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TITLE OF THESIS

VALUE ASSESSMENT AND RENOVATION DESIGN OF BUILDINGS IN THE PERSPECTIVE OF URBAN RENEWAL: CASE STUDIES IN CHINA AND ITALY

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Abstract

In the process of rapid urban development, as the economy develops and the scope of the architecture continues to expand, buildings face the serious problem of conservation and renewal, adapting to contemporary needs has become the direction of development of architecture. At the same time, as a cultural carrier of the building needs to be renewed, not only become an important way of sustainable urban development but also will the creation of architectural renovation design provides an opportunity, this thesis on the urban renewal of such a social context of the perspective to explore the renovation design. Urban renewal promotes the renovation and regeneration of existing buildings. In order to improve the function of existing buildings and match the current situation of the surrounding area and enhance their value, the content of renovation and regeneration involves the accurate assessment of the value of existing buildings.

Generally speaking, architects rarely carry out a comprehensive value assessment of a building before carrying out a renovation design but basically carry out an analysis of pre-design ideas after obtaining basic data, that is, directly into the design stage. The primary prerequisite for the renovation design ideas advocated in this thesis is a comprehensive and accurate value assessment of the building, and the establishment of an accurate and applicable value evaluation system is also an effective method for determining the value of the building. This thesis also expresses that when researching an object, a qualitative analysis of its value composition and characteristics should be carried out first, on the basis of which an assessment system applicable to the object is constructed, a quantitative assessment is carried out, and on the basis of this assessment, recommendations are made for the grading of the research object. Finally, based on the grading results, the object should be designed for renovation and a more reasonable renovation plan should be proposed. Due to the complexity of the object of study, four different cases were chosen to describe the value assessment and renovation design, without assigning the value assessment and renovation design to a single case. However, this is sufficient to demonstrate that it is necessary and important to assess the value of the target before the renovation design is carried out.

This thesis follows the logical relationship of posing a problem, analyzing the problem, solving the problem, and drawing a conclusion. Chapter 1 is about the background of the thesis and the purpose and literature review, the necessity, urgency, and feasibility of establishing a value evaluation system and renovation design under the perspective of urban renewal. Chapter 2 is about the value evaluation of a historical ancient village in China using the entropy weight method, and also the spatial analysis of the village, which yields the protection level obtained by each building in different locations of the village, thus giving a reference for renovation design. Chapter 3 combines artificial intelligence techniques in order to improve the efficiency of conventional value assessment methods, using GA-BP neural network methods to assess the value of a Chinese village and then derive the different grades. chapter 4 is a study on the application of HBIM technology to the renovation design of a church in Italy, mainly describing how this method has helped the renovation design. Chapter 5 is the application of TLS technology to the design of a Chinese shop interior renovation project, expressing how this technology can be integrated into the design and how it can be updated in real-time, resulting in a collaborative design. Chapter 6 is a summary of the thesis and a description of the sections that need improvement and continued research in the future.

Keywords: Value evaluation; Urban regeneration; HBIM; Collaborative design; Terrestrial laser scanning

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1. INTRODUCTION

1.1. Background of research

Before the 1960s, urban renewal was based on the idea of morphism, with the goal of purely emphasizing the physical aspect of renewal. After the 1960s, it was found that large-scale demolition and redevelopment did not solve the problems in the city well, but also generated many social problems and the disappearance of historical and cultural features (Versaci, 2016). In 1961 Jacobs Jane, in his book The Life and Death of Great American Cities, took New York and Chicago as examples, emphasizing the need for old buildings in cities and the use of pavements, reflecting on the diversity of cities and the needs of people in cities. In the same year, Lewis Mumford published The City in History： Its Origins, Its Tranformations and Its Prospects, in which he argued that commercial urbanism had neglected the space for human activity and human safety, and that large-scale urban regeneration could destroy the organic function of cities, arguing that the best way to restore urban vitality was to make people the objects of service and dependence in planning (Connolly, 2019). In 1975 the American architect Christopher Alexander's book The Oregon Experiment proposed a small-scale approach to development and user participation in planning, pointing out that large-scale urban renewal had destroyed much of the city. It is hoped that future urban renewal will focus more on preserving the good parts of the urban environment (Nachmany & Hananel, 2022). Urban regeneration in the 1970s increasingly focused on the needs and experiences of people, urban history and culture, and the relationship between social functions (Miatto et al., 2019).

By the 1980s, as economic imbalances became more pronounced and the world entered a period of economic restructuring, the promotion of regional economic growth became a major part of urban regeneration. Governments began to work with the wider market, creating incentives for public investment in the city center and building luxury entertainment facilities to attract the middle class back to the city center, thus stimulating economic growth (Kim et al., 2020). This is when urban regeneration began to shift from neighborhood redevelopment to property-led redevelopment of older cities as a result of the participation of the public department. In the 1990s, the concept of people-centered and sustainable development became increasingly popular, and people began to realise that urban regeneration did not simply rely on real estate development to achieve physical improvements and economic recovery, but also to improve the living environment (Kim et al., 2020). At this time, urban regeneration takes a more integrated and holistic approach to solving urban problems, making long-term and sustainable improvements and enhancements to the changing city from social, economic, physical, and environmental aspects (De Smet & Van Reusel, 2018).

Before the 1970s, urban regeneration research was mainly a critique of urban planning and construction based on formalism and focused on basic theories, trying to propose theoretical guidance to solve urban problems, also from the perspective of planning and sociology, but after the 1970s, the problems caused by traditional regeneration methods led scholars to think about human needs (F. Chen, 2011). With the changing needs of urban development, urban regeneration as an important way to restore economic development and solve social problems, although it has again turned to commercial development, the research on urban regeneration has also taken more into account various factors such as social needs, cultural needs, and ecological needs (Dutta et al., 2007).

It can be seen that renovation design will be an important driver of urban regeneration and historic building conservation for some time to come. At the same time, strict conservation plans and a shortage of urban land supply will require cities to regenerate and renovate areas that are not suitable for future development (Panteli et al., 2020). In the process of renovation, areas in decline are systematically renewed by means of demolition, alteration, and restoration to improve the physical and social environment of the inhabitants and to inject new vitality into the decaying areas, thus ensuring balanced urban development and promoting the overall economic improvement of the city (Giordano et al., 2018). In order to improve the quality of new buildings, it is necessary to maximize the value of all aspects of the renovation, and it is particularly important to assess the value of the renovation design in a scientific and rational way, so as to analyze and summarise the shortcomings of the renovation work and provide reference and rationalization suggestions for future renovation design (Vodopivec et al., 2014). In this context, a comprehensive and holistic approach to the evaluation of the value of renovation design from the perspective of urban regeneration, not only focuses on the technical methods of improving the physical and spatial form of the renovation process, but also takes into account comprehensive sustainable development, will not only help to promote the orderly implementation of renovation and the development of the urban economy, but also contribute to the progress of the architectural design industry (Geng et al., 2020).

The rapid development of science and technology has further pushed the world into the Industry 4.0 era, where industry is more closely integrated with information technology such as big data, the internet and artificial intelligence, and production is becoming more intelligent, with cities becoming less dependent on traditional technology (Lekan et al., 2021). Retention or demolition has long been a focus of urban regeneration, and the previous approach of knocking down and rebuilding has destroyed a large number of valuable buildings, resulting in economic losses and the loss of urban character. Currently, urban regeneration is paying more and more attention to the preservation of architectural culture, and the increased emphasis on building renovation design has placed higher demands on the technology involved in urban regeneration, with renovation design beginning to be based on conservation levels (C. S. Tang & Veelenturf, 2019). The role played by the design of architectural renovation is increasingly involved in driving urban regeneration. The continuation of architectural civilisation actively explores how to revitalise existing buildings, improve urban functions and achieve urban regeneration.

1.2. Purpose of research

Based on the above background thoughts, this thesis presents a value assessment and renovation design study of different cases from an architectural design perspective under the perspective of urban regeneration. The core ideas of urban regeneration theory are invoked, which does not stop at beautification and redevelopment at the level of physical space, but is linked to the overall positioning of the city and industrial transformation and upgrading to further extend urban function renewal. The core ideas such as the historical and cultural values of the city are unearthed, which is an important guide for the planning and design of the buildings after renovation. Starting from the common values of the buildings, the value of different building types is analysed, an evaluation system is constructed to determine the different levels of conservation, and the mode of renewal under different levels of conservation is explored. Through the analysis of this thesis, the following purposes are expected to be achieved:

- The design of a value assessment system is based on the characteristics of different projects, quantifying the level of conservation or renovation and identifying the value factors that influence the character of the building after the value assessment. The different levels allow for a more accurate proposal for the renovation and conservation of the building.

- Through the application of GA-BP neural network in value assessment in the thesis, hopefully it will bring more ideas to scholars, so as to gradually apply artificial intelligence technology in value assessment as well as renovation design, and explore more development possibilities of artificial intelligence technology in architectural design and heritage conservation.

- The use of 3D scanning technology in renovation design allows for a more accurate representation of design ideas. Explore more innovative collaborative design, which means that data can be obtained at different stages of the project before and during construction by using 3D scanning technology, which can then be modified and adjusted to form a collaborative design system that is updated in real time.

- It is expected that this thesis will inspire the exploration of more new technologies in architecture, such as VR, AR, MR, and the metaverse. Research into AI algorithms to generate architectural designs that gradually deeply from building surface, form, urban context, and internal function to urban design. To be used as much as possible in practical projects to inspire and increase the efficiency of architects.

1.3. Framework of research

This thesis discusses the value assessment and renovation design in the background of urban regeneration using four different case studies, in which the different effects of the different methods on them are explored. The two chapters in the value assessment section are described using the entropy weight method and the GA-BP neural network method respectively. The entropy weight method is able to assign more accurate weight values to the research objects from an objective point of view. However, when the number of research objects is large, the entropy weight method is less efficient, so in order to improve efficiency, this thesis incorporates an artificial intelligence approach. The GA-BP neural network technique is used to calculate the research objects, which can increase efficiency to a large extent and has a high accuracy based on the results of the number of iterations. The two chapters in the renovation design section illustrate the use of HBIM for historic buildings and the use of TLS technology for the collaborative design of interior space renovation. HBIM technology is able to accurately represent the data information of historic buildings and to form BIM systems quickly and accurately, thus facilitating the renovation design of the study object. However, due to the less-than-ideal results of the presented case study, this thesis uses a case study of interior space renovation to express this concept more clearly. Combining TLS technology with spatial design and renovation design to form a collaborative design system. This allows the user to control and adjust the project before and during construction, thus making the final result more desirable and accurate. Finally, a summary of value assessment and renovation design is presented, advocating the need to assess the value of the research object before undertaking renovation design, so that the design outcome obtained is more reasonable.

Therefore, the research framework of this thesis is Chapter 1, which describes the background and purpose of the thesis; Chapter 2, which introduces the application of the entropy method in value assessment; Chapter 3, which introduces the application of

GA-BP neural network method in value assessment; Chapter 4, which introduces the application of HBIM technology in the renovation design of historical buildings; Chapter 5, which introduces the application of TLS technology in the renovation design of interior spaces; Chapter 6, which introduces the application of value Chapter 6 is an explanation of how value assessment and renovation design can be applied together and a summary of the thesis.

2. HERITAGE EVALUATION AND ANALYSIS BASED ON ENTROPY WEIGHT METHOD

The assessment of the value of villages is the basis of village conservation work. By evaluating the value of residential houses, it is possible to carry out graded conservation and targeted use of traditional villages with limited resources while also helping to guide the urban planning of architectural heritage sites scientifically. This chapter intends to evaluate the value of representative and ethnic Wengji villages in southern China to deal with the trend of traditional architectural culture being submerged by urbanization. First, according to the actual situation of the world-famous village, 12 evaluation index systems, including three subsystems of Historical and cultural values, Aesthetic values, and Architectural values, have been established. The entropy value method analyzes each index objectively and then solves it by MATLAB. The results are divided into four classes. Each building is numbered to obtain the corresponding weight. The main results show that: the most weighted factors are obtained, architectural style (12%), building material (10.76%), and architectural space(9.68%). From the total value scores of 83 buildings in Wengji village and the distribution map of important value areas, it is known that the geographical location and the origin of village culture have a positive impact on the cultural value of buildings. These findings could provide a policy that offers a breakthrough point for stakeholders to protect traditional villages with architectural heritage in the future.

2.1. Questions description

The traditional village is considered one of the essential types of tangible cultural heritage, providing abundant cultural resources in historical stories and folk customs both spatially and temporally (E. Park et al., 2019). In China, as a country with a history of more than five thousand years, the interaction between the ancestors and the natural environment has formed some unique residential styles, which reflect the past lifestyles of the locals, and at the same time, serve as some special cultural symbols. Therefore, maintaining the authenticity and diversity of traditional culture is indispensable for studying Chinese history, art, customs, and religions (Dutta et al., 2007). Especially since 2012, more experts and scholars in China have started to be concerned about 'traditional villages. And the Chinese government is also trying to emphasize the value of historical villages in recent years and increasing funding applied for the protection and redevelopment of those villages. Consequently, the Research Center of China's Traditional Village (RCCTV) was established in the same year.

However, with the acceleration of modernization, traditional rural cultures have always been ignored or assimilated during their interaction with urban development. The preservation of traditional villages has become an increasingly important issue in the current trend of globalization (Kovacs et al., 2015). After ten years of efforts, in 2021, the RCCTV published five lists for National Traditional Villages. According to this report, nearly 80 to 100 historical villages disappear every day in China in the past decade. Furthermore, the crisis of the traditional village is also a global problem facing other countries. Studies that focus on traditional villages have been conducted from different points of view in different countries. For example, scholars from the United Kingdom researched the historical landscape of traditional villages (Namicev & Namiceva, 2016); socio-economic impacts of villages were studied in France; and popular settlers and settlements were studied in the USA (Havinga et al., 2019). The counties, such as France, Slovakia, the United Kingdom, Germany, and Italy, have made substantial efforts in the field of village conservation, carried out relative practical guidance and protective policies, focusing on choosing suitable restoration materials, as well as providing training for relative workers and participants (Versaci, 2016; Vijulie et al., 2021). Consequently, the practices of traditional village conservation have led to the birth of many conservative approaches and models, such as the conservation of retirement villages dealing with the aging population; the proposal of ecological museums based on the ecological and historical heritage of villages (Filipe & de Mascarenhas, 2011); the model of rural tourism development based on the economic values (Haven-Tang & Jones, 2012); and the model of industrial linkage solving the problem of a single industry in villages, etc..

Among these, the assessment of heritage value is the basis for the conservation of architectural heritage and a foundation for the protection, identification, and redevelopment of traditional villages (Y. H. Li et al., 2019). As early as 1933, the Athens Charter proposed that architectural heritage value should include three principal factors, namely artistic, historic, and scientific values (Winter, 2014). As time passed, the perception of the importance of architectural heritage has also changed. The formulation of heritage values has become more extensive and profound but still revolves around the three fields of art, history, and science (K. et al., 2017). By evaluating the value of architectural heritage, it is possible to carry out the protection and reuse of architectural heritage in a graded manner with limited resources and to guide the planning of architectural heritage sites in a way more scientific. At the same time, the evaluation of the external factors of heritage can provide a quantitative basis for the further economic management that must be faced in the protection of architectural heritage. Then, policy recommendations for reuse and redevelopment can also be presented. Thus, the restoration process of an architectural heritage should include a comprehensive evaluation of the heritage values, plan feasibility, recurring maintenance costs, etc. (Pizzigatti & Franzoni, 2021). Then what destroyed buildings with high architectural and cultural value? And how to focus on protecting which buildings with limited funds? For a village, whether the value of the whole is greater than the sum of its parts, or whether it pays more attention to the protection of characteristic buildings remains to be studied. In addition, with the expansion of urbanization and the improvement of residents' economic conditions, the original ancient buildings with national characteristics cannot meet the needs of residents and have been destroyed. Therefore, balancing residents' needs for living conditions and the protection of ancient buildings is very urgent.

The "Guidelines for the Protection of Chinese Cultural Relics and Historic Sites" state: "The protection of architectural heritage must be carried out by scientific procedures (Y. Liu et al., 2021). All the procedures shall comply with relevant legal provisions, professional rules, and opinions from relevant to folders (Zhong & Chen, 2017). The value evaluation of cultural relics should be done first". However, there are currently few studies on the evaluation and protection of individual traditional dwellings to implement protection policies. With a deep understanding of the value composition of traditional dwellings, including the importance of various values and the internal relations among them, we can accurately distinguish and measure which heritage sites must be preserved intact, what adjustments and changes can be made along with the development of time, and which parts can be abandoned if necessary (Kinghorn & Willis, 2008; X. Wang & Aoki, 2019). On this basis, the heritage protection process can achieve the goal of comprehensive protection and full utilization of heritage values (Báez & Herrero, 2012). Unfortunately, there is still no detailed classification in preserving architectural and cultural heritage. We should prioritize handicrafts, humanities, arts, building materials, and the protection of building structures or historical events with characters; architectural style is more important. These issues are still worth discussing.

Currently, many methods are proposed to evaluate the value of architectural heritage, with cooperation between different disciplines. The popular comprehensive evaluation methods include the fuzzy evaluation method using subjective or qualitative indexes; principal component analysis, factor evaluation, and cluster analysis based on multivariate statistical analysis; efficacy coefficient method and the analytic hierarchy process (AHP) for some complex heritage objects; entropy weight method (EWM) and gray correlation method mainly based on the information theory and gray system theory (Fig. 2.1).

In recent years, the most popular methods in the evaluation of architectural heritage value mainly include the following three methods: AHP as a practical multi-scheme or multi-objective decision-making method was proposed by the American researcher Saaty in the 1970s (Yuan & Li, 2021). It is a combination of qualitative and quantitative decision-making analysis methods. It was applied to the value evaluation of Pinghe Tulou (A traditional Chinese dwelling in Fujian Province in China), and policy recommendations for reuse and redevelopment are put forward. It turns out that a solution that only focuses on found is not feasible. Then, the architectural heritage protection and restoration plan should include the heritage assessment report, clarify and analyze the feasibility report of the value of the heritage, the result feasibility report, and the daily periodic maintenance report (Pizzigatti & Franzoni, 2021). Multi-criteria decision making (MCDM) is designed to find the best results in complex scenarios including various indicators, conflicting goals, and standards (Dotoli & Pellegrino, 2018). It allows a choice between a finite (infinite) set of conflicting, non-commensurable options (Pamucar et al., 2019). Multiple projects can be judged, ranked, and selected for merit. When a heritage site is studied, each influencing factor is treated as a criterion for the judgment of the project, and the values of the factors are subject to a series of information processing and extraction to assign weights to the importance of each factor (Chowdhury & Paul, 2020).

Compared to AHP and MCDM, the entropy weight method can be used as a more objective and quantitative assessment, avoiding errors caused by subjective factors,

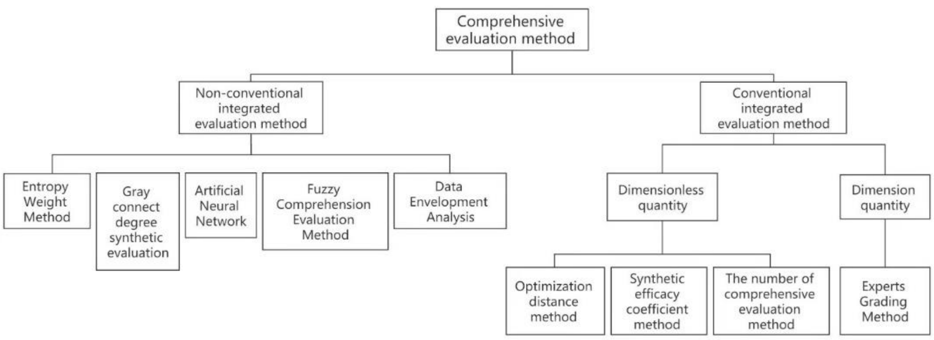

Fig. 2.1 Comprehensive evaluation method

such as expert interviews and survey questionnaires (Zhaowen Liu et al., 2020). It objectively describes multiple dimensions of information and establishes a model to obtain a quantitative result, which is helpful for further site analysis (Cerreta et al., 2021). There is no contradiction in the indicators to evaluate the value of a single residential building in a traditional village. The entropy method can quickly determine the weight of each index. It is also applied in many other fields, such as determining the weight of the evaluating indicators in water quality assessment (Zou et al., 2006); to address high-dimensional reliability analysis, a new sampling approach is proposed in the fractional moments-based maximum entropy method. The results indicate that the proposed method is accuracy efficiency for high-dimensional reliability analysis (J. Xu & Dang, 2019). With the help of the entropy method, the weight of vulnerability quantified by social and physical factors can be determined and revealed as a reasonable contribution (Perera et al., 2019). Through the objective and quantitative analysis of the value evaluation of heritages, it can make more precise the application of policies and the sustainability of the protection of the architectural heritage. For example, Del and Tabrizi obtained weights to represent the magnitude of uncertainty in the continuous probability distribution and, by examining 188 papers, calculated the values for 34 architectural heritages (Del & Tabrizi, 2020).

