaining walls of Zhongqian Suo have collapsed, with incomplete infrastructure and lack of guidance in the scenic area. The subsequent management should focus on more scientific protection and repair, as well as more perfect tourism development.

Conflicts between official policies and heritage values

A total of 34 military settlements belong to Huludao City and Jinzhou City in Liaoning Province currently. The different attitudes of local governments towards the protection of military settlements in the Ming Dynasty also lead to regional differences in the value evaluation, which is reflected in the protection level indicators. Except for the well preserved Ningyuan Wei (level 3) and Zhongqian Suo (level 2), most of the military settlements under the jurisdiction of Huludao City are provincial cultural relics protection units, but there is no significant difference between them and some settlements without protection level under the jurisdiction of Jinzhou. For example, Yong'an Castle (level 1) remains a few remnants of its

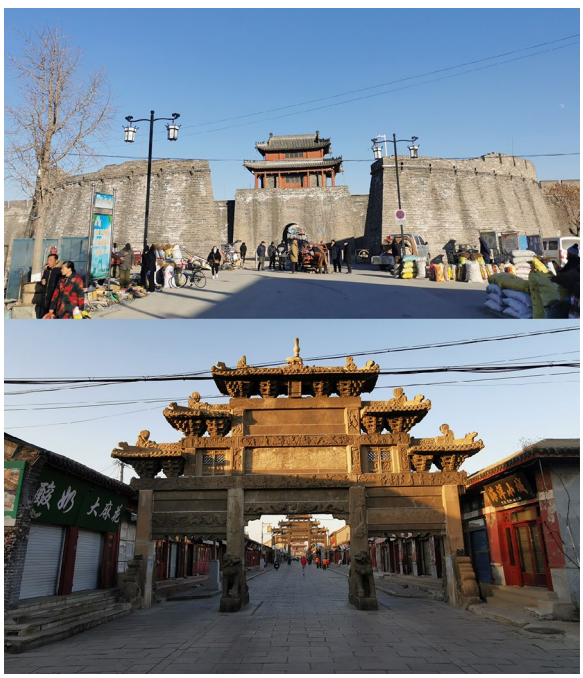

Fig. 7 Historic relics of Ningyuan Wei city

Fig. 8 Current problems in Ningyuan Wei city

walls, while Gaotai Castle (level 1) sees almost no tangible remains, and even the layout of the city is unknown. However, both settlements are under the protection of same level.

Therefore, the protection level of the settlements does not reflect the protection status of the settlements completely and intuitively, which is the difference in value evaluation caused by the policy guidance of the local governments. It is precisely because of this difference that the protection of military settlement system in the Liaoxi Corridor is in lack of integrity.

Correlation between value types

The five types of settlement values do not exist in isolation; they are interrelated. For example, historical and scientific values influence cultural and artistic values. The higher the historical status of the settlement, the larger the scale of construction, the more complete the urban infrastructure, and the greater the technological, cultural, and artistic richness. In addition, the better the protection of the settlements, the more material remains that can be visualized to reflect its culture and decoration, which will also make the cultural and artistic value scores higher.

The social and historical values of the settlements are also highly correlated. Due to the special topography of the Liaoxi Corridor, the settlements with high historical status are mostly located in the coastal plains, with better accessibility and high potential for building scenic spots. On the other hand, the better the location conditions, the easier it is to build settlements of higher defense level in the early stage of construction, which is conducive to command, coordination and transportation in the rear, and the higher the historical value. The cities like Ningyuan Wei (level 3), Jinzhou Wei (level 3), and Zhongqian Suo (level2) are typical examples.

Conclusions

This paper constructs a value evaluation model applicable to the military settlements. Taking 34 representative military settlements in Liaoxi Corridor as an example, this paper determines the evaluation indicators by five dimensions of historical, scientific, social, cultural and artistic values, and conducts the evaluation by the AHP-CRITIC method. Among the top 10 scoring settlements, Ningyuan Wei (level 3) has received the highest comprehensive score due to its historical significance and good state of conservation. Jinzhou Wei (level 3) has a crucial historical position, so it has achieved better results despite of poor preservation. Zhongqian Suo (level 2), Yong'an Castle (level 1) and other low-level settlements have received high scores because they're well-preserved. In addition, military settlements with a comprehensive heritage value of below 4 points accounted for 47% of the total. This proves that they are under poor protection generally, with insufficient development potential in a short time. The results of the evaluation of these settlements will serve as a reference for their conservation and management.

The Ming Great Wall Military Defense System is a complex and large-scale system, of which the Liaoxi Corridor region studied in this paper is only a part. A value evaluation model applicable to military settlements is proposed, which provides a sample for subsequent research on military settlements in other regions. The research ideas in this paper can be applied to these studies and eventually form the knowledge of the whole military defense system.

Supplementary Information

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Additional file 1. Expert questionnaires based on the AHP group decision method.

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Author contributions

Conceptualization, Z. W.; methodology, X. F.; formal analysis, X. F.; resources, S. L.; writing—original draft preparation, Z. W.; writing—review and editing, Z. W.; visualization, Z. W.; supervision, X. F.; project administration, X. F.; funding acquisition, S. L. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no Conflict of interest.

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