There are still many difficulties in China waiting for different solutions, such as a lack of national conservation regulations and on-site management, ignorance of the architectural unity during heritage renovation, etc. Based on current heritage problems, this chapter proposes and analyzes the method and future development goals for traditional Chinese villages. The objective of this chapter is as follows: 1) establish a heritage value evaluation system to quantify the heritage levels; 2) find out the high-value factors influencing the architectural characteristics after the heritage assessment; 3) propose conservative strategies and recommendations for traditional villages in China.

The organization of this research is as follows (Fig. 2.2),the part of materials and methodology introduces the basic situation of villages and the use of the entropy weight method (EWM); then analyzes the relationship between village space and nature and the spatial elements of villages based on the results of Section four, and also interprets

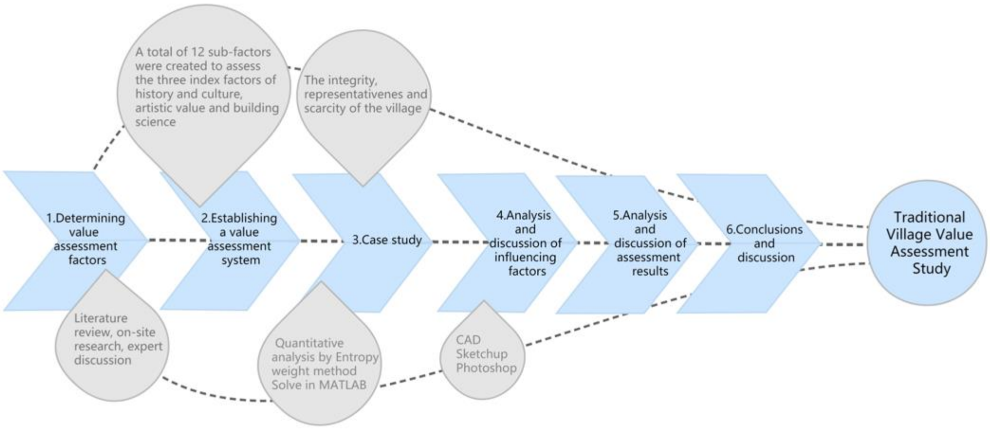

Fig. 2.2 Research framework

the traditional architecture of villages and the space types and transformations; the final part concludes and proposes specific strategies for the future conservation of village heritage.

2.2. Materials description

2.2.1. Study area

The Wengji ancient village is the subject of research in this investigation, located in Yunnan province in the south of China. The ethnic characteristics and architectural style of the Brown people (one of China's 55 minority groups) have been well maintained in this village (Gao & Hu, 2020; Qi et al., 2013). Wengji is located in the mountainous area of Jingmai in Pu'er City (South of Yunnan), located within the ancient tea plantation of Jingmai, which is recognized as one of the 'National Traditional Chinese Villages'. Geographically, the village is situated in a subtropical low-latitude area with relatively more rainfall in its southwest. However, since the village is in the Heng duan Mountain Range, the Blang people live in the high mountains and deep valleys (Bai & Zong, 2016). Therefore, the climate varies vertically with height change, forming a clear three-dimensional view between high mountains and low valleys (Hung, 2013; Lin & Wen, 2018). And the humidity is relatively high; the temperature difference between different valleys is noticeable, forming an extraordinary cloudy landscape in this area (Fig. 2.3).

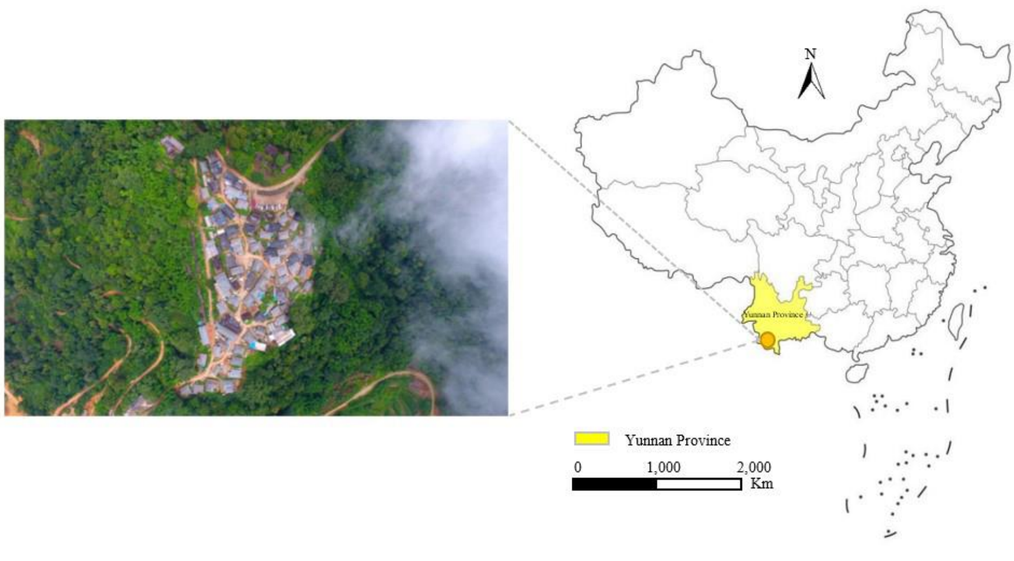

Fig. 2.3 Location of Wengji ancient village in Yunnan, China

To support the heritage evaluation, historical information was obtained from local archives in news, reports, yearbooks, ethnic culture, etc. After systemizing related literature, this research combines fieldwork and heritage research in the village of Blang using the Unmanned Aerial Vehicle (UAV) (Afif et al., 2021) to get a more comprehensive three-dimensional view of the village, study building materials, and detailed design, and grasp the development of settlements and residential spaces. As a result, all the 83 buildings in the village are selected for the next steps of surveying, analyzing, and evaluating, especially on their historical and cultural, artistic, and architectural values (Z. Liu et al., 2020).

2.2.2. Architectural features of the village

The Wengji ancient village has the architectural features of the long history of the Brown people. To present the value of the village, the following is a description of the architectural style, building materials, and architectural spaces.

Analysis of architectural style: The traditional architectural form of Wengji ancient village has the following standard features from Fig. 2.4. The buildings themselves are almost entirely made of two colors of wood and tiles, with no attempt to stand out. The exposed building components are not overly decorated, allowing the original beauty to shine through; the overall look of the staggered is extremely rich in layers. Stilt houses are characterized by an elevated ground floor and living space on the second floor. With the development of society, the ground floor is no longer simply a place to store miscellaneous things but also has many functions, such as a bathroom, a warehouse, and a tearoom. The second floor even has a leap floor, which increases the usable area but maintains the overall traditional style, and the interior space becomes more and more flexible. This achieves the unity of architectural form and function, but it also presents the local architectural style and formal aesthetics(Chen, 2011).

Fig. 2.4 Selected photographs of traditional residences

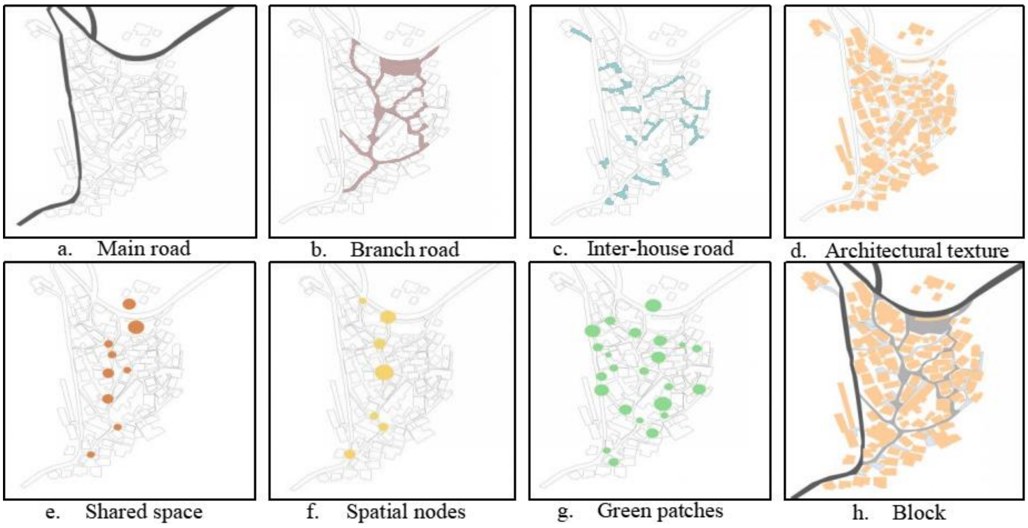

Fig. 2.5 Spatial analysis of the village

Analysis of building materials: Almost all the building materials in the Wengji ancient village are locally sourced. Some of the common materials used in the area are wood, bamboo, thatch, and Burmese tiles can be bought in the town not far from these villages. Burma's tile can be bought in the towns not far from these villages (R. P. Wang & Cai, 2006). Thatch, which is not resistant to decay and is flammable, is no longer used in large quantities, but it is still used in the region. These primitive materials are taken from nature and returned to nature. The rustic gray color of these traditional settlements also shows tremendous respect for the surrounding environment. Architecture is integrated with local nature (B. jun Zhang & Chen, 2021).

Analysis of architectural spaces: The combination of roads and buildings forms the most obvious relationship between traditional settlements and the alignment, grade and length of the roads reflect the scale and aggregation of a settlement, of which the roads can all be divided into three grades: the main road, the branch road, and the inter-house road. The shared space is generally concentrated on both sides of the main road, around the village center, and around the Buddhist temple and the degree of openness of the shared space is closely related to human activity, and the location has the characteristics of high flow of people or a certain period of concentrated human flow (Uzun et al., 2018). Spatial nodes are part of the shared space, including road intersections, wall centers, squares, etc. They have different levels according to their location and scale of occupation. A patch is a relatively homogeneous, nonlinear area within a colony that differs from the surrounding context (Havinga et al., 2019). While a settlement is a kind of patch in relation to the larger surrounding mountain environment, the greenery within a settlement is also a patch, which we call a greenery patch here (Fig. 2.5). Another vital part of the residence is the exhibition stand exposed outside the building, like the balcony in the city, which is an essential place of daily life for the residents. A fire pit is a sacred place, it is only one square meter in all, which no one is allowed to cross, and a three-legged iron stand is placed in the fire pit for use in cooking (Lin & Wen, 2018). Next to or not far from the fire pit is a distinctive pillar, called a central pillar, which is enshrined, and not to be touched or relied upon. The architectural space represents a culture that belongs to the intangible cultural heritage and is indispensable for studying the culture, religion, beliefs, and art of traditional (Cha et al., 2021). (Fig. 2.6)

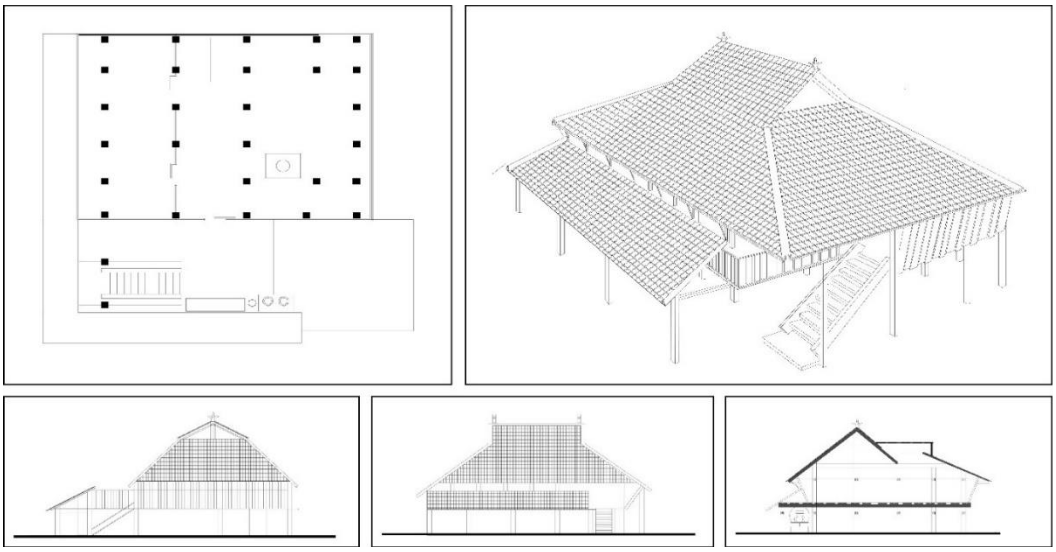

Fig. 2.6 Typical architecture of the village (orthogonal projections and axonometric)

2.3. Construction of the evaluation system

According to the above statements, 12 evaluation index systems, including three subsystems of Historical and cultural values, Aesthetic value, and Architectural value have been established based on the entropy weight method as follows Table 1. Twelve Secondary Indicators are represented by the numbers A1, A2, C3, and C4 respectively. Then, according to the scoring criteria in Table 2.1 and the actual situation of 83 houses in the ancient village of Wengji.

Table 2.1 Construction of an evaluation indicator system

Primary indicators		Secondary Indicators	Scoring criteria			Reference
			1 point	2 points	3 points	
A-Historical and cultural values	A1	History information	More refurbishment, More damage, Less historical information	Partially refurbished, better preserved, better preservation of historical information	Rarely refurbished, historical Information is well preserved	(Alshweiky & Ünal, 2016)
	A2	Culture Presentation	Overall culture Less presentation, Strong business atmosphere	The overall cultural presentation is relatively high, with some commercial atmosphere	The overall education level is very high, less business atmosphere	(Yousif et al., 2018)
	A3	Landform	The landform is uncharacteristic, and the land is in poor condition	There are some landform features, and the land condition is average	Strong landform features and good land conditions	(Žlender, 2021)
	A4	Historical events with characters	Very few related historical figures and historical events occurred	Related historical figures and historical events	More related historical figures, stories and historical activities	(Abdelmonem & Selim, 2012; Turnpenny, 2004)
B-Aesthetic value	B1	Architectural style	Very inconsistent with the architectural style. of the traditional houses of the Blang people	conform to the traditional architectural style of Brown Village, basically	completely conforms to traditional residential architectural style	(Alshweiky & Ünal, 2016; López Cruz et al., 2016)
	B2	Formal aesthetics	Villages, buildings, landscapes and other elements rarely conform to formal aesthetics	Village, architecture, landscape and other elements are in line with formal aesthetics	Villages, buildings, landscapes, etc. are in line with formal aesthetics	(Sadeqi et al., 2019)
	B3	Handicraft	It did not promote the traditional handicrafts of Pu'er tea culture	Better inherit the traditional handicrafts of Pu'er tea culture	Well, carried forward the traditional handicrafts of Pu'er tea culture	(Harahap & Siahaan, 2020)
	B4	Humanities and Arts	Very few local residents, and they rarely carry forward the local humanities and arts.	There are some residents, better promote the local humanities and arts	Many local residents, perfect for promoting local humanities and arts	(Vodopivec et al., 2014)
C-Architectural value	C1	Building materials	Excessive use of modern building materials and not making good use of local materials	Some contemporary building materials are used, local materials are used to some extent	The perfect combination of modern and local building materials	(E. Wu et al., 2021)
	C2	Building structure	Greatly changed the original building structure model	To a certain extent, the original building structure model has been changed	The original building structures model is well preserved	(Uzun et al., 2018)
	C	Architectural	Rarely use and reflect the construction	Some Blang construction skills	It fully represents the construction	(Hou et al., 2021)

3	skills	skills of the Blang people in architecture	are embodied in the architecture	skills of the Blang people	
C4	Construction space	Greatly changed the architectural space form of traditional Blang dwellings	Less transformed the architectural space form of traditional Blang dwellings	Fully preserve the traditional architectural space form	(Y. Q. Zhao et al., 2020)

2.4. Application of the entropy weight method

After reviewing the literature, the EWM is chosen to apply in this article to determine the weight of each indicator based on objective observation, thereby facilitating the comprehensive evaluation of the evaluated targets. The specific steps are as follows.

- Build the matrix

According to the evaluation objects and indicators of traditional residences, set the jth indicator of the $i$theobject of 83 evaluation objects and 12 valuation indicators as X_{ij}. Structure the original data matrix $X = [X_{ij}]_{n*m}$, From the actual situation of the village we chose, we can know that n=83, m=12.

Use the range transformation method to standardize the positive indicators and the negative indicators separately, as follow Eqs (1) (2) (3):

$$Y_{ij} = \frac{x_{ij} - min(x_i)}{max(x_i) - min(x_i)} \tag{2.1}$$

$$Y_{ij} = \frac{min(x_i) - x_{ij}}{max(x_i) - min(x_i)} \tag{2.2}$$

$$0" Y_{ij} "1 \tag{2.3}$$

- Calculate the entropy value e_j

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} P_{ij} \ln P_{ij} \tag{2.4}$$

Where $P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{12} Y_{ij}}$, If $P_{ij} = 0$, then define $P_{ij} = 10^{-6}$ .Because $P_{ij} = 0$, the logarithmic function in Eq.(4) is not mathematically tenable. The value of 10^{-6} is small enough not to affect the result. In information theory, entropy is the measurement of uncertain information. The greater the amount of information, the smaller the uncertainty, and the smaller the entropy; the smaller the amount of information, the greater the uncertainty, and the greater the entropy.

- Calculate the weight w_j

$$w_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{2.5}$$

Where w_j refers to the weight of the jth index. w_j fight, the impact fight to the evaluation target. The larger the value of w_j, the more important the corresponding index and the greater the impact on the value, and vice versa.

- The comprehensive score of the evaluated targets

It shows that the respective value of traditional residences in different dwellings is calculated as:

$$s_i = \sum_{j=1}^{n} w_j P_{ij} \qquad (2.6)$$

As a result, the larger the s_j is, the higher the heritage value of the traditional rural dwelling is indicated.

2.5. Weight analysis of influencing factors for heritage value

After a comprehensive quantitative evaluation from the perspectives of history, culture, art, and value using the entropy value method in Matlab, the result can be seen in Fig. 2.7. Among the secondary indices, the weight of architectural style (0.12) is ranked first; the index of building materials (0.1076) is in the second place; architectural space (0.0968) is the third. The last three factors are architectural structure, historical information, and formal aesthetics. The factor of architectural style with the greatest weight belongs to the artistic indicator. The factors of architectural material, architectural space, and architectural structure belong to the architecture indicator. The factor of historical information belongs to the history and culture indicator. The previous weight values of these indicators have little difference and are all important to the heritage value of the building. The weight value of the index ranked number one is nearly three times of the last index-manual art (0.0473).

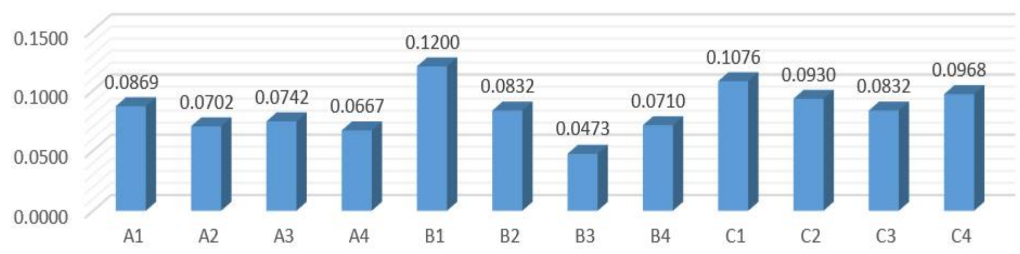

Fig. 2.7 Weights for evaluating the value of indicators

According to the weight of each index of the traditional village, specific factors that influence the value of traditional residences can be further identified, as shown in Fig. 8. The numbers on the abscissa in Fig. 8 represent the number of houses in the village, the ordinate represents the weight value corresponding to each house, and each color represents a different evaluation index. The results show that the values of the twelve indicators of some houses are relatively high, some are relatively low, and the difference is rather significant in landform, handicraft, and architectural skills. Combined with the analysis of Figs. 2.7 and 2.8, architectural style, building materials, and building space. have the most significant impact on the value of traditional buildings. The architectural style results from the long-term integration, and nature embodies the customs, culture, and lifestyle of a nation and is the best mark and symbol for recording a nation. Natural elements, landforms, rivers, mountains, historical events, and historical figures are also essential to preserve the memory of a historic village. The abscissa in the figure represents 83 residential houses, and each color in the bar graph represents an index. Matlab calculates the Eq. (6), a total score for 83 residential houses is shown in Fig. 2.9. The x-coordinate represents a building (1, 2...83), and the ordinate is a composite score of house value from Fig.9. To analyze better the dwellings, this study ranks the total scores of 83 dwellings according to the actual situation of the village and the 'pyramid theory' (Qiushan Li et al., 2019)(Qingxia Li et al., 2019) , forming an order of 10%, 20%, 30%, 40% from high to low according to their heritage value, and divided into

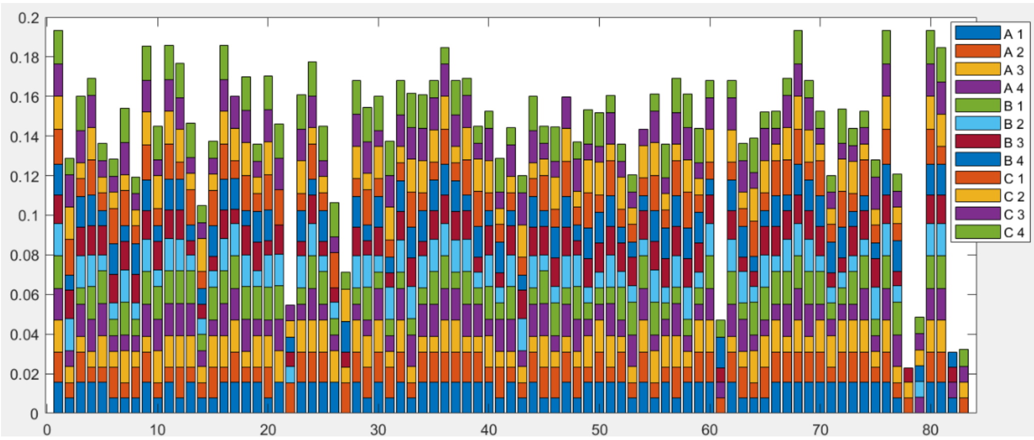

Fig. 2.8 Sub-entropy weight diagrams of indexes

four grades: I, II, III and IV (from high score to low score).

As is seen from the resulting map, grade I corresponds to the top 10% of the buildings in the ranking (Fig. 10). They are mainly located in and around the Buddhist temple, the ceremony of the village. Important events such as local weddings and funerals are often held here. And these parts are well preserved and reflect the characteristics of this ancient village. It also reflects that the protection of contemporary buildings is the first to protect their cultural atmosphere and unique architectural style. The second grade is mainly located in the central part of the village, where the villagers conduct market activities and cultural activities, where it has the advantage of geographical location and reflects the local culture well; The third grade is mainly located near the center of the village and is the place where the villagers live in general, which can probably reflect the architectural characteristics; The fourth grade is scattered in all corners of the village, where it is unsuitable for living due to the remoteness; substantial renovations; newly constructed buildings for a living, and the original architectural form and cultural connotation have been lost here.

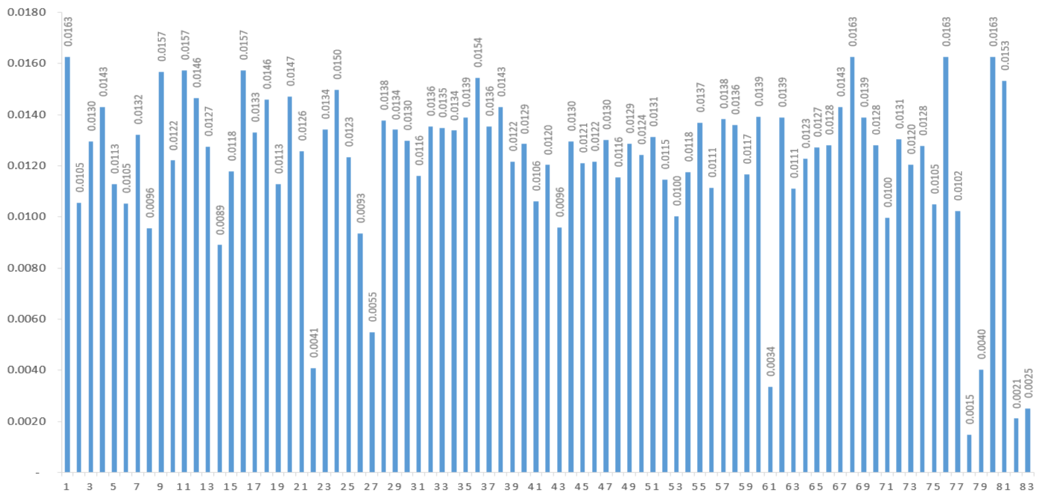

Fig. 2.9 Comprehensive score of 83 houses

In summary, relative stakeholders can adopt more accurate strategies for developing the village for profit or protection and publicity Fig. 2.10 For example, tourism practitioners should focus on promoting and developing grades 1 and 2 with the highest value to attract tourists to increase their income (Eken et al., 2019)(Eken et al., 2019). Furthermore, non-profit organizations (such as heritage protection groups) can call on relevant government departments to formulate strategies to protect the grade 3 buildings, which have relatively extensive damage influencing the architectural heritage and renovate the grade 4 buildings as soon as possible.

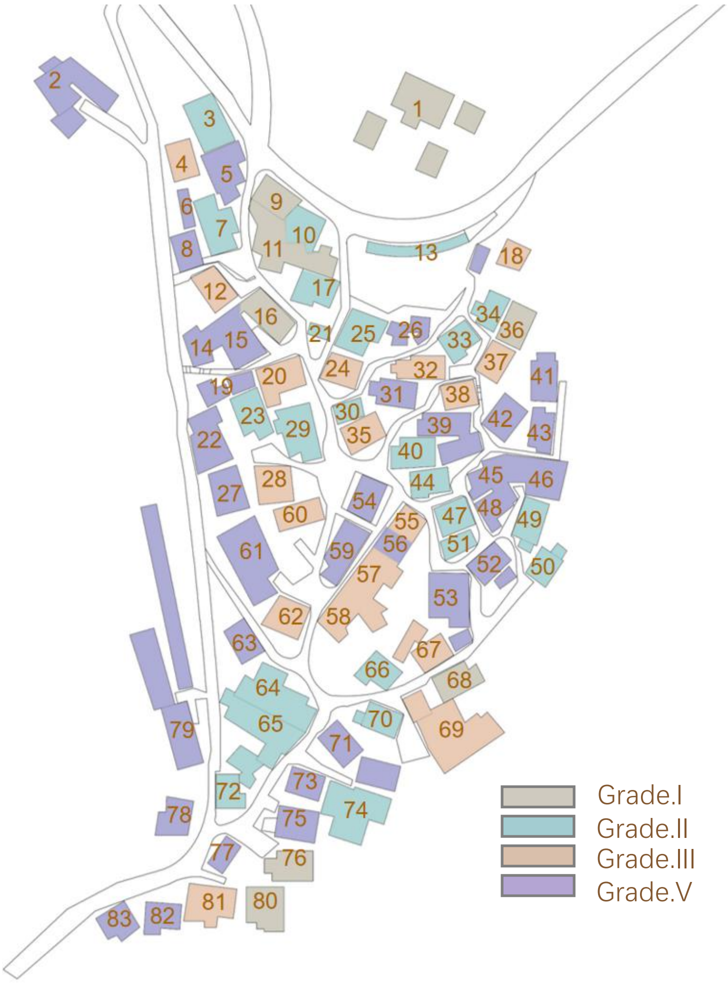

Fig. 2.10 Distribution of the different grades in the 83 houses

2.6. Summary of the chapter

In view of the increasingly severely damaged architecture of traditional houses, this study uses qualitative and quantitative methods to assess the value of the overall architecture of the village, and then solves the problem using Matlab. This study still has some limitations. Though using the EWM to evaluate the value of Wengji ancient villages, the established index evaluation scores are still not specific enough. Though this study has established 12 indexes based on predecessors, many aspects affect the value of architectural heritage. And this chapter only evaluates the historical and cultural, artistic value, and architectural science of the current situation of the village; a more in-depth analysis, including social, economic, environmental, and other macrolevels, needs to be added in the future research. Other factors should also be taken into account in future research, such as improving the awareness of heritage for locals and improving the public participation of village residents during the entire heritage protection and evaluation process. Thus, further suggestions can be provided according to the research result from the following perspective.

(1) The local people's government should focus on protecting buildings with high assessed value and architectural heritage culture, instruct residents in detail not to further damage and protect them during use, and concentrate limited funds for repairs.

(2) Environmental protection departments and cultural government departments should work together to protect the local built, natural environment, and good geographical features. For example, the natural preservation of ancient buildings is inseparable from the surrounding environment, and the repair also requires local wood or other raw materials.

(3) The local government and residents should actively cooperate with the professional advice of ancient architecture experts and pay attention to the overall integrity and harmony of the village. For example, the street should be protected and excavated from the texture form, road form, open space, architectural interface, landscape decoration, etc. At the same time, it is necessary to pay attention to the learning and inheritance of handicrafts and architectural skills of traditional buildings, which have a relatively high

heritage value to a single building.

(4) Actively introduce tourism developers, explore cultural tourism symbols, and provide new financial support for the inheritance of national culture and ancient architecture. Pay attention to the overall protection and planning of the village, renovate the houses with uncoordinated appearance, and demolish the buildings that seriously affect the village landscape.

(5) Local authorities must develop strategies for the development and protection of sustainable architectural heritage according to local conditions, not only to improve the living standards of local residents but also to inherit and carry forward ethnic characteristics; relevant practitioners and scholars must improve the evaluation and research of the value of the architectural heritage of ancient Chinese villages as soon as possible and provide professional training and guidance to practitioners who restore ancient buildings; when developers develop traditional buildings, they should plan the entire project and make use of ancient buildings with more excellent value.

3. ASSESSMENT OF THE EXTERIOR QUALITY OF TRADITIONAL RESIDENCES: A GENETIC ALGORITHM-BACKPROPAGATION APPROACH

The visual aesthetics of villages are remarkably affected by the exterior quality of traditional residences, influencing the impression and assessment of local culture. A proper scientific assessment of exterior quality can protect traditional cultures and improve the development of villages. This research was conducted in a village consisting of 115 residences (Mengjinglai village, which is on the border between China and Myanmar). The backpropagation (BP) neural network model with genetic algorithm (GA) was applied to evaluate the quality of the dwellings. All the evaluation values of the dwellings were defined by scores. Meanwhile, the score of each residence was affected by three main factors: architectural spatial elements, architectural construction elements, and historical and cultural elements. The results show that the village's dwellings are well preserved and clearly express the traditional Dai style. Moreover, the GA–BP approach is more suitable than the traditional BP method for the assessment of the exterior quality. The quantitative machine learning model would be useful for other aspects of the assessment of similar villages in the future.

3.1. Questions description

Traditional villages are settlements that possess cultural heritage in both tangible and intangible forms and have strong historical, cultural, scientific, artistic, social, and economic values. With the rapid development of global industrialization and urbanization, the phenomenon of the decline and disappearance of traditional villages is intensifying, and to resist this, it is necessary to strengthen their conservation and development (Philokyprou & Michael, 2021). Although efforts to preserve the heritage of traditional villages are gradually increasing, there is also a need for more innovation in theoretical research and re-search methods (Verdini et al., 2017). The conservation of traditional villages involves changes in spatial patterns, social and cultural loss, the ecological deterioration of landscapes, the loss of populations, the preservation of vernacular architecture habitats, and the development of traditional cultural and social relations (Hearn, 2021). Therefore, the conservation and development strategies, renewal strategies, and value assessments of traditional villages have gradually become areas of concern for scholars (Karahan & Davardoust, 2020).

Interpreting, measuring, quantifying, and delineating the value of traditional villages, and determining weights, make this a relatively complex issue for scholars. Thus, traditional village evaluation has a strong component of interdisciplinary research, including architecture, urban and rural planning, geographic science, sociology, tourism, and statistics (Tobi & Kampen, 2018). Most of the current research on village value-assessment systems for evaluation purposes is based on merit assessment and graded protection. The evaluation methods have gradually developed from mainly qualitative to combining some quantitative methods, such as hierarchical analysis, the entropy weight method, the Delphi method, the fuzzy evaluation method, and the material element analysis method (Fu et al., 2021). In addition, artificial intelligence has been applied in various fields, and machine learning, one of the branches of artificial intelligence, is capable of supervised learning for the evaluation of the architectural quality of traditional villages. However, building quality is influenced by a combination of influencing factors and is not in a purely linear relationship, while neural networks are suitable for processing non-linear information problems influenced by multiple factors (Astuti, 2019). Therefore, the use of neural networks is suitable for the comprehensive evaluation of the quality of traditional buildings.

The BP neural network is a multilayer feed-forward network with a multilayer neural network structure that is more mature than traditional neural networks in theory and application. It is widely used, but also has disadvantages, such as its easy formation of local minimum and no global optimum, low efficiency, slow convergence rate, etc. (HECHT-NIELSEN, 1992). Therefore, the optimization of neural networks is receiving increasing attention. Among various optimization methods, GA has the advantages of better global search capability, fast solution space search, and strong robustness (Whitley, 1994). Since a single genetic algorithm code does not fully represent the constraints of the optimization problem, the solution needs to be considered using thresholds, which in turn increases the workload and solution time (Hammouche et al., 2008). In order to fully circumvent the above disadvantages, GA and BP are combined to take advantage of each other's strengths and learn from existing research achievements to identify improved solutions. Gonzalo combined the supervised and unsupervised optimization of genetic algorithms to assess the quality of water over five years, determine quality classes, and demonstrate confidence (Sotomayor et al., 2018). Zhang proposed an optimization method based on genetic algorithms combined with the energy requirements in classrooms and applied it to a school building (A. Zhang et al., 2017). Yousef investigated a BP neural network classifier for extracting the external quality features of dates and grading and ranking them accurately by date (Al Ohali, 2011). Lin applied GA–BP to knowledge-fusion risk assessment, constructing an innovative ecosystem knowledge-fusion risk-assessment index system, thereby providing a new practical approach (L. Wang & Bi, 2021). Li applied GA–BP to assess the risk of tunnel cavern surge and tunnel karst (Z. Li et al., 2020). Zhu compared GA–BP with PSO–BP and the initial BP neural networks to assess the risk of rainfall-induced land-slides (C. Zhu et al., 2020). Dai used the AHP–FCE and GA–BP methods to assess an intelligent learning environment in higher education and concluded that the GA–BP model could simplify the assessment process and improve fault tolerance (Dai et al., 2021).

A genetic algorithm is an adaptive search algorithm, proposed by J. H. Holland in 1975, that is able to find optimal solutions in a global space (Kastenholz et al., 2012). The optimal network weights and thresholds are used as the initial network models, which can not only overcome the problem that the prediction results of the traditional BP neural networks are easily influenced by initial weights and thresholds and easily fall into the local optimum, but also greatly improve the accuracy of model evaluation (Polo López et al., 2021). The GA–BP neural network shares the advantages of both the global convergence of GA and the local search of BP, which can significantly improve the performance of the neural net-work model. The GA–BP model guides the sensitivity to the initial values of weight and thresholds, which may reduce the influence of human subjectivity to a certain extent, and serves as a reference for other scholars to apply the neural network in the field of village assessment. Therefore, the GA–BP neural network model can be applied to effectively evaluate the quality of traditional residential buildings using the connection weights optimized by the genetic algorithm (İpekoğlu, 2006). It is clear from the a forementioned literature that GA–BP is applicable to quality rating assessments, except that there is a large gap in current research on external quality, particularly that of traditional buildings. This study focuses on an assessment of Mengjinglai village in Yunnan province as a case study, constructs an evaluation index system applicable to the traditional architecture of this village, and applies the GA–BP neural network model to conduct a com-prehensive evaluation of the exterior quality.

3.2. Materials description

3.2.1. Study area

The dynamic distribution of the external building evaluation results enables more challenging and more accurate verification of artificial intelligence assessment methods. On the border between Yunnan Province and Myanmar, there are a number of villages with a mixture of architectural cultures. Mengjinglai village, known as the “The First Village of China–Myanmar”, is rich in cultural features and has both traditional and modern architectural forms. Mengjinglai village is located within the jurisdiction of Daluo Town, Menghai County, Xishuangbanna Dai Autonomous Prefecture, Yunnan Province, across the river from Myanmar, with a village area of approximately 5.6 km2 and a total of 115 households (L. Yang & Wall, 2008, 2009). The village is surrounded by mountains on all sides, is situated close to water sources, and features a beautiful natural environment. The terrain is a low-mountain hilly area, and the climate is characterized by a typical northern tropical climate. In order to adapt to the hot and humid natural environment, the Dai people have developed unique stilt-style architecture (Fig. 3.1).

Mengjinglai is typical of traditional Dai villages, whose populations have historically had frequent contact with Burmese residents and intermarried with them, creating a rare form of mixed settlement. The buildings in the village are all built according to the terrain, with an overall fan-shaped distribution. The layout of the village harmoniously unites human architecture with nature, forming a unique architectural style (Gao et al., 2019).

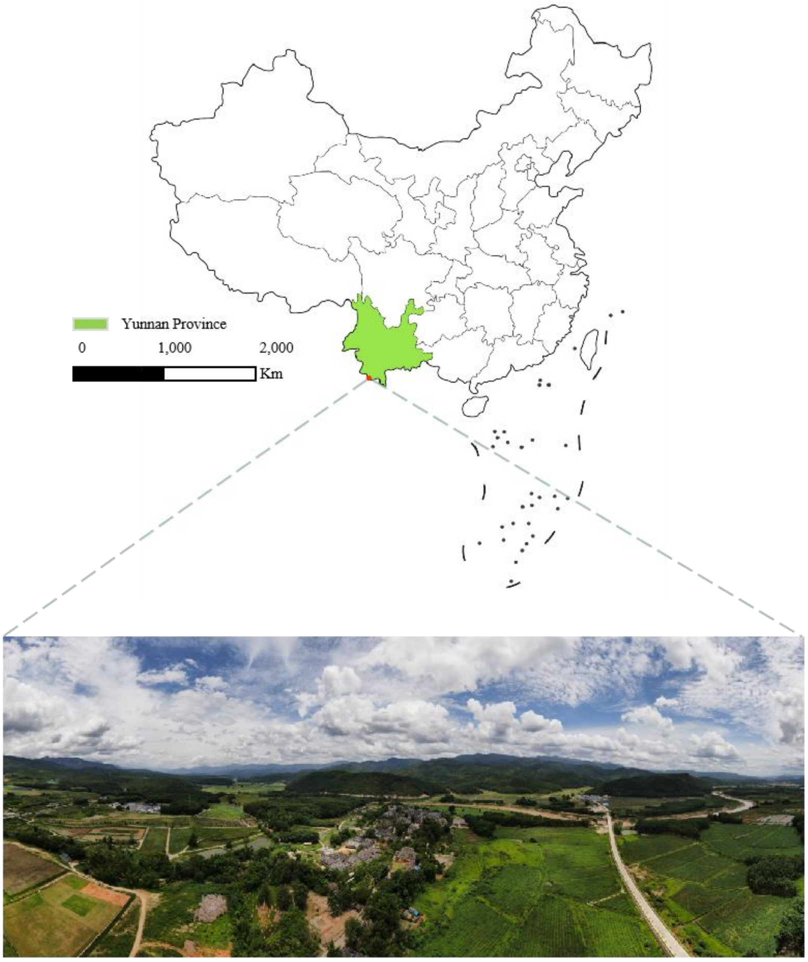

Fig. 3.1 Location of Mengjinglai village in Yunnan, China

3.2.2. Data Sources

The rural settlement data used in this study consisted mainly of remotely detected image data, and economic, demographic, and historical village information data (Kokorsch & Benediktsson, 2018). Satellite map data of Mengjinglai village were obtained through Google Earth Engine. Economic and population data were obtained from the Menghai County Statistical Yearbook and the monthly report of the Bureau of Statistics on the Menghai County People's Government website. Information on the history of Mengjinglai village was obtained from Menghai County Records (Shang et al., 2021). Photographs of buildings, water systems, mountains, roads, interior spaces, and other details were obtained by the author through fieldwork in 2021 (Fig. 3.2). During the site survey, each of the 115 traditional residences was scored and the actual condition of the architectural space, the architectural constructional elements, and the historical and cultural elements were recorded (Table 3.1)

Fig. 3.2 Selected photographs of traditional residences

Table 3.1 Construction of an exterior quality assessment indicator system

Primary Indicators	Secondary Indicators		Scoring Criteria			Reference
			1 Point	2 Points	3 Points	
A—Architectural spatial elements	A1	Void deck	Substantial replacement of timber-frame materials with modern materials and untidy interiors	Partly timber-framed materials and largely furnished interiors	Complete with timber-frame materials and well-furnished interior of the space	(Chew & Norford, 2018)
	A2	Landscape space	The interior and exterior are largely devoid of landscaped surroundings	Interior and exterior design with partially landscaped surroundings	Interior and exterior design with good landscape setting	(Nawre et al., 2021)
	A3	Interior space	Less use of timber-frame materials, confusing interior layout, and poor lighting and ventilation	Partly timber-framed materials, average interior layout, average lighting and ventilation	Well-preserved timber-frame materials, good interior layout, good lighting and ventilation	(Suryono, 2021)
B—Architectural construction elements	B1	Building materials	The materials used are heavily influenced by the overall Dai style of the dwelling	The materials used have a lighter influence on the overall Dai style of the dwelling	The materials used largely do not detract from the overall Dai style of the dwelling	(Su et al., 2019)
	B2	Architectural form	A lighter representation of the characteristic Dai style of dwelling	A larger display of the characteristic Dai residential style	A full display of the characteristic Dai style of dwelling	(Pappas et al., 2016)
	B3	Roof frame	Traditional materials are less well preserved and more rarely used	General conservation, mostly in traditional materials	Well-preserved and largely traditional materials	(Bláha et al., 2018)
C—Historical and cultural elements	C1	Architectural style	Fairly well preserved and not very in keeping with the style of the village	More uniformly preserved and in keeping with the style of the village	The overall architectural style is uniform and in complete harmony with the village	(Oakes, 2016)
	C2	Cultural value	Has fewer cultural elements	Has general cultural elements	Has significant cultural elements	(Masuda et al., 2019)
	C3	Historical value	Has fewer historical elements	Has general historical elements	Has very strong historical elements	(Kastenholz et al., 2012)

3.2.3. Exterior quality evaluation of traditional residences and value grading

The 115 dwellings in the village, which generally include the typical buildings of Mengjinglai village, were selected for rating. The reaction to the quality of the appearance of traditional buildings is the most direct response of visitors and researchers. The ratings of village dwellings were judged to facilitate quick improvements in the image of villages (Hasanova, 2020). Therefore, this study focuses on the architectural methodology proposed by İpekoğlu to assess the exterior characteristics of buildings, with some adaptations, by integrating indicators of Dai elements, depending on where on the border the Mengjinglai village buildings were located (Geng et al., 2020). After scoring each indicator, the exterior characteristics of the traditional dwellings were calculated using the entropy method to find the desired value.

According to the results of the field surveys, data collection, expert consultations, indicators, and grades, the quantitative value classifications of traditional rural dwellings were determined based on their location in Mengjinglai village. The three main indicators were: architectural spatial elements (A), architectural construction elements (B), and historical and cultural elements (C). The nine secondary indicators were: void deck (A1), landscape space (A2), interior space (A3), building materials (B1), architectural form (B2), roof frame (B3), architectural style (C1), cultural value (C2), and historical value (C3). The values of the traditional buildings were quantified in a comprehensive way using the corresponding scoring criteria (1–3 points). The quality of the buildings was divided into 4 levels: (1) Grade I: top 10% of the residential dwellings, indicating very high quality; (2) Grade II: top 20% of the residential dwellings, indicating high quality; (3) Grade III: top 30% of the residential dwellings, indicating fair quality; (4) Grade IV: top 40% of the residential dwellings, indicating poor quality (Fu et al., 2021).

According to the evaluation samples and indicators of the exterior quality of the traditional residences, let X_{ij}, $i = 1, \ldots ,115; j = 1, \ldots ,9$, denote the jth indicator of the ith dwellings. First, we standardize nine indicators in order to eliminate the impact of the dimension and the different variation results in

$$Y_{ij} = \frac{X_{ij} - min(X_j)}{max(X_j) - min(X_j)} \tag{3.1}$$

$$Y_{ij} = \frac{min(X_j) - X_{ij}}{max(X_j) - min(X_j)} \tag{3.2}$$

where $Y_{ij} \in [0,1]$ represents the value of the indicator after standardizing the jth indicator and i th sample; $min(X_j)$ and $max(X_j)$ represent the minimum and maximum values of the jth indicator. Subsequently, the entropy value e_j results in

$$e_j = -\frac{1}{\ln\ 115} \sum_{i=1}^{115} P_{ij} \ln\ P_{ij} \tag{3.3}$$

where $P_{ij} = \frac{Y_{ij}}{\sum_{i=1}^{115} Y_{ij}}$. If $P_{ij} = 0$, it is replaced with $P_{ij} = 10^{-6}$, which makes the logarithmic function valid. It should be noted that the value of 10^{-6} is small enough not to affect the result. Finally, the comprehensive score of the evaluated target of different dwellings is computed by

$$s_i = \sum_{j=1}^{9} w_j P_{ij} \tag{3.4}$$

where the weight $w_j = \frac{1-e_j}{\sum_{j=1}^{9}(1-e_j)}$. The larger the s_i, the higher the evaluation score of the exterior quality (Fu et al., 2021).

3.3. Application of GA–BP neural network

3.3.1. GA–BP neural network

The scores of the 115 traditional buildings were first calculated using the entropy method, and were used as the output values for the neural network model training. The scores were compared with those of the BP and GA–BP neural network models. The most reasonable approach was chosen to recalculate the scores of 115 buildings, which were divided into four classifications. Finally, the results were analyzed and discussed. The BP neural network is an information processing system designed in the basis of the structure and function of simulated neural networks. The BP algorithm is more efficient at capturing the non-linear relationship between factors and output. Repeated network learning is very accurate at correcting training errors. The general BP neural network model consists of three layers: the input layer, the hidden layer, and the output layer. The exterior information is received through each node in the input layer and passed to the hidden layer, where the information is processed and transformed before becoming the output value. Training is finished if the training error reaches the expected error. Otherwise, the training error reverses into the network and the iteration process is repeated (Y. Wu et al., 2020).

The use of the genetic algorithm to optimize the neural network connection weights consists of two main parts: firstly, the genetic algorithm is used to optimize the initial weights of the network; and secondly, the optimized values provided from the GA are assigned to obtain an optimized BP neural network to predict the output accurately. Throughout the evolutionary process, the neural network structure, including the number of layers in the hidden layer, the number of nodes in the hidden layer, and the connections between the nodes, is fixed (L. Pan et al., 2021). The corresponding GA–BP neural network flow is shown in Fig. 3.3 and 3.4.

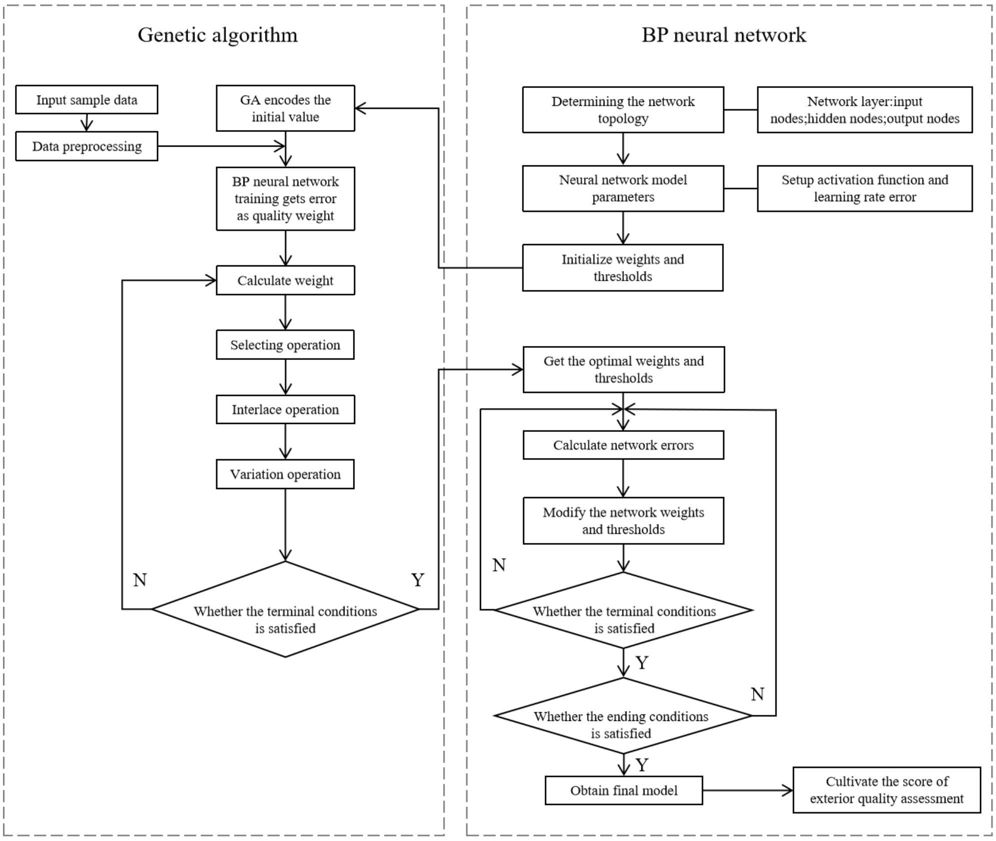

Fig. 3.3 The flow of the GA–BP neural network model

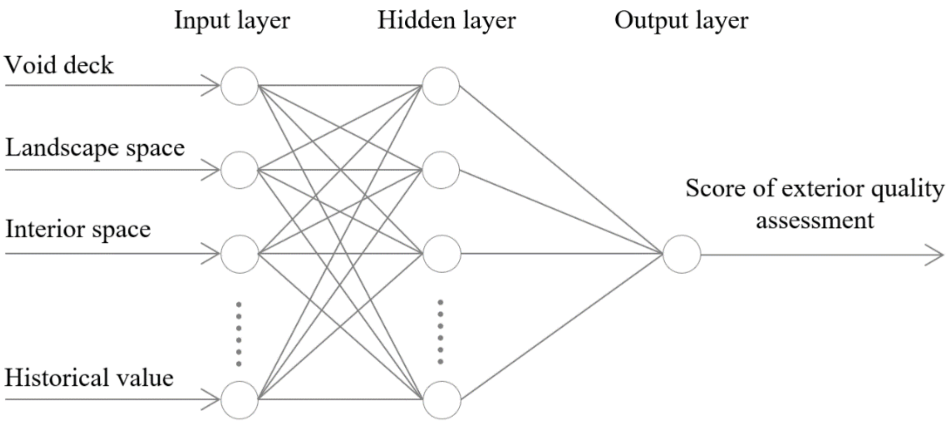

Fig. 3.4. BP neural network structure for the exterior quality

In order to measure the statistical relationship between two random indicators, a Spearman's rank correlation, which is a non-parametric correlation between the ranking of two random indicators, is applied here. The closer the correlation is to 1, the stronger the relationship between the two indicators. The following formula is used to calculate the Spearman's rank correlation:

$$\rho = 1 - \frac{6\sum_{i=1}^{n} d_i}{n(n^2-1)} \tag{3.5}$$

where d_i denotes the difference between two ranks of corresponding indicators and n is the number of observations. In particular, we have $n = 115$. Fig. 3.5 displays the Spearman's rank correlation between each indicator. The greater the correlation, the larger the points in the figure. In particular, a strong correlation corresponds to large points. The results show that all correlations are less than 0.5, which indicates that there is no strong correlation and a small probability of the presence of multicollinearity. Moreover, we also compute the condition number to diagnose multicollinearity. By using the Spearman's rank correlation matrix, the condition number is equal to 8.617, which is less than 10, which indicates the absence of multicollinearity. Thus, all nine indicators should be considered in the GA–BP neural network model (Y. Pan et al., 2019).

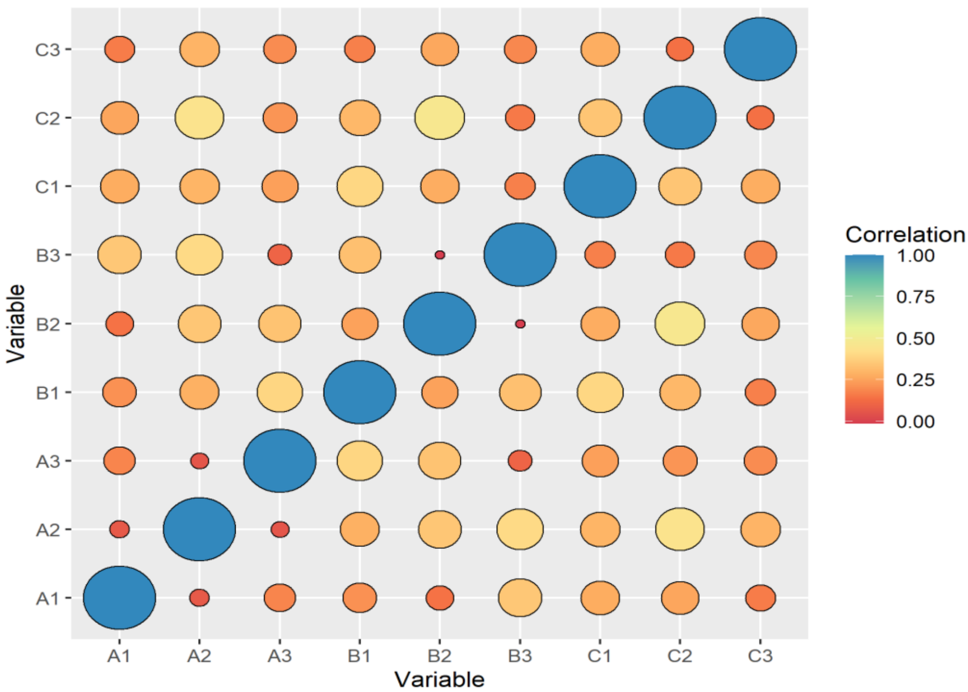

Fig. 3.5 Spearman rank correlation between variables

The BP neural network structure in this chapter consists of an input layer, a hidden layer, and an output layer, of which the hidden layer is one layer. According to the correlation analysis, we selected nine indicators to assess the exterior quality of traditional dwellings in Mengjinglai village. Thus, the input layer has nine nodes. According to the assessment requirements of exterior quality, one output node can effectively differentiate house quality, i.e., there is one node in the output layer. For the nodes in the hidden layer, we make a preliminary determination of the number of nodes according to Equation (6), and finally determine the number of nodes in the hidden layer of the final neural network model by the model training error. Based on empirical studies, Cheng proposed that the number of nodes N_hid in the hidden layer can be initially determined by the following formula (Cheng et al., 2021):

$$N_{hid} = \sqrt{N_{in} + N_{out}} + a \tag{3.6}$$

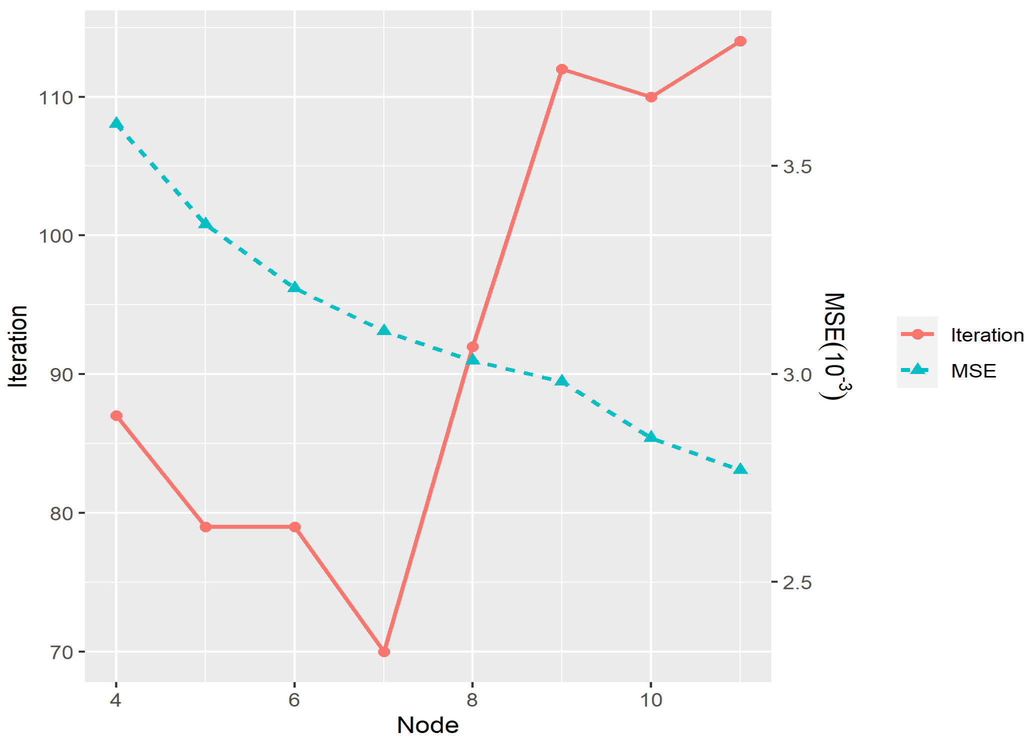

Fig. 3.6 The number of iterations and MSE of BP model in the hidden layer

3.3.2. GA setting

The genetic algorithm consists of four main parts: coding, selection, crossover, and mutation. At first, coding is performed, followed by selection, crossover, and mutation. All three operations are evaluated by the fitness value calculated from the fitness function, where a higher value means that the individual is more adaptable and should have a higher probability of reaching a higher value, which makes it more likely that the individual is to be selected to pass on its advantages. The BP neural network designed in this chapter has a 9–7–1 structure, and, by using binary coding, can easily cause the coding string to be too long, leading to a decrease in the operation rate; thus, real number coding is used. The output of the evaluation of the exterior quality of the traditional residential buildings in Mengjinglai village is required to be non-negative, the inverse of the MSE can be used as the adaptation function, and the adaptation function takes the form of 1/MSE. A roulette wheel is used to select some individuals to form a new population and to eliminate some individuals with lower target values (Adame & Salau, 2021). Crossover is a process whereby two paired chromosomes exchange some of their genes in some way based on the crossover probability, thus forming two new individuals, and variation is a process whereby some gene values in the coding string of an individual are replaced with other gene values based on the variation probability to form a new individual. The crossover and variance probabilities are set at 0.7 and 0.05, respectively (Veller et al., 2020).

To increase the credibility of the model, the 115 samples were randomly divided into training and testing samples in a 6:4 ratio. In total, 69 samples were randomly selected for training according to the ratio, and the model parameters were trained. The remaining 46 were used as testing samples to evaluate the model and to calculate the quality weight values of the appearance of the residential dwellings. All calculations in this chapter were implemented in R and Python; the GA–BP neural network results were obtained using the TensorFlow module in Python, with an optimized learning rate of 0.1 (Fok et al., 2018). The learning rate, a hyper-parameter, was used to control the rate of the GA–BP algorithm, which updated the learning values of the parameter of interest.

3.3.3. Analysis of evaluation results

In order to build a highly accurate model between the 9 indicators and the exterior quality evaluation of traditional residential buildings, 69 training data were first used to train the models to obtain the estimate of the model's parameters. Next, the training model was used to compute the 115 predictors of the exterior quality evaluation value. In order to assess the performance of BP and GA–BP algorithms, we also computed the training MSE and the iterations of BP and GA–BP algorithms. In particular, in the BP algorithm, the 115 iterations were needed to train the model with the training MSE 2.548 ×10^(-3), while the GA–BP algorithm only needed 100 iterations and reduces the training MSE to 0.714 ×10^(-3), which was much smaller than that of the BP algorithm. This result confirms that the training error of the GA–BP neural network model is significantly smaller than that of the BP network, and the GA–BP neural network algorithm can reduce the number of iterations for model training (S. Wang et al., 2016; Yan et al., 2020). In this sense, it can be concluded that the GA–BP neural network is more stable and better adapted than the BP neural network model. Fig. 3.7 presents further comparable details and shows that the predicted values of the evaluation value in different residences in the GA–BP model are closer to the true values than those of the BP model, which indicates that the points of the GA–BP are closer to the diagonal line.

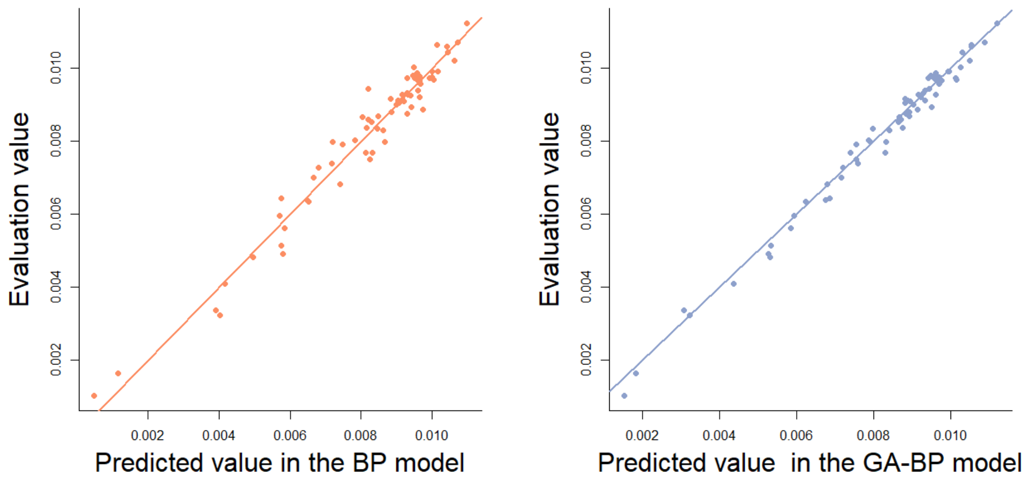

Fig. 3.7 Predicted values in different residences of the BP model and GA–BP model

According to the evaluation results, the final exterior quality of the dwellings was divided into four grades, with proportions of 10%, 20%, 30%, and 40% corresponding to Grade I, Grade II, Grade III, and Grade IV, respectively. The scatter plot of the evaluation values of the exterior quality of the different dwellings is shown in Fig.3.8. The four grades of 115 dwellings in Mengjinglai village are distributed in Fig. 3.9. As can be seen from the diagram, most of the Grade I dwellings are located in the center of the village, with a well-preserved appearance and good architectural space, and the history and culture are well displayed; the Grade II dwellings are concentrated in the central part of the village, with good preservation of the original style in terms of building materials, but with a certain commercial space; the Grade III dwellings are scattered in various parts of the village, with a certain amount of renovation, in terms of appearance; the Grade IV dwellings are mainly located at the edge of the village, and most were recently renovated or have a strong commercial space.

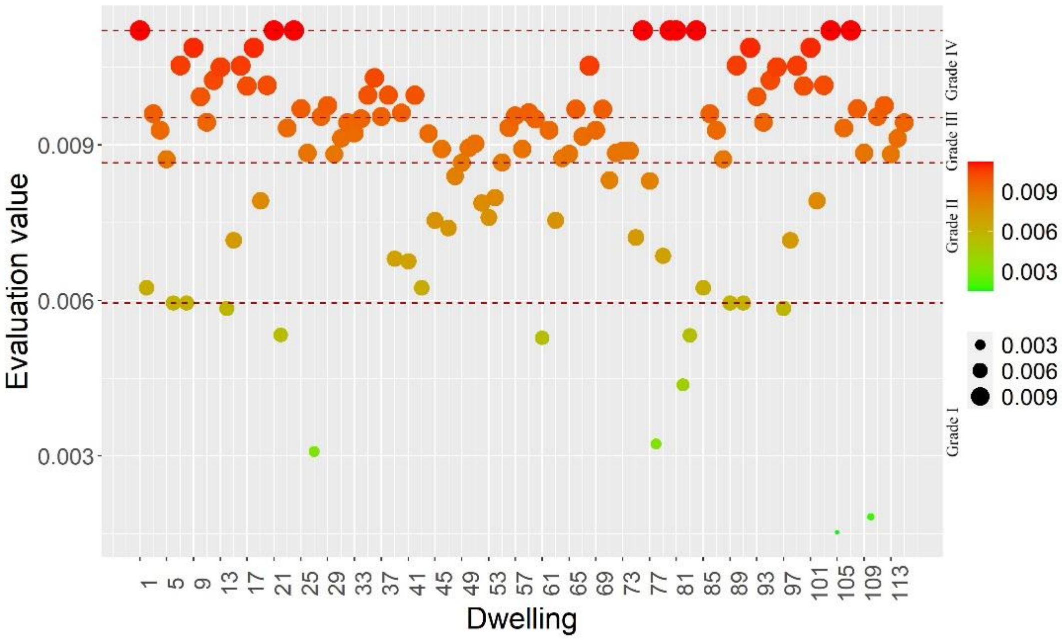

Fig. 3.8 Scatter plot of the evaluation values of different residences

Fig. 3.9 Distribution of residential grades in Mengjinglai village

3.4. Summary of the chapter

The evaluation of the quality of the appearance of traditional residential dwellings is currently not unified due to the resistance to variation and the diversity of elements that make up the quality of the appearance of buildings. The exterior quality of traditional dwellings is one of the most direct forms of contact for tourists and scholars, and also affects the direct impression of villages, while good exterior quality can also better convey and promote the culture of villages. Most studies on the architecture of villages still focus on spatial form, development and evolution, community satisfaction, and public participation. In this chapter, the external quality of the dwellings was assessed by using machine learning approaches, and the results can be used to help in the planning and design of villages. Architects can select the design priorities for renovation based on the assessment levels and can influence the design ideas based on the results of the different assessment factors; for example, increasing the use of local timber and tiles leads to better assessment results. Traditional houses can be assessed using the GA–BP method, but also the external quality of urban buildings or other aspects of quality.

The GA–BP neural network model is significantly more efficient than the BP net-work, reducing the number of iterations for model training, and is more effective in terms of global search capability. The GA–BP neural network model is more stable and adapts better than the BP neural network model. The focus of this chapter is on how machine learning can quantify the assessment of the exterior quality of traditional residential buildings, and more work is needed to apply the assessment system and pro-vide an analysis of exterior quality. More elements of assessment could be added in future studies to make the results more accurate, and further research could be conducted on the subject of predicting future trends in external quality.

This chapter took Mengjinglai village as a case study and applied the GA–BP neural network model to evaluate the exterior quality of residential houses based on the respective advantages of the BP neural network and the GA, classified the quality levels, and compared and analyzed the results of the BP neural network model and the GA–

BP neural network model. The main conclusions are as follows: (1) The GA–BP network model is less error-prone and more efficient than the traditional standard BP neural network. Using the GA–BP network model in the exterior quality evaluation of traditional residential houses can lead to a more rational and scientific approach to village assessment, and provide a reference for other, similar studies. (2) The overall exterior quality of Mengjinglai village is well preserved, highlighting the traditional Dai architectural style, and there was little difference in the scores of the four classifications assessed. However, the village's architecture still needs to be combined with local policies and customs to reflect the traditional culture.

4. THE APPLICATION OF HBIM IN THE RENOVATION DESIGN OF HISTORIC BUILDINGS

This chapter firstly provides real-time observations of historical building information through 3D laser scanning technology, from program development, data collection, and processing, and 3D model reconstruction to achieve rapid, to the efficient acquisition of 3D information. Secondly, the conservation and renovation design scheme of the historic building is explored to propose a conservation strategy that is in line with the local cultural heritage. The reconstruction of the building information model and the research of its history and surrounding information is then used to integrate and optimize the reconstruction model in terms of assisting design decisions and virtual representation of scenes and developing a conservation and renovation design plan for the building. Finally, an in-depth analysis of the project's geographical and historical context, as well as the spatial characteristics of the building, led to the conclusion that the façade will be restored in the style of the medieval historical building, and the internal space will be transformed into a public space for public participation. The proposal also takes into consideration the role of contemporary culture as a carrier to increase the vitality of the area, in order to bring about a revitalization of the area from social, economic, and cultural perspectives and to reuse the historic building. The theoretical analysis proves that HBIM (Historic Building Information Modelling) technology-based historic building renovation design can quickly and accurately obtain 3D models with detailed information, and improve the efficiency and science of renovation by combining the models with historic building renovation design ideas that are in keeping with the local cultural heritage, so as to achieve scientific and digital conservation and reuse of historic buildings.

4.1 Questions description

As an essential component of urban regeneration and a major carrier of historical values, the conservation and reuse of historic buildings is of primary importance (Guo et al., 2021). More and more architects are focusing on preserving the cultural memory of historic buildings and their historical value while adding new designs to revitalize and regenerate them, and the conservation and reuse of historic buildings have been a popular topic of research and reuse (Said et al., 2013). In the process of designing the reuse of historic buildings, the presentation of two different consciousnesses of conservation and reuse has caused architects to be prone to extreme behaviour when judging the value of historic buildings. Some architects, when faced with the continuation of architectural culture and the transmission of its architectural historical values, often take stylistic unity as the primary goal, choosing to completely imitate the characteristics of the original elements without considering the reality of the situation, making the historical traces unclear and indistinguishable (Khalaf, 2016). This erroneous approach to cultural relationships is a common problem in the renovation of historic buildings, resulting in the failure to protect the value of historic buildings after reuse, with the problems of historical and cultural heritage and spatial function being particularly prominent (Bleibleh & Awad, 2020). It can be seen that in many cities with deep historical and cultural heritage, a large number of historic districts and buildings have not been improved in good condition, and many have even been knocked down and replaced by blocks of antique buildings of indistinguishable style (Sun et al., 2022). As a result, the historic environment of the city is being destroyed, the historic districts are diminishing and the historical heritage is being destroyed, thus creating a uniform urban appearance and the overall historical atmosphere of the city is no longer available (Yung et al., 2014).

The restoration of Italy's architectural heritage has been a specialized discipline since the fifteenth century, and the conservation of historic buildings has a long history. Faced with the destruction of the original historic landscape as a result of economic development and the ensuing urban regeneration after the Second World War, Italian architects became more aware after the 20th century that the architect's responsibility could not be limited to the present, to new buildings, but that every project in the historic landscape should preserve the existing urban identity (De Medici, 2021). In contrast, even the practice of the relationship between the renovation and the regeneration of historic buildings is a fundamental issue to be considered in architectural design. Italy attaches great importance to the conservation and reuse of architectural heritage and historic buildings, and through the accumulation of experience has developed a relatively mature system for the conservation of historic architectural heritage, which has been integrated into the basic policies of national development (Lerario, 2020). There are many examples of the conservation and reuse of historic buildings and cultural heritage in Italy, represented by the work of the Italian architect Carlo Scarpa, which is based on the idea of distinguishing the original historical relationship between the building and the co-evolution of the new building and the original building (La Gennusa et al., 2005). The appropriate adaptation and exploitation of historic buildings allow them to be extended and adapted to the new needs of the times, thus allowing them to be effectively revitalized and reused.

At the stage of reuse and renovation design of historical buildings, information acquisition of the original data plays a key role and is concerned with the accuracy of design and construction (Hashem et al., 2022). With the development of digitalization of buildings, the way of collecting architectural information has gradually diversified. In the early days, manual measurement was the main method, which was inefficient and easily affected by the weather and site environment (Han & Leite, 2022). At the same time, for some buildings with high protection requirements, manual measurement is likely to cause damage to the protected buildings, and at the same time, it is easy to cause measurement errors. With the development of electronic information technology as well as aerial and satellite technology, 3D GIS technology, low-altitude photogrammetry, and multi-dimensional reconstruction technology, the use of true 3D models to analyze and preserve historic conservation buildings is becoming more and more developed (X. Yang et al., 2020). In the acquisition of building information, laser point cloud data is acquired quickly, independent of terrain, environment, and weather, and can obtain changes in building 3D information in real-time. At the same time, LiDAR is penetrating and not affected by tree shading, and can also obtain information on the layering of building interiors, which has become one of the main means of acquiring building 3D information in recent years (O'Neil-Dunne et al., 2014). Lidar scanning as an emerging 3D data acquisition technology is increasingly used in the mapping of architectural heritage due to its high accuracy, non-contact, high density and high-speed acquisition (Giordano et al., 2018). The accuracy of LIDAR scanning varies according to the measurement range, and depending on the state of the heritage object different 3D scanners with different accuracies can be selected (Systems et al., 2022). However, as the accuracy increases, the number of point clouds also increases rapidly. The difficulty of post-processing point clouds increases accordingly. At present, the point cloud processing is relatively weak, and many studies have made 2D representations of the rich 3D data in CAD or combined it with BIM to create BIM components (Y. W. Zhou et al., 2020). At the same time, the limited acquisition range of terrestrial laser scanners does not allow for large-scale data acquisition. A single measurement method is not good enough for a good 3D reconstruction of architectural heritage. 3D realistic reconstruction techniques with data fusion are developing faster due to the advantages of better accuracy and large-scale acquisition (Ji & Luo, 2019). Combining photogrammetry and laser scanning can bring out the advantages of both and circumvent their disadvantages, making it a better way of collecting the digital heritage of architecture. In addition, the use of ground and airborne images can be fused to achieve a multi-angle image of the building, reducing the problem of missing data due to tree and roof obstructions. This allows for the construction of more accurate and detailed building models. Data fusion based on data acquisition will be the future trend in the digital reconstruction of buildings (Alavipanah et al., 2018).

Murphy M. and Eugene McGovern of the University of Dublin, Ireland, have been working on the application of new technologies to enhance the documentation of historic building information, first introducing the concept of HBIM in 2009. In his Ph.D. thesis in 2012, Murphy M used Graphisoft ArchiCAD as the software platform and described in detail the application process of HBIM for Henrietta Street (Murphy et al., 2009). Stephen Fai has worked on the application of BIM to the documentation of cultural heritage information, and in 2011 he proposed the creation of a BIM model containing all quantitative and qualitative information related to historic buildings, which could introduce a temporal dimension to reflect the full extent of the building's past, present, and future (Street, 2019). Juan Enrique Nieto-Julián combines HBIM with cultural heritage restoration projects based on the concept of teamwork, taking into account the irregularities of the target objects during the data collection process, and then adding automatic recognition by artificial intelligence through a BIM system that analyses the characteristics of the historic buildings (Nieto-Julián et al., 2022). Fodil Fadli has developed an HBIM platform for the different specialties in construction, which can be used for digitally integrated work on data collection and archiving, through which measures can be taken to improve the clarity and manageability of research data (Fadli & AlSaeed, 2019). Alexa Woodward's case study of a house in the UK not only collates key information such as heritage values and house data from the HBIM framework of the case study, but also the design of the renovation in the context of heritage conservation. It is a good platform for communication between the owner, architect, and builder, but does not go into enough detail about the design concept of the renovation (Woodward & Heesom, 2021). Most of the current research in the field is still focused on the use of HBIM technology for the information management of architectural heritage and the lack of subsequent design updates for the adaptive reuse of projects.

This chapter investigates the application of HBIM technology to the design of the renovation of a church in the Tuscany region of Italy, analyzing it in relation to the Italian concept of architectural heritage conservation and combining it with the renovation proposal. Consider the design principles and design strategies in dealing with the conservation and reuse of historic buildings. Explore how to achieve a harmonious coexistence between historic buildings and new parts in the process of renovation of historic buildings, and add traces of contemporary life to the renovation design of historic buildings while expressing the historical and environmental heritage. It is hoped that through practical examples, design thinking, design strategies, and methods for the relationship between history and the status quo in the process of conservation and reuse of historic buildings will be explored, considered, and discussed.

4.2 Materials description

The focus of this study is on an approach that explores how to enhance the value of historic buildings so that HBIM does not act as a database of information in isolation, but also contributes to the subsequent reuse of built heritage conservation. Allowing historic buildings and renovated parts to generate new vitality through urban needs, spatial functions, and formal features (Pasetto et al., 2020). The new spaces or elements are spliced into the original historic building so that they are integrated into contemporary design, so that the two spaces or elements are interlinked and integrated, and so that their overall value is enhanced through symbiosis, thus enabling the revitalization and reuse of the historic building (Giordano, 2019a).

4.2.1 Data collection

This chapter was analyzed on the example of the Church of Santo Stefano, located in the town of Volterra in the Tuscany region of Italy, Fig. 4.1 shows a Google map and photographs of the site . In the research process, the scanning control system is used to control the scanning range and the accuracy of the acquired point clouds, the data processing system is used to collect the collected original data, and the spatial coordinates are used to convert the coordinate values of the three directions into global coordinates, and the laser point cloud is filtered several times to make the function curve smooth and finally to reconstruct the triangular grid data (B. Wang et al., 2021). After several experiments, it is proved that the system can adapt well to complex 3D scenes and get better model reconstruction results using point cloud technology (P. Tang et al., 2010).

Fig. 4.1 Google map view and photographs of the site

4.2.2 Renovation design

The design of the renovation of historic buildings has come along with the continuous development and improvement of architectural heritage conservation theories. As research progresses, people are increasingly aware that restoration is not enough, and that the ultimate aim of architectural heritage conservation is that it is given a suitable social and economic function, so that it can be reintegrated into the productive life of society and its own values can be revealed and promoted (Murzyn-Kupisz, 2013). From the point of view of adaptive design and reuse, the ultimate aim is also to achieve a more valuable presence of architectural heritage in contemporary society, and this presence is achieved on the basis of the proper conservation and restoration of architectural heritage (Carraro et al., 2019). At this level, the conservation of built heritage is a prerequisite for reuse and an essential part of the process of its realization. The churches involved in this project are characterized by their diversity of types, their distinctive architectural style, and the concentration of their main spaces (Mehrbod et al., 2019). Through these measures, the church buildings will be well preserved and integrated into modern society in a new way, enhancing their functional value.

The reuse of churches needs to provide a stable and safe spatial environment to accommodate the various behavioral activities that take place. However, over time, the structural elements of church buildings, such as the walls, floor slabs, columns, pendentive, and dome, inevitably deteriorate, even as some church structures or elements become more and more dilapidated under prolonged use (Giustetto et al., 2017). The continuation of the building's function is complemented by the maintenance of the building itself, which, if restored without functional renewal, is tantamount to starting the next process of decay. The renewal of functions needs to be matched to the needs and characteristics of the historic space itself, and a reasonable renewal of functions can enhance the overall value of the historic building (Giordano, 2019).

With the renewal of the building's function, the design of the new space and the original space is another key point in the symbiotic relationship between the building itself (Blagojević & Tufegdžić, 2016). The mode of association between the historic and the existing spaces has a bearing on the strength and effectiveness of the subsequent renovation methods, and it is necessary to give due consideration to the appropriate mode of spatial association based on the principles of minimal intervention and reversibility in the process of the intervention of the new spaces (Asteris et al., 2014). It can be concluded that the harmony of the two spaces requires consideration of the following two aspects: (1) Reasonable functional renewal: the need to combine the characteristics of the historic building itself and to analyze and match them in order to carry out a reasonable design for the functional transformation of the building. (2) Spatial association: the new spaces created after the functional renewal can be subdivided into four basic modes of association: embedded, overlaid, superimposed, and juxtaposed, depending on the connection between the old and the new spaces. In this project, overlay and superimposed modes are used for the renovation design (Q. Zhao, 2020).

As heritage is often materialized in historical buildings in the form of architecture, the formal expression of the historical and current space has always been the focus of attention during the renovation of historical buildings (Hegazy, 2015). In addition to the simple expression of history and culture, it is also worthwhile to recognize the past from the new perspective of the current era and to interpret tradition in an innovative way. Architecture is both historical and co-temporal, and the present is part of its historical composition for the future, so it is important not to rely only on passive inheritance, but to lead tradition into creation (Cassar et al., 2021). The design of the renovation of this work is based on the following three aspects of the relationship between the historic building and the cultural lineage: (1) the typological extraction of architectural forms: by extracting and transforming the spatial prototypes of the historic building, creating new spatial forms on this platform, or through the expression of historical elements to achieve the continuation of the cultural lineage; (2) Material association: on the premise of respecting the historical cultural nature, the materials are used to simulate or create a dialogue with the historical building materials. (3) The continuation of scenes: connecting the former historical spaces with paths or involving people through event planning as a complement to the formal expression, interconnecting the cultural lineage with the old and new buildings (Y. Li et al., 2022).

4.2.3 Point cloud model

After collecting the point cloud data from each station, the software of ReCap pre-processes it and automatically stitches it together with the image data in the overlapping areas on the adjacent stations collected by the scanner. The point cloud data is converted to the same coordinate system with a stitching accuracy of better than 2mm, and the point cloud data is converted to a coordinate system based on the control points in the field with a conversion accuracy of better than 5mm (Gu et al., 2020). For this step, choose the "SOR filter" command and the "Noise filter" command in the software to complete the denoising of the point cloud. To make the point cloud smoother, a further filtering process is required. The "Gaussian filter" command and the "Bilateral filter" command can be used in the software to perform the filtering process. It should be noted that the filtered point clouds are hidden in this step and the results will be generated in a separate file in the software, if the results are not satisfactory you can restore the data by clicking on the file before the filtering operation (Azzopardi & Petkov, 2015).

The different application areas of the target point cloud data are exported from the software in different common formats, of which the "*.zfs, *.asc, *.las, *.pts, etc." format is represented to make the point cloud data have a wide range of applications, and the files under this format are completed in the Revit software to guide the generation of The "*.pts" format allows the church point cloud data to be linked to the modelling software for subsequent operations (Ri et al., n.d.). During the scanning process, the camera built into the scanner captures the image data, and during the scanning process at each station the scanner takes pictures in parallel with the scanning, and the point clouds are coloured in the Register360 software module, and each point cloud is coloured to obtain a colour panoramic photograph, and through algorithmic calculations, the colour information of the panoramic image can be mapped to the corresponding position on the the algorithm allows the colour information of the panoramic image to be mapped to the point cloud at the corresponding location. While the scanning is in progress, it can be used in conjunction with a Global Positioning System (GPS) or Total Station, as required, to provide a basis for subsequent coordinate conversions. The point accuracy of the acquired point cloud data can be analysed by comparing the coordinates of the total station and the scanner at the same point in the external co-ordinate system. 10 position points, such as the sill edge of some of the ground floor windows, are selected as feature points, and the results of the scanner and total station measurements at the feature points are compared (Julin et al., 2020).

The data processed in the Couldcompare software needs to be converted to a format that can be recognised and processed by the popular BIM modelling software Revit. The method used in this work is to convert the "*.zfs, *.asc, *.las, *.pts etc" format of the point cloud data processed by the software into "*.rcs" format files by linking the function modules of the point cloud. This format file is linked directly in Autodesk Revit software and is used as a reference for reverse modelling in the software (Moyano et al., 2021). The point cloud data imported into the Revit software is shown in Fig. 4. 2.

Fig. 4.2 The point cloud data of the church

4.2.4 The plan of renovation design

Modeling by opening the transcoded point cloud data in Revit software. The contour lines of the model are drawn according to the point cloud. The main function of the drawn contour line is identifying the model boundary; drawing the outline of the components according to the point cloud, and collecting the dimensional information of the components with the help of the functions of measurement and annotation, as a reference for the dimensions of the loaded components such as doors and windows. The establishment of elevation and axis lines also plays a role in the modeling by dividing the floors, generating floor plan, determining the position of the top and bottom of the floors, and determining the position of the columns and walls. Once the preliminary work has been completed, the main body of the model can be modelled (J. Zhu et al., 2014).

After the modeling was completed, the architectural style of the town of Volterra and the local historical context was taken into account and the medieval style was restored as far as possible. The typical medieval style of rose windows, dome, and semi-circular arches were used, and the materials of the existing building were retained, while the same materials were used in the new part of the building, which is a typological extraction of the building form and a correlation of materials (Chiozzi et al., 2018). The design of the existing walls has been combined with the height of the existing walls to create an innovative design, adding elements such as arches, crosses, and sequential pointed arches, and using the symmetrical relationship of the axes to show the church's solemn character, which is a continuation of the spatial scene and creates a dialogue between the new space and the existing space (W. Li et al., 2020). The information on the location of the doorways and the height of the story of the existing building has been retained in the renovation design scheme, and the front façade has been designed using an overlay approach. As the main church space no longer exists, this has an impact on the design of the renovation scheme, as there is no contextual reference. However, on the other hand, if the main façade is preserved in style, it is possible to make the best use of the space of the main part of the church, with superimposed spatial implantation, which may be a new experiment and a spatial innovation, so this work is an innovative design for its interior (Rakow, 2020). Fig. 4.3 shows the effect of the renovation design scheme.

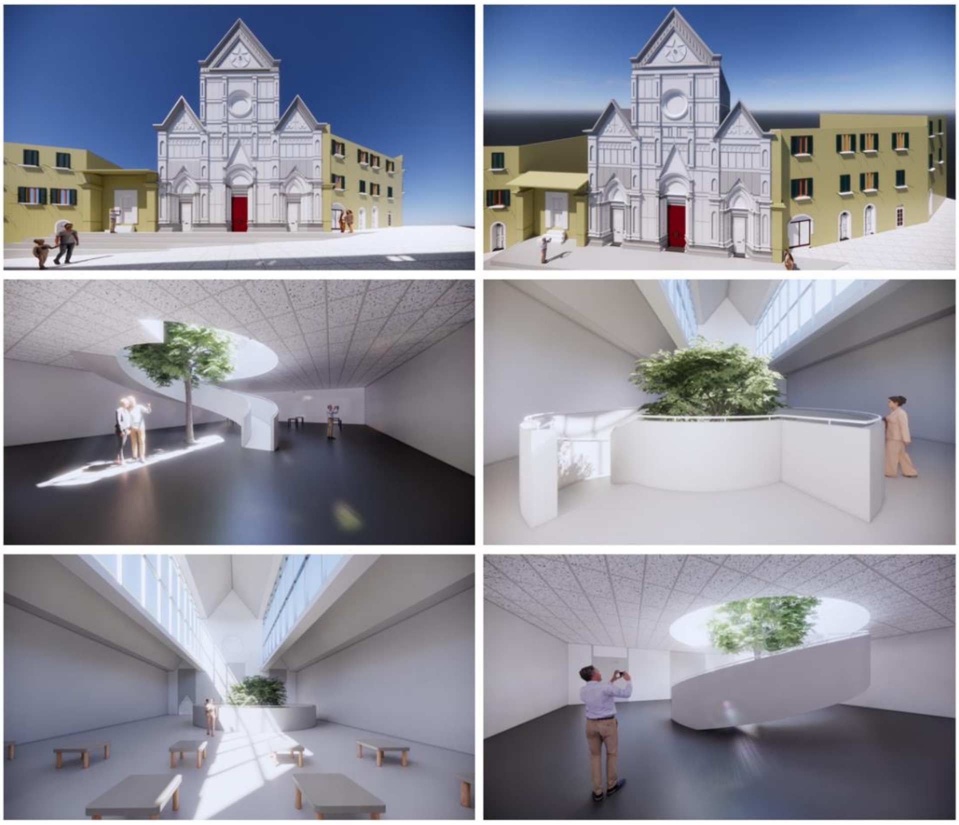

Fig. 4.3 The renovation design plan

4.3 Summary of chapter

In this chapter, a point cloud model of the historic building was created by means of a 3D laser scanner, and the design of the renovation was based on the existing conditions of the church. The concept of the design is based on the relationship between the new space and the original space, the extraction of the historical context, the restoration of the materials, and the innovation of the scenic space. In the course of this chapter, an adaptive reuse strategy is proposed for the church in response to the problems it faces. On the one hand, through the overall planning of the surrounding site, and on the basis of meeting urban management regulations, the conservation of the heritage building is opened up to the city through the introduction of adaptive functional spaces or other public spaces, so that it can be integrated as much as possible into the current public life of the city. On the other hand, by adapting and replacing the internal functions, the daily contact points with the historic buildings are increased. By expanding the range of contact and the diversity of the replacement functions, the building will be able to better meet the diverse needs of people today, while at the same time bringing vitality to the city's culture, thus enhancing the vitality of its surroundings and ultimately achieving sustainable development together with the city.

The design of the interior space, while reflecting the basic design flow, is intended to present some more lively spaces. However, due to the limitations of the site space and design thinking, the design is only expressed in a relatively straightforward manner. In addition, as the author's design is based on a rather idealistic environment, he has not taken into account the many social factors involved in the implementation of the scheme and lacks practical testing. However, the main intention of this chapter is to demonstrate how HBIM technology can be applied to the renovation of historic buildings and, more importantly, to demonstrate a methodology. This method can meet the accuracy requirements of historic building renovation and has unparalleled advantages over traditional methods, which are now being gradually applied in the urban renovation. However, the existing point cloud data processing software has certain drawbacks due to the limitations of the algorithm itself and must be combined with practical targeted processing improvements before it can be applied to project production. Although there are some areas that need to be improved, this work investigates the renovation scheme and reuse design of historical buildings, and proposes conservation concept measures and reuse renovation strategies based on the current problems, which provides some reference for the future conservation and reuse of similar historical buildings and has a greater significance for exploration.

In terms of spatial layout, the overall layout of the original building will be retained, a small number of buildings of low historical value and unsuitable for renovation will be demolished, the original flow will be maintained, and landscape flow and public space will be injected; a public urban environment for leisure and recreation will be provided for the surrounding residents and visitors. This chapter explores the advantages and development prospects of combining HBIM technology with historical building renovation design and gives the design ideas proposed in this chapter to combine historical building renovation design ideas through the HBIM platform. Based on the renovation of historic buildings, this chapter validates and practices its approach by presenting problems, analyzing and solving them through the digital informatization of buildings and sites as an aid for the whole process of architectural design and renovation. The current process of building informatization is in the exploratory stage, and the depth and breadth of the application of 3D models need to be further studied in depth, and the automation process of the application of 3D reconstruction models and the rapid vectorization of models need to be further studied in depth in the future.

5. SPATIAL CO-DESIGN WITH TLS TECHNOLOGY

In the context of urban renewal and informationization, it is essential to examine the traditional design industry innovatively. From the perspective of collaborative design, this work uses Terrestrial Laser Scanning (TLS) technology in surveying and drawing combined with traditional design methodologies and BIM platforms to conduct a practical study on the stores in Guangzhou's commercial complexes. This study focuses on how to comprehensively and realistically present the project's design concept. After the entire research from the early design stage, the construction process, and the post-completion stage, the results indicate that TLS technology can assist designers and owners in collaborating on the design and realizing ideas more realistically. This project has been favored and welcomed by consumers because of its good representation of Hanfu culture and has established a modular and standardized foundation for similar work in the future, which has positive significance for the trend of collaborative design in the design industry.

5.1 Questions description

With the development of the economy, people have new requirements for physical space, causing urban planning and construction gradually enter a critical period of rapid development, urban construction enters a fine development stage, and cities gradually and rapidly turn from rapid development based mainly on incremental economic development to the potential type of development; thus the theory of urban renewal comes into being (Suh & Cho, 2021). Usually, urban renewal projects are government-led, market-led, and property-led. The source of market-led retail space renewal is the change of consumption environment owing to the change of the main consumer, and the essence of commercial space renewal is to provide consumers the greatest spiritual satisfaction in the commercial scene, including the improvement of business format, interior design, and soft decoration (Short & Fundingsland Tetlow, 2012). The comprehensive development of information technology has penetrated almost every field. The informationization of commercial space design is a significant driving force in enhancing design efficiency and improving management. It is an essential tool for developing the entire urban renewal field in a huge stride (Boyle et al., 2018). 3D spatial information is a hot topic in geospatial information science research, and 3D laser scanning technology is an emerging technology related to this hot research field (Gruen, 2021). 3D laser scanning technology is also known as "real scene replication technology", through laser scanning tools for 3D entities to laser scanning, and then use the computer and related software for data processing of the collected point cloud, and finally realizing the real scene 3D model reconstruction of the collected target, which is a high precision 3D inverse modeling process (C. Xu et al., 2022).

Information technology has significantly contributed to the development and progress of interior design. Traditional computer-aided software such as CAD has made it impossible to achieve true multi-disciplinary collaboration and sharing of data and data correlation between drawings and models, resulting in low work accuracy and efficiency (Zhuang et al., 2018). In the design process, incorporating the information of the whole life cycle of the building model to accomplish multi-disciplinary and collaborative cooperation among all parties involved can promote the efficiency and progress of the spatial design (Singh et al., 2011). Collaborative design is storing, converting, and sharing information, including collaboration between design disciplines and upstream and downstream project participants, the cooperation between 2D and 3D design, and the transfer of information throughout the project life cycle (Ren et al., 2011). 2D collaborative design is a file-level collaboration based on the external reference of computer-aided drafting software, which is a stage-by-stage collaboration based on regular updates of 2D drawings in the field of construction engineering (Xiao & Bhola, 2022); The 3D collaborative design is a collaborative model in which all professionals design in parallel in the same environment based on 3D models, and complete the same project through information exchange, communication, and collaboration. The development of TLS technology provides a new operation trajectory for the current 3D collaborative design, and the collaborative design based on TLS technology is a new paradigm of spatial design expression and a new way of design, communication, organization, and management, utilizing the 3D visualization technology of TLS and the interactive sharing characteristics of information to enable the building, structure and equipment professionals to collaborative design on a unified digital model. The design and drawings can be modified in real-time based on the results of the construction site, and the construction parties, including construction units, supervision units, material suppliers, and operation units, can begin the implementation of the project to achieve a more desirable construction results (L.-K. Chen et al., 2021; Wen, 2019).

Co-design is increasingly being utilized in design practice. Jiayuan investigated the connections between the various designers and participants through the study of BIM in construction projects, and the development of an analytical model concluded that the teamwork atmosphere has the most significant influence on collaborative design. Concurrently, work and interpersonal interaction can also positively impact teamwork. It is evident that communication and cooperation among designers, owners, and consumers are essential and that collaborative design can be coordinated in these aspects (J. Wang et al., 2021). The transformation of industrial parks, commercial areas, old districts, urban neighborhoods, historic preservation, urban villages, and public services constitute urban renewal. Walaa establishes a methodology for enhancing the value of commercial areas in the midst of historic cities, a methodology that preserves historical values and has a positive impact on the vitality and movement of the city. It indicates that the value of commercial areas can be renewed through architectural design and urban design to accomplish urban regeneration following the overall context of urban regeneration (Mehanna & Mehanna, 2019). Using TLS technology, the object can be scanned and produced as a model in the building design process. Tarvo produced a BIM model of the building utilizing TLS technology, which was used to detect and define façade damage and proved that TLS technology might be beneficial to design (Mill et al., 2013). Including a specific theme in the design facilitates a unified expression of the style of the space. Based on a survey of four urban regeneration projects in China, Fei discovered that the embodiment of value in commerce is strongly related to the local culture. Creating spaces with traditional forms can positively impact commercial places (F. Chen, 2011). It is evident from the above literature that the addition of traditional culture to commercial spaces in the context of urban regeneration can have a positive effect, that collaborative design can assist with teamwork in the design process, and that TLS technology can aid in the design to increase the accuracy of the model. However, this literature has been scattered across various pieces of work, and it has rarely been combined to produce a complete platform for design. Therefore this work builds on the TLS-based collaborative design of a shop space in Guangzhou in the context of urban regeneration, utilizing the traditional Chinese cultural theme of Hanfu.

5.2 Materials description

The construction was carried out after conceptualizing the design of the commercial space, and the furniture design was finalized after numerous communications with the owner in the context of urban renewal and the combination of consumer and spatial aesthetics. TLS technology was utilized to scan the store's interior to achieve the point cloud data and 3D model throughout the construction process to make the final construction results better match the design expectation. Under the collaborative design concept, errors can be found by comparing the 3D model to the final results, and the design or construction can be modified in real-time (Giordano, 2017).

5.2.1 Study area

This study's research project is the renovation of commercial space in Guangzhou's Zhengjia Plaza. Designed as an experiential theme shopping park, it is a modern shopping center that integrates retail, leisure, entertainment, catering, convention, exhibition, recreation, tourism, and business. The store is themed as a Hanfu aesthetics experience hall to highlight its business characteristics in the shopping center; still, it has no advantage in the location of the entire commercial plaza, and the owner wants to enhance the commercial value and popularity through renovation, and design value (Lee et al., 2019; Y. Zhang, 2008). Fig. 5.1 depicts the current situation in the mall and the stores before the renovation.

Fig. 5.1 The mall and the stores (inside pictures)

5.2.2 Commercial space design philosophy in the context of urban renewal

High-quality urban renewal will also stimulate the transformation of industries and business models in the urban renewal process, thus promoting the evolution and iterative upgrading of commerce and consumption (Zhao Liu et al., 2019). The introduction of high-tech commercial industries will better meet diversified requirements and give more incremental value and utilize the commercial space, thus optimizing urban functions and layout and promoting economic development (Zhaowen Liu et al., 2020). In the context of urban renewal, it is especially significant to operate the commercial space in the whole life cycle of value discovery, value creation, and value enhancement. Chinese civilization has a great historical background, and Hanfu has a long history in the Chinese nation (LUO et al., 2021). Hanfu is a precious cultural treasure and a symbol of the national spirit, carrying a profound cultural accumulation and historical heritage, interpreting the traditional Chinese aesthetic meaning and the traditional aesthetic thought of ancient China, which is worthy of people's inheritance (S. Hu, 2014). This chapter incorporates the store owner's idea of operating a Chinese costume culture experience center, which is highly suitable for the space renovation design under the concept of urban renewal.

5.3 Application of TLS

Fig. 5.2 The laser scanning operations

The 3D model was obtained during the project construction process after scanning the project with TLS technology. The 3D laser scanning technology employs the laser ranging principle to record the 3D coordinates, reflectivity, and texture of a large number of dense points on the surface of the object to be measured, allowing the 3D model of the target to be measured as well as various figure data such as lines, surfaces, and bodies, to be rapidly reconstructed (Mill et al., 2013; P. Tang et al., 2010). Following the site survey, a feasible scanning route is planned based on the actual circumstances of the site and integrated with the design drawings to develop a three-dimensional scanning program (Borin et al., 2020). The effective distance measured by the scanner is 350 meters, and the area of the indoor space of the project is approximately 450 square meters. To improve the overlap between the respective sites, 25 scanning sites were arranged in the whole space, and the sites should be set up in numerous angles and directions for the key scanning areas to meet the requirement of full coverage of the scanned data collocation. The scanning data will be imported from several sites (Ding et al., 2016; Nahon et al., 2019). The multi-site site scan data will be imported into the point cloud processing software of Recap for point cloud denoising, point cloud stitching, point cloud trimming, and other data processing work in turn to synthesize the overall point cloud model of the scan (Jones & Church, 2020; Z. Xu et al., 2020). Fig. 5.2 depicts some locations where the scanner was employed in the construction work.

5.3.1 Spatial co-design

The 3D model of the construction process was compared to the design drawings to provide a platform for collaborative design. This project's components, in particular, feature many curved elements, which can be found during the comparison if the construction accuracy is not up to the required level, allowing it to be corrected. It is also possible that after analyzing the construction process drawing, the idea of modifying the prior design concept will occur; at this time, there is also an opportunity to modify it (Ibrahim & Pour Rahimian, 2010). The comparison enables modifications to be made in terms of layout changes, finishes, component installations, furniture placement, etc. The perspective of the 3D simulation ensures that the design is coordinated, efficient, and smooth. The level of spatial collaborative design is improved with three-dimensional design and data information analysis by analyzing the relationship between the 3D model and the actual space. (Paes et al., 2021). In the project's construction process, the scanned 3D model is employed as the object, combined with the design drawing update and integrated management means of each profession, to realize the collaborative design of this project (Nee et al., 2012). Additionally, it is possible to conduct collaborative design cooperation online in various regions to improve collaboration efficiency and enhance the practical application of spatial collaborative design through off-site collaboration (Giordano et al., 2019).

5.3.2 Space design products

After numerous communications with the owner, the following design concept and results were formed. Fig. 5.3 depicts the floor plan, illustrating the store's various functional partitions and designs. The entrance design is based on a lotus flower in full bloom, with the petal lines spreading outward around the lotus pistil, swaying and shining. It signifies that the revival of Hanfu culture, just like the lotus flower, is slowly gaining global attention, allowing the Chinese Han aesthetic culture to bloom worldwide. In contrast to the traditional window design, the project extracts its curved elements from the owner's brand logo and employs the dynamic curves as the compositional elements of the window with exquisite patterns, which not only adds some elegance to the space design but also expresses the artistic tension to the fullest, and makes it more agile and ethereal. Pedestrians can peek through the window to observe the aesthetics of the Chinese style and then be attracted in. Traditional Chinese aesthetics believes that the ultimate beauty focuses on the context (Q. (Bill) Zhou et al., 2013). The project cleverly employs the interplay between white and log colors to reveal a delicate artistic context and the beauty of the national style.

The Hanfu display area adopts a simple design approach, extracting Chinese characteristic elements and utilizing white with soft lighting, resulting in a harmonious visual integration. Simultaneously, the shelves are utilized to organize the movement of the entire commercial space, and through the creation of scenes from various angles, the theme image is strengthened to the maximum, allowing customers to feel the culture of Hanfu and the owner's brand from the entire store display effect. To assist spread the culture of Hanfu aesthetics, a cultural creation area was designed to represent a traditional culture to the public through the grafting of contemporary design and creative products, hoping that customers can experience the profound cultural values and unique connotations carried behind. The concept of "lotus flower" is also used in the cultural creation area, and the lotus petals obtained through the golden division method are employed to turn the space of the cultural creation hall into a painting scroll, inviting the viewers to savor the beauty of traditional Chinese culture and experience various national style cultural creation products (J. Park, 2022).

Clothing has always been the most intuitive carrier of national culture, and accessories play a significant role in it, which is one of the reasons why we designed the accessories area. The design of the accessories area follows the overall style of the store, emphasizing the beauty of the national style mood. The project also designed the children's area, hoping that children could feel the charm of Hanfu aesthetics and the deeper meaning of the culture from a young age. The fitting room maintains a consistent personality and aesthetic with the overall image of the owner's brand in all aspects, including overall vision, lighting, color, and layout. Neutral white lighting is employed in the fitting room, and good light reveals the most authentic and perfect side of customers and enhances the fitting experience (Jonu & Auglys, 2019). The cashier area is designed with lotus petals for outlining, and the smooth curve design demonstrates an elegant and written temperament. The natural and comfortable color scheme depicts a comfortable and natural space mood, and the soft lighting design makes the space appear more layered. The Tang Dynasty style furniture utilized is unique in its shape, featuring wide and heavy, round and full, fresh and gorgeous. Fig. 5.4 and 5.5 illustrates the rendering images from various angles and zones of the interior and exterior.

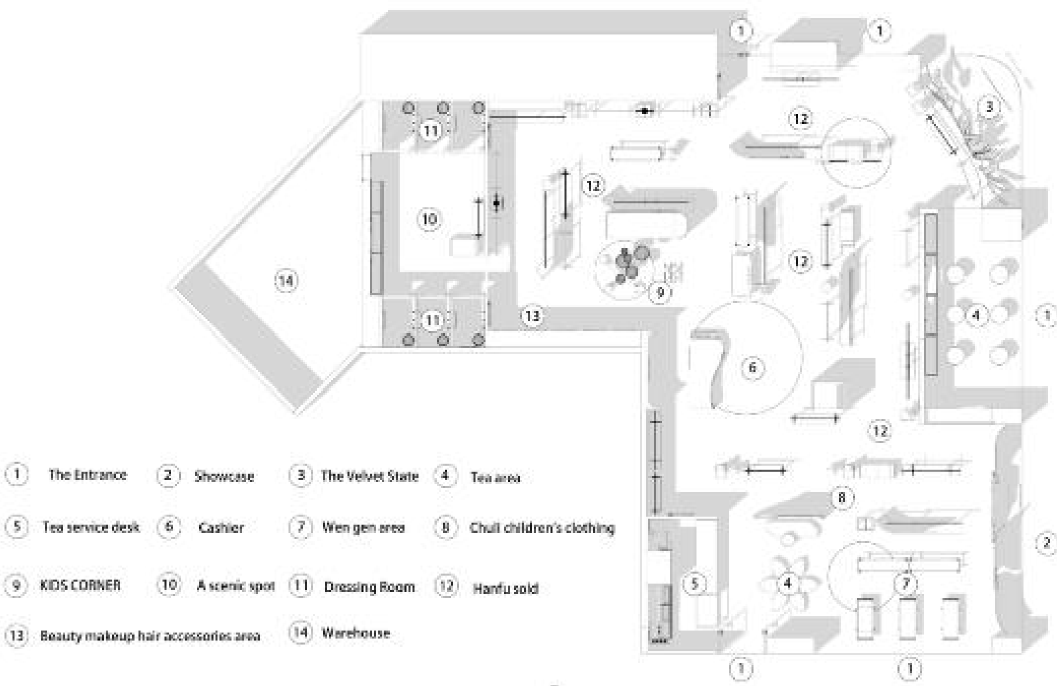

Fig. 5.3 Floor plan

Fig. 5.4 The rendering images

5.3.3 Application of TLS technology in co-design

After scanning the commercial space under construction with a 3D laser scanner, an ideal point cloud can be obtained after processing. From the point cloud data results, it can be observed that the construction site is the same as the design pattern. However, there are still deviations in some places due to the limited accuracy of the arcs and details in construction and the variations between the 2D drawings and the three entities (P. Tang et al., 2010). According to the deviations in the location, modifications are made at the construction site. Utilizing BIM technology, the interaction between the building and MEP was processed in the model for co-design. After obtaining data models of the overall layout, decorative surfaces, fixtures, furniture placement, etc., from each of the 25 scanned sites, the three-dimensional model was compared with the construction site data (Z.-Z. Hu et al., 2018). Dynamic updates were maintained

Fig. 5.5 Environmental streamline analysis diagram

between the construction site results and the design drawings, and modeling and analysis were used to enhance the final effect. TLS technology, construction organization management, design management, and BIM are fully integrated with the collaborative design process to improve the practical application of interior collaborative design. Fig. 5.6 depicts the images of the processed point cloud (Novak, 2014).

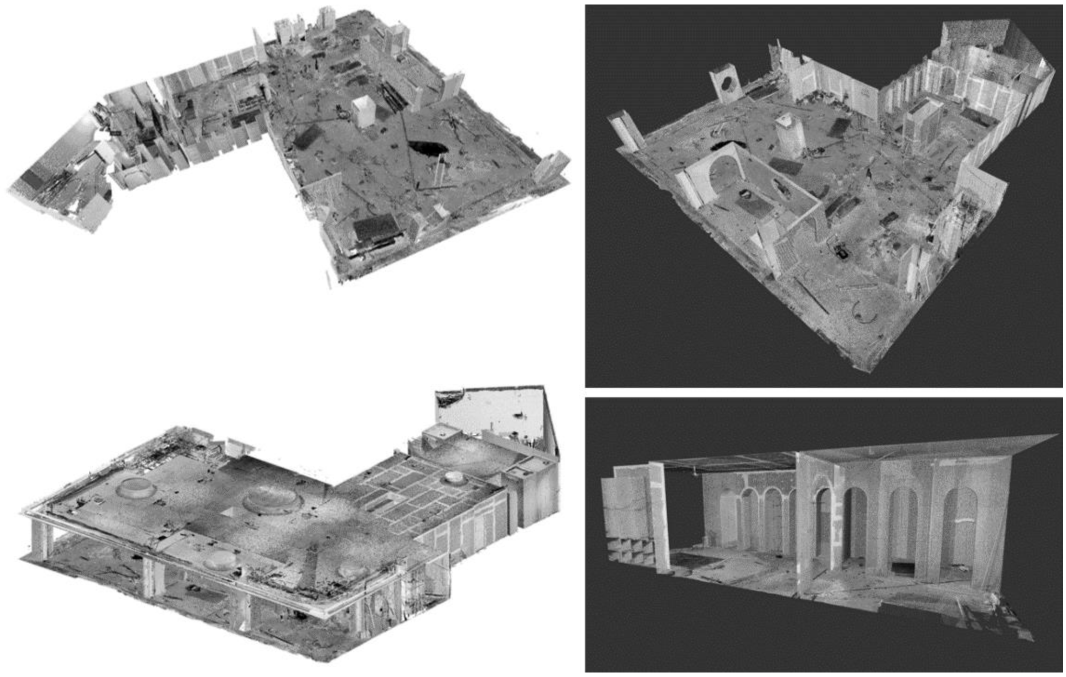

Fig. 5.6 Point cloud images

5.3.4 Construction results

To maximize the value of commercial space, after the collaborative design of the design scheme and construction process according to TLS technology, the value of commercial space is more thoroughly reflected in the context of urban renewal. This research has significantly improved the storage space's functional structure, spatial layout, and shopping experience environment (Santos et al., 2017). As a consequence of the collaborative design of TLS technology, the entrance, display area, children's area, tea area, and other areas have been optimized to varying degrees, and the displayed results more accurately reflect the Lotus theme. The charm of Chinese costume can be perceived in the entire atmosphere of the interior space. The lotus flower is paired with the owner's brand VI concept, which is simplified and outlined by the soft posture of the lotus flower blooming. The whole is simple, fashionable, and innovative, expressing the oriental beauty everywhere and providing a clear and ethereal poetic sense. A large area of Chinese traditional stylized red and white as the main color, such as a charming red series and dreamy white fusion into a smooth painting, in the flow of the visual feast, interpretation of the country-style aesthetic ethereal poetry. It provides people a sense of intertwined beauty as if they are in a lotus fairyland hidden in the city.

Fig. 5.7 Contrast photos (rendering photo, point cloud photo, real photo)

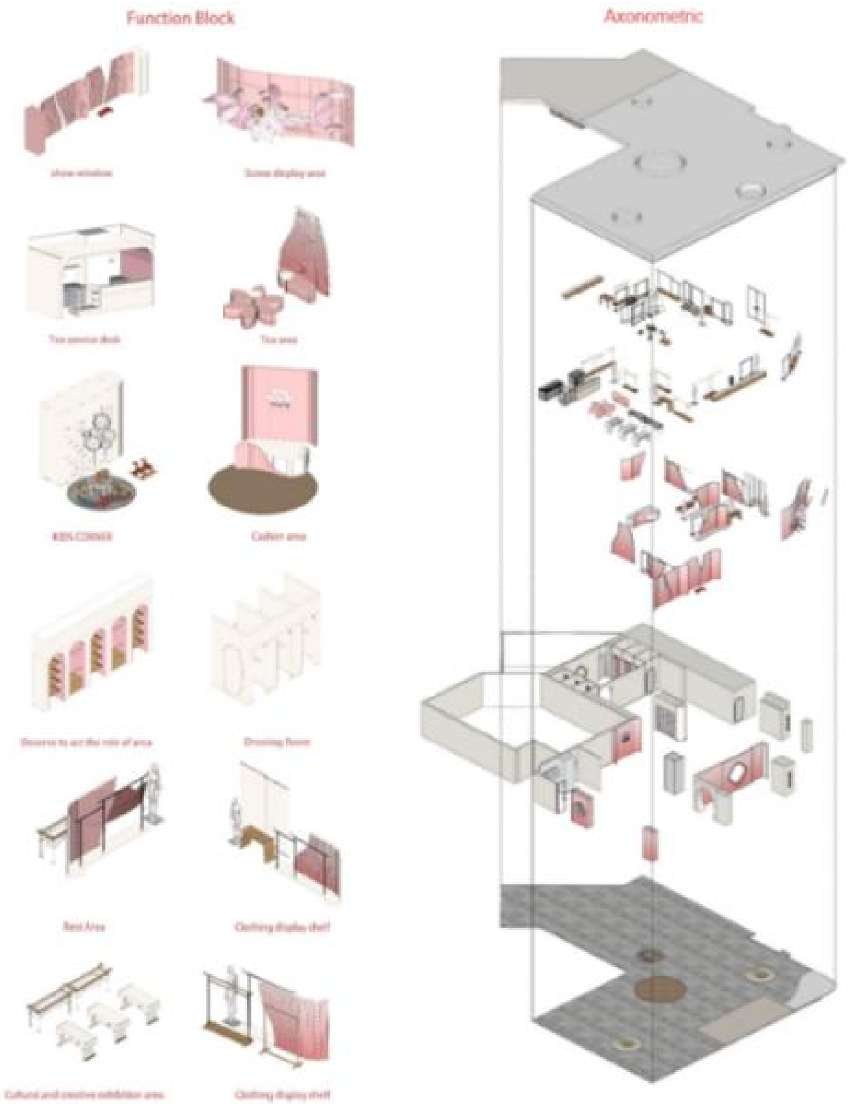

Fig. 5. 8 Axonometric and function block photo

5.4 Summary of chapter

It can be collaboratively designed and dynamically modified during the whole project life cycle. In the context of urban renewal, integrating information technology, mapping technology, and 3D technology in combination with the design concept of traditional Chinese culture increases the popularity and value of the entire mall. The essence of urban renewal has switched from expansion to quality enhancement, and this project incorporates the site design in terms of consumer flow, adding as many entrances as possible to make the indoor and outdoor spaces transparent (Miao, 2011). As illustrated in Fig. 5.6, the interior of the stores can be accessed from various entrances, bringing vitality to the environment. As a commercial complex in the city, the case of this chapter profoundly represents the power of design to optimize the traditional design and enhance the value and quality of the storage space through the integration of information technology. This research focuses on the interactivity of information in collaborative design for data sharing of interior spaces, with varying degrees of adjustment from outdoor to indoor stores, as evidenced by the comparison of three stages: rendering photo, point cloud photo, and real photo (Fig. 5.7), all with subtle differences. It is assumed that the final idealized result would not have been attained without the intervention of TLS co-design.

Furthermore, the design results of this project established the foundation for the owner to expand the store in other areas in a modular, assembled manner. The modular materials can be refined and altered in future projects based on the project's specific needs (Rausch et al., 2017). Fig. 8 depicts the axonometric and function block, which can all be replicated in future projects for the owner. This study has shortcomings, mainly the processing of point cloud data, which requires optimization; therefore, the scanning results are more realistic, and the obtained models can assist in subsequent design (Goi et al., 2020).

6 CONCLUSIONS AND DISCUSSIONS

6.1 Conclusions

Four different case studies are used to explore how to assess the value and design of urban renovation in the context of urban renewal. It explores how to combine the historical and cultural values of the local heritage with a comprehensive consideration of the study object before renovation and design. The value of different building types is analysed and different methods are used to construct different evaluation systems and obtain different levels of protection. The different levels of conservation can influence different conservation strategies and renovation design concept, and the renewal patterns under different levels of conservation are discussed. Based on the different renovation design cases, HBIM and TLS technologies were used to collect and model the data, and then the platform was used for research and analysis to obtain more efficient results. The following conclusions were reached as a result of these analyses:

- The chapter 2 took Wengji ancient village as the research object and uses the entropy weight method to carry on the value evaluation in three parts, and the main conclusions are as follows: (1) The architectural value of traditional houses is influenced by many factors, among which the most influential are architectural style, building materials and architectural space, which constitute the diversity, richness and specificity of traditional house architecture. (2) Traditional residential architecture has been influenced by its environmental geography, mountains and rivers with the development of the times, and these are mainly reflected in historical and cultural stories, the landscape of the village. (3) Some villages have well-preserved ancient buildings mainly because the buildings still play their role in the development process of the times, for example, the better-preserved buildings in wengji village are mainly located in the center of the village and the temples responsible for rituals, while the peripheral areas are more seriously damaged due to fewer people living there. The protection of the value of the ancient architecture of the village should be coordinated with the local environment and its role.
- The chapter 3 took Mengjinglai village as a case study and applied the GA–BP

neural network model to evaluate the exterior quality of residential houses based on the respective advantages of the BP neural network and the GA, classified the quality levels, and compared and analyzed the results of the BP neural network model and the GA–BP neural network model. The main conclusions are as follows: (1) The GA–BP network model is less error-prone and more efficient than the traditional standard BP neural network. Using the GA–BP network model in the exterior quality evaluation of traditional residential houses can lead to a more rational and scientific approach to village assessment, and provide a reference for other, similar studies. (2) The overall exterior quality of Mengjinglai village is well preserved, highlighting the traditional Dai architectural style, and there was little difference in the scores of the four classifications assessed. However, the village's architecture still needs to be combined with local policies and customs to reflect the traditional culture.

- The chapter 4 took the church in Tuscany, Italy as the research object, and uses HBIM technology to carry on the transformation design analysis. This chapter integrates HBIM into the renovation design process by applying the design concept of reuse of historic buildings based on the use of 3D laser scanner technology. More detailed models and data were obtained and the data recorded information about the whole building, as well as individual components, which plays a crucial role in the conservation of architectural heritage. Through the exploration of the 3D reconstruction method based on image fusion, it is shown that the 3D reconstruction results obtained by photogrammetry through the fusion of ground photography and the study of local historical heritage tracts can preserve the 3D spatial information of buildings and sites, which is fast, accurate, efficient and low-cost, and has technical advantages for the collection and preservation of the original information of historical buildings, and can form a good combination with the conservation of buildings. It is a good combination with the conservation of buildings. Through the analysis of the architectural background of the church in Tuscany, the spatial structure of the Church of Santo Stefano is sorted out according to the field research and the 3D reconstruction model, and the design and analysis of the layout and flow of the renovation, the form and functional distribution of the building renovation are proposed.

- The chapter 5 took an indoor shop space reconstruction case as the research object, and takes TLS technology is combined with the renovation design to form a collaborative design system. Collaborative design is an innovation in the design industry; however, it still faces many challenges. There are several problems to be solved in information, management, and design, and an adaptation process is required for various professions' collaborative design to achieve construction integration more effectively. Together with the intervention of TLS technology, it adds value to the mall in the context of urban renewal through the coordination and efforts of several professions, from the conception of the scheme to the opening of the case. The image and spatial value of the Hanfu store boosted the mall's overall popularity, particularly among the young group. The following two are the main contributions of this work: 1. The application of TLS technology in collaborative interior design integrates the design scheme stage, project construction stage, and post-design and construction management stage; 2. It provides significant support conditions for the parametric design and modular design of similar projects in the future, which improves the efficiency of the design industry and reduces the owner's cost.

6.2 Discussions

This thesis combines the discussion of value assessment and retrofit design, achieving methodological innovation, especially by adding artificial intelligence algorithms to the discussion. TLS techniques are also used in depth throughout the process of renovation design, with good results. This thesis mainly advocates this integrated approach to each other, and although the role of value assessment is presented in its application, it is not presented step by step with a case study from value assessment to retrofit design. The overall description of a case will also be deepened in future research, where a case is assessed for value and then a renovation design plan is planned based on the results of the assessment made.

And there is also a need to experiment with different methods in terms of innovative technologies, such as and VR, AR, MR, remote sensing and metaverse. Through different methods, it is hoped that architects, designers and heritage conservationists will be inspired to bring about more technological revolutions. Thus creating more relevant solutions that integrate with the surrounding environment, symbiosis with the city and harmonisation with the cultural context.

REFERENCES

Abdelmonem, M. G., & Selim, G. (2012). Architecture, memory and historical continuity in Old Cairo. *Journal of Architecture*, *17*(2), 163–189. https://doi.org/10.1080/13602365.2012.678634

Adame, B. O., & Salau, A. O. (2021). Genetic Algorithm Based Optimum Finger Selection for Adaptive Minimum Mean Square Error Rake Receivers Discrete Sequence-CDMA Ultra-Wide Band Systems. *Wireless Personal Communications*, *0123456789*. https://doi.org/10.1007/s11277-021-09199-0

Al Ohali, Y. (2011). Computer vision based date fruit grading system: Design and implementation. *Journal of King Saud University - Computer and Information Sciences*, *23*(1), 29–36. https://doi.org/10.1016/j.jksuci.2010.03.003

Alavipanah, S., Schreyer, J., Haase, D., Lakes, T., & Qureshi, S. (2018). The effect of multi-dimensional indicators on urban thermal conditions. *Journal of Cleaner Production*, *177*, 115–123. https://doi.org/10.1016/j.jclepro.2017.12.187

Alshweiky, R., & Ünal, Z. G. (2016). An approach to risk management and preservation of cultural heritage in multi identity and multi managed sites: Al-Haram Al-Ibrahimi/Abraham's Tombs of the Patriarchs in Al-Khalil/Hebron. *Journal of Cultural Heritage*, *20*, 709–714. https://doi.org/10.1016/j.culher.2016.02.014

Asteris, P. G., Chronopoulos, M. P., Chrysostomou, C. Z., Varum, H., Plevris, V., Kyriakides, N., & Silva, V. (2014). Seismic vulnerability assessment of historical masonry structural systems. *Engineering Structures*, *62–63*, 118–134. https://doi.org/10.1016/j.engstruct.2014.01.031

Astuti, K. A. (2019). Community-based tourism: measuring readiness of artificial intelligence on traditional village. *International Journal of Social Sciences and Humanities*, *3*(3), 81–89. https://doi.org/10.29332/ijssh.v3n3.352

Azzopardi, G., & Petkov, N. (2015). Computer analysis of images and patterns: 16th international conference, CAIP 2015 valletta, malta, september 2-4, 2015 proceedings, part II. *Lecture Notes in Computer Science (Including Subseries*

Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), *9257*, 394–402. https://doi.org/10.1007/978-3-319-23117-4

Blagojević, M. R., & Tufegdžić, A. (2016). The new technology era requirements and sustainable approach to industrial heritage renewal. *Energy and Buildings*, *115*, 148–153. https://doi.org/10.1016/j.enbuild.2015.07.062

Bláha, J., Kloiber, M., & Serafini, A. (2018). A comparison of two distinct roof timber frame systems implemented in the past in house No. 414/I in Prague. *International Journal of Architectural Heritage*, *12*(4), 749–759. https://doi.org/10.1080/15583058.2018.1449916

Bleibleh, S., & Awad, J. (2020). Preserving cultural heritage: Shifting paradigms in the face of war, occupation, and identity. *Journal of Cultural Heritage*, *44*, 196–203. https://doi.org/10.1016/j.culher.2020.02.013

Borin, P., Longhin, A., Giordano, A., & Xotta, G. (2020). From Scripting to Structural Computation of Conical Vaults. *Nexus Network Journal*, *22*(4), 1201–1217. https://doi.org/10.1007/s00004-020-00508-x

Boyle, L., Michell, K., & Viruly, F. (2018). A Critique of the Application of Neighborhood Sustainability Assessment Tools in Urban Regeneration. *Sustainability*, *10*(4), 1005. https://doi.org/10.3390/su10041005

Carraro, F., Monego, M., Callegaro, C., Mazzariol, A., Perticarini, M., Menin, A., Achilli, V., Bonetto, J., & Giordano, A. (2019). THE 3D SURVEY of the ROMAN BRIDGE of SAN LORENZO in Padova (Italy): A COMPARISON between SFM and TLS METHODOLOGIES APPLIED to the ARCH STRUCTURE. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, *42*(2/W15), 255–262. https://doi.org/10.5194/isprs-archives-XLII-2-W15-255-2019

Cassar, J., Galdies, C., & Muscat Azzopardi, E. (2021). A new approach to studying traditional roof behaviour in a changing climate—a case study from the mediterranean island of Malta. *Heritage*, *4*(4), 3543–3571. https://doi.org/10.3390/heritage4040196

Cerreta, M., Daldanise, G., Di Girasole, E. G., & Torre, C. M. (2021). A cultural heritage low entropy enhancement approach: An ex post evaluation of creative practices. *Sustainability (Switzerland)*, *13*(5), 1–22. https://doi.org/10.3390/su13052765

Cha, Y. W., Lu, Y., & Guan, Q. (2021). Study on the Cultural Characteristics of Blang Nationality Residential Space in Lancang County, Yunnan Province(In Chinese). *Architecture & Culture*, *11*, 243–244. https://doi.org/10.19875/j.cnki.jzywh.2021.11.091

Chen, F. (2011). Traditional architectural forms in market oriented Chinese cities: Place for localities or symbol of culture? *Habitat International*, *35*(2), 410–418. https://doi.org/10.1016/j.habitatint.2010.11.012

Chen, L.-K., Yuan, R.-P., Ji, X.-J., Lu, X.-Y., Xiao, J., Tao, J.-B., Kang, X., Li, X., He, Z.-H., Quan, S., & Jiang, L.-Z. (2021). Modular composite building in urgent emergency engineering projects: A case study of accelerated design and construction of Wuhan Thunder God Mountain/Leishenshan hospital to COVID-19 pandemic. *Automation in Construction*, *124*, 103555. https://doi.org/10.1016/j.autcon.2021.103555

Cheng, S., Wu, Y., Li, Y., Yao, F., & Min, F. (2021). TWD-SFNN: Three-way decisions with a single hidden layer feedforward neural network. *Information Sciences*, *579*, 15–32. https://doi.org/10.1016/j.ins.2021.07.091

Chew, L. W., & Norford, L. K. (2018). Pedestrian-level wind speed enhancement in urban street canyons with void decks. *Building and Environment*, *146*(August), 64–76. https://doi.org/10.1016/j.buildenv.2018.09.039

Chiozzi, A., Grillanda, N., Milani, G., & Tralli, A. (2018). UB-ALMANAC: An adaptive limit analysis NURBS-based program for the automatic assessment of partial failure mechanisms in masonry churches. *Engineering Failure Analysis*, *85*(December 2017), 201–220. https://doi.org/10.1016/j.engfailanal.2017.11.013

Chowdhury, P., & Paul, S. K. (2020). Applications of MCDM methods in research on corporate sustainability: A systematic literature review. *Management of Environmental Quality: An International Journal*, *31*(2), 385–405. https://doi.org/10.1108/MEQ-12-2019-0284

Connolly, J. J. T. (2019). From Jacobs to the Just City: A foundation for challenging the green planning orthodoxy. *Cities*, *91*(May 2018), 64–70. https://doi.org/10.1016/j.cities.2018.05.011

Dai, Z., Sun, C., Zhao, L., & Li, Z. (2021). Assessment of Smart Learning Environments in Higher Educational Institutions: A Study Using AHP-FCE and GA-BP Methods. *IEEE Access*, *9*, 35487–35500. https://doi.org/10.1109/ACCESS.2021.3062680

De Medici, S. (2021). Italian architectural heritage and photovoltaic systems. Matching style with sustainability. *Sustainability (Switzerland)*, *13*(4), 1–23. https://doi.org/10.3390/su13042108

De Smet, A., & Van Reusel, H. (2018). How one tree can change the future of a neighbourhood: The process behind the creation of the Boerenhof Park as an example for tactical urban planning. *Urban Forestry and Urban Greening*, *30*(September 2016), 286–294. https://doi.org/10.1016/j.ufug.2017.09.001

Del, M. S. T. T., & Tabrizi, S. K. (2020). "A methodological assessment of the importance of physical values in architectural conservation using Shannon entropy method." *Journal of Cultural Heritage*, *44*, 135–151. https://doi.org/10.1016/j.culher.2019.12.012

Ding, L., Dai, S., & Mu, P. (2016). CAD-Based Path Planning for 3D Laser Scanning of Complex Surface. *Procedia Computer Science*, *92*, 526–535. https://doi.org/10.1016/j.procs.2016.07.378

Dotoli, M., & Pellegrino, R. (2018). *Multi-criteria decision-making for sustainable metropolitan cities assessment*. *226*(August), 46–61. https://doi.org/10.1016/j.jenvman.2018.07.075

Dutta, M., Banerjee, S., & Husain, Z. (2007). Untapped demand for heritage: A contingent valuation study of Prinsep Ghat, Calcutta. *Tourism Management*, *28*(1), 83–95. https://doi.org/10.1016/j.tourman.2005.07.021

Fadli, F., & AlSaeed, M. (2019). Digitizing vanishing architectural heritage; The design and development of Qatar historic buildings information modeling [Q-HBIM] platform. *Sustainability (Switzerland)*, *11*(9).

https://doi.org/10.3390/su11092501

Fok, W. W. T., He, Y. S., Yeung, H. H. A., Law, K. Y., Cheung, K., Ai, Y., & Ho, P. (2018). Prediction model for students' future development by deep learning and tensorflow artificial intelligence engine. *2018 4th International Conference on Information Management, ICIM 2018*, 103–106. https://doi.org/10.1109/INFOMAN.2018.8392818

Fu, J., Zhou, J. L., & Deng, Y. Y. (2021). Heritage values of ancient vernacular residences in traditional villages in Western Hunan, China: Spatial patterns and influencing factors. *Building and Environment*, *188*(August 2020), 107473. https://doi.org/10.1016/j.buildenv.2020.107473

Gao, J., Ryan, C., Cave, J., & Zhang, C. (2019). Tourism border-making: A political economy of China's border tourism. *Annals of Tourism Research*, *76*(July 2018), 1–13. https://doi.org/10.1016/j.annals.2019.02.010

Geng, Z., Zhang, Y., Li, C., Han, Y., Cui, Y., & Yu, B. (2020). Energy optimization and prediction modeling of petrochemical industries: An improved convolutional neural network based on cross-feature. *Energy*, *194*, 116851. https://doi.org/10.1016/j.energy.2019.116851

Giordano, A. (2017). Mapping venice. From visualizing venice to visualizing cities. In *Urban Design and Representation: A Multidisciplinary and Multisensory Approach* (pp. 143–151). https://doi.org/10.1007/978-3-319-51804-6_11

Giordano, A. (2019a). New interoperable tools to communicate knowledge of historic cities and their preservation and innovation. In *Advances in Intelligent Systems and Computing* (Vol. 919, Issue 1). Springer International Publishing. https://doi.org/10.1007/978-3-030-12240-9_5

Giordano, A. (2019b). The map of padua by Giovanni Valle: Hypertext/hyper-representation ante litteram. *Disegno*, *2019*(4), 21–24. https://doi.org/10.26375/disegno.4.2019.04

Giordano, A., Borin, P., & Panarotto, F. (2019). Digital wood trusses. geometry and parameters/fabrication and monitoring. In *Lecture Notes in Civil Engineering* (Vol. 24). Springer International Publishing. https://doi.org/10.1007/978-3-030-

03676-8_18

Giordano, A., Friso, I., Borin, P., Monteleone, C., & Panarotto, F. (2018). Time and space in the history of cities. In *Communications in Computer and Information Science* (Vol. 817). Springer International Publishing. https://doi.org/10.1007/978-3-319-76992-9_4

Giustetto, R., Moschella, E. M., Cristellotti, M., & Costa, E. (2017). Deterioration of building materials and artworks in the 'Santa Maria della Stella' church, Saluzzo (Italy): Causes of decay and possible remedies. *Studies in Conservation*, *62*(8), 474–493. https://doi.org/10.1080/00393630.2016.1217694

Goi, E., Zhang, Q., Chen, X., Luan, H., & Gu, M. (2020). Perspective on photonic memristive neuromorphic computing. In *PhotoniX* (Vol. 1, Issue 1). https://doi.org/10.1186/s43074-020-0001-6

Gruen, A. (2021). Everything moves: The rapid changes in photogrammetry and remote sensing. *Geo-Spatial Information Science*, *24*(1), 33–49. https://doi.org/10.1080/10095020.2020.1868275

Gu, Y., Zhou, D., Zhang, D., Wu, K., & Zhou, B. (2020). Study on subsidence monitoring technology using terrestrial 3D laser scanning without a target in a mining area: an example of Wangjiata coal mine, China. *Bulletin of Engineering Geology and the Environment*, *79*(7), 3575–3583. https://doi.org/10.1007/s10064-020-01767-1

Guo, P., Li, Q., Guo, H., & Li, H. (2021). Quantifying the core driving force for the sustainable redevelopment of industrial heritage: implications for urban renewal. *Environmental Science and Pollution Research*, *28*(35), 48097–48111. https://doi.org/10.1007/s11356-021-14054-7

Hammouche, K., Diaf, M., & Siarry, P. (2008). A multilevel automatic thresholding method based on a genetic algorithm for a fast image segmentation. *Computer Vision and Image Understanding*, *109*(2), 163–175. https://doi.org/10.1016/j.cviu.2007.09.001

Han, B., & Leite, F. (2022). Generic extended reality and integrated development for visualization applications in architecture, engineering, and construction.

Automation in Construction, *140*(April), 104329. https://doi.org/10.1016/j.autcon.2022.104329

Harahap, R. H., & Siahaan, N. M. (2020). Handicraft Gallery Of North Sumatera (Metaphor Architecture). *International Journal of Architecture and Urbanism*, *04*(03), 300–310. https://doi.org/10.32734/ijau.v4i3.5042

Hasanova, N. (2020). A Comparative Study of Particle Swarm Optimization and Genetic Algorithm. *Qubahan Academic Journal*, *1*(1), 33–45. https://doi.org/10.48161/qaj.v1n1a7

Hashem, O. M., Wahba, S. M. E., & Nasr-Eldin, T. I. (2022). Urban voids: identifying and optimizing urban voids potential as a revitalization source in enhancing developing countries' city income. *Journal of Engineering and Applied Science*, *69*(1), 1–30. https://doi.org/10.1186/s44147-021-00053-5

Havinga, L., Colenbrander, B., & Schellen, H. (2019). Heritage attributes of post-war housing in Amsterdam. *Frontiers of Architectural Research*, *9*(1), 1–19. https://doi.org/10.1016/j.foar.2019.04.002

Hearn, K. P. (2021). Mapping the past: Using ethnography and local spatial knowledge to characterize the Duero River borderlands landscape. *Journal of Rural Studies*, *82*(July 2020), 37–53. https://doi.org/10.1016/j.jrurstud.2021.01.024

HECHT-NIELSEN, R. (1992). Theory of the backpropagation neural network. Neural Networks for Perception. In *Academic Press* (Issue June 1989). Academic Press, Inc. https://doi.org/10.1016/b978-0-12-741252-8.50010-8

Hegazy, S. M. (2015). Conservation of historical buildings – The Omani–French museum as a case study. *HBRC Journal*, *11*(2), 264–274. https://doi.org/10.1016/j.hbrcj.2014.03.010

Hou, X. W., Cheng, B., & Yang, J. (2021). A quantitative study on the exterior wall texture of stone-built dwellings in traditional villages in China: A case study of the xisuo village in the Jiarong Tibetan area. *Journal of Building Engineering*, *42*(May 2020), 102357. https://doi.org/10.1016/j.jobe.2021.102357

Hu, S. (2014). Hanfu elements in modern fashion design and innovation. In *Asian*

Social Science (Vol. 10, Issue 13, pp. 89–94). https://doi.org/10.5539/ass.v10n13p89

Hu, Z.-Z., Tian, P.-L., Li, S.-W., & Zhang, J.-P. (2018). BIM-based integrated delivery technologies for intelligent MEP management in the operation and maintenance phase. *Advances in Engineering Software*, *115*, 1–16. https://doi.org/10.1016/j.advengsoft.2017.08.007

Ibrahim, R., & Pour Rahimian, F. (2010). Comparison of CAD and manual sketching tools for teaching architectural design. *Automation in Construction*, *19*(8), 978–987. https://doi.org/10.1016/j.autcon.2010.09.003

İpekoğlu, B. (2006). An architectural evaluation method for conservation of traditional dwellings. *Building and Environment*, *41*(3), 386–394. https://doi.org/10.1016/j.buildenv.2005.02.009

Ji, H., & Luo, X. (2019). 3D scene reconstruction of landslide topography based on data fusion between laser point cloud and UAV image. *Environmental Earth Sciences*, *78*(17), 1–12. https://doi.org/10.1007/s12665-019-8516-5

Jones, C. A., & Church, E. (2020). Photogrammetry is for everyone: Structure-from-motion software user experiences in archaeology. *Journal of Archaeological Science: Reports*, *30*, 102261. https://doi.org/10.1016/j.jasrep.2020.102261

Jonu, L., & Auglys, E. (2019). *ICGG 2018 - Proceedings of the 18th International Conference on Geometry and Graphics* (Vol. 809). Springer International Publishing. https://doi.org/10.1007/978-3-319-95588-9

Julin, A., Kurkela, M., Rantanen, T., Virtanen, J. P., Maksimainen, M., Kukko, A., Kaartinen, H., Vaaja, M. T., Hyyppä, J., & Hyyppä, H. (2020). Evaluating the quality of TLS point cloud colorization. In *Remote Sensing* (Vol. 12, Issue 17). https://doi.org/10.3390/RS12172748

Karahan, F., & Davardoust, S. (2020). Evaluation of vernacular architecture of Uzundere District (architectural typology and physical form of building) in relation to ecological sustainable development. *Journal of Asian Architecture and Building Engineering*, *19*(5), 490–501. https://doi.org/10.1080/13467581.2020.1758108

Kastenholz, E., Carneiro, M. J., Peixeira Marques, C., & Lima, J. (2012). Understanding and managing the rural tourism experience - The case of a historical village in Portugal. *Tourism Management Perspectives*, *4*, 207–214. https://doi.org/10.1016/j.tmp.2012.08.009

Khalaf, R. W. (2016). Distinguishing new architecture from old. *Historic Environment: Policy and Practice*, *7*(4), 321–339. https://doi.org/10.1080/17567505.2016.1252492

Kim, G., Newman, G., & Jiang, B. (2020). Urban regeneration: Community engagement process for vacant land in declining cities. *Cities*, *102*(January), 102730. https://doi.org/10.1016/j.cities.2020.102730

Kokorsch, M., & Benediktsson, K. (2018). Prosper or perish? The development of Icelandic fishing villages after the privatisation of fishing rights. *Maritime Studies*, *17*(1), 69–83. https://doi.org/10.1007/s40152-018-0089-5

La Gennusa, M., Rizzo, G., Scaccianoce, G., & Nicoletti, F. (2005). Control of indoor environments in heritage buildings: Experimental measurements in an old Italian museum and proposal of a methodology. *Journal of Cultural Heritage*, *6*(2), 147–155. https://doi.org/10.1016/j.culher.2005.03.001

Lee, J., McCuskey Shepley, M., & Choi, J. (2019). Exploring the effects of a building retrofit to improve energy performance and sustainability: A case study of Korean public buildings. *Journal of Building Engineering*, *25*, 100822. https://doi.org/10.1016/j.jobe.2019.100822

Lekan, A., Clinton, A., & James, O. (2021). The disruptive adaptations of construction 4.0 and industry 4.0 as a pathway to a sustainable innovation and inclusive industrial technological development. *Buildings*, *11*(3), 1–28. https://doi.org/10.3390/buildings11030079

Lerario, A. (2020). Article the iot as a key in the sensitive balance between development needs and sustainable conservation of cultural resources in italian heritage cities. *Sustainability (Switzerland)*, *12*(17). https://doi.org/10.3390/su12176952

Li, W., Yang, N., Mei, Y., Zhang, Y., Wang, L., & Ma, H. (2020). Experimental investigation of the compression-bending property of the casing joints in a concrete filled steel tubular supporting arch for tunnel engineering. *Tunnelling and Underground Space Technology*, *96*(August 2018), 103184. https://doi.org/10.1016/j.tust.2019.103184

Li, Y., Gao, W., & Lin, B. (2022). From type to network : a review of knowledge representation methods in architecture intelligence design. *Architectural Intelligence*, 1–13. https://doi.org/10.1007/s44223-022-00006-9

Li, Z., Wang, Y., Olgun, C. G., Yang, S., Jiao, Q., & Wang, M. (2020). Risk assessment of water inrush caused by karst cave in tunnels based on reliability and GA-BP neural network. *Geomatics, Natural Hazards and Risk*, *11*(1), 1212–1232. https://doi.org/10.1080/19475705.2020.1785956

Lin, Q. Q., & Wen, J. J. (2018). Tea Tourism and its Impacts on Ethnic Marriage and Labor Division. *Journal of China Tourism Research*, *14*(4), 461–483. https://doi.org/10.1080/19388160.2018.1511490

Liu, Zhao, Wang, S., & Wang, F. (2019). Isolated or integrated? Planning and management of urban renewal for historic areas in Old Beijing city, based on the association network system. *Habitat International*, *93*, 102049. https://doi.org/10.1016/j.habitatint.2019.102049

Liu, Zhaowen, de Jong, M., Li, F., Brand, N., Hertogh, M., & Dong, L. (2020). Towards Developing a New Model for Inclusive Cities in China—The Case of Xiong'an New Area. *Sustainability*, *12*(15), 6195. https://doi.org/10.3390/su12156195

López Cruz, O., García Bueno, A., Medina Flórez, V. J., & Sánchez-Navas, A. (2016). A methodology for timing interventions made on the polychrome decorations of the façade of the Palace of King Peter I, the Royal Alcázar of Seville, Spain. *Journal of Cultural Heritage*, *20*, 573–582. https://doi.org/10.1016/j.culher.2016.01.007

LUO, C., ZHENG, H., & LI, J. (2021). Cross-cultural Perspective of Ethnic Cultural Changes in Panxi Region of China. *Revista de Cercetare Si Interventie Sociala*, *72*, 353–377. https://doi.org/10.33788/rcis.72.22

Masuda, A. D., Sortheix, F. M., Beham, B., & Naidoo, L. J. (2019). Cultural value orientations and work–family conflict: The mediating role of work and family demands. *Journal of Vocational Behavior*, *112*(March), 294–310. https://doi.org/10.1016/j.jvb.2019.04.001

Mehanna, W. A. E.-H., & Mehanna, W. A. E.-H. (2019). Urban renewal for traditional commercial streets at the historical centers of cities. *Alexandria Engineering Journal*, *58*(4), 1127–1143. https://doi.org/10.1016/j.aej.2019.09.015

Mehrbod, S., Staub-French, S., Mahyar, N., & Tory, M. (2019). Characterizing interactions with BIM tools and artifacts in building design coordination meetings. *Automation in Construction*, *98*(October 2018), 195–213. https://doi.org/10.1016/j.autcon.2018.10.025

Miao, P. (2011). Brave New City: Three Problems in Chinese Urban Public Space since the 1980s. *Journal of Urban Design*, *16*(2), 179–207. https://doi.org/10.1080/13574809.2011.548980

Miatto, A., Schandl, H., Forlin, L., Ronzani, F., Borin, P., Giordano, A., & Tanikawa, H. (2019). A spatial analysis of material stock accumulation and demolition waste potential of buildings: A case study of Padua. *Resources, Conservation and Recycling*, *142*(November 2018), 245–256. https://doi.org/10.1016/j.resconrec.2018.12.011

Mill, T., Alt, A., & Liias, R. (2013). COMBINED 3D BUILDING SURVEYING TECHNIQUES – TERRESTRIAL LASER SCANNING (TLS) AND TOTAL STATION SURVEYING FOR BIM DATA MANAGEMENT PURPOSES. *Journal of Civil Engineering and Management*, *19*(Supplement_1), S23–S32. https://doi.org/10.3846/13923730.2013.795187

Moyano, J., Nieto-Julián, J. E., Lenin, L. M., & Bruno, S. (2021). Operability of Point Cloud Data in an Architectural Heritage Information Model. *International Journal of Architectural Heritage*, *00*(00), 1–20. https://doi.org/10.1080/15583058.2021.1900951

Murphy, M., Mcgovern, E., & Pavia, S. (2009). Historic building information modelling (HBIM). *Structural Survey*, *27*(4), 311–327. https://doi.org/10.1108/02630800910985108

Murzyn-Kupisz, M. (2013). The socio-economic impact of built heritage projects conducted by private investors. *Journal of Cultural Heritage*, *14*(2), 156–162. https://doi.org/10.1016/j.culher.2012.04.009

Nachmany, H., & Hananel, R. (2022). The Fourth Generation: Urban renewal policies in the service of private developers. *Habitat International*, *125*(May), 102580. https://doi.org/10.1016/j.habitatint.2022.102580

Nahon, A., Molina, P., Blázquez, M., Simeon, J., Capo, S., & Ferrero, C. (2019). Corridor mapping of sandy coastal foredunes with UAS photogrammetry and mobile laser scanning. In *Remote Sensing* (Vol. 11, Issue 11). https://doi.org/10.3390/rs11111352

Nawre, A., Wong, T. W., & Boyle-Milroy, L. (2021). Landscape architecture in rural India - lessons for developing countries from Dhamori village. *Landscape Research*, *46*(8), 1089–1105. https://doi.org/10.1080/01426397.2021.1946774

Nee, A. Y. C., Ong, S. K., Chryssolouris, G., & Mourtzis, D. (2012). Augmented reality applications in design and manufacturing. *CIRP Annals*, *61*(2), 657–679. https://doi.org/10.1016/j.cirp.2012.05.010

Nieto-Julián, J. E., Farratell, J., Bouzas Cavada, M., & Moyano, J. (2022). Collaborative Workflow in an HBIM Project for the Restoration and Conservation of Cultural Heritage. *International Journal of Architectural Heritage*, *00*(00), 1–20. https://doi.org/10.1080/15583058.2022.2073294

Novak, V. M. (2014). Design management of sustainability values: a learning organization perspective. *Architectural Engineering and Design Management*, *10*(3–4), 218–232. https://doi.org/10.1080/17452007.2014.896782

O'Neil-Dunne, J., MacFaden, S., & Royar, A. (2014). A versatile, production-oriented approach to high-resolution tree-canopy mapping in urban and suburban landscapes using GEOBIA and data fusion. *Remote Sensing*, *6*(12), 12837–12865. https://doi.org/10.3390/rs61212837

Oakes, T. (2016). Villagizing the city: turning rural ethnic heritage into urban modernity in southwest China. *International Journal of Heritage Studies*, *22*(10), 751–765. https://doi.org/10.1080/13527258.2016.1212387

Paes, D., Irizarry, J., & Pujoni, D. (2021). An evidence of cognitive benefits from immersive design review: Comparing three-dimensional perception and presence between immersive and non-immersive virtual environments. *Automation in Construction*, *130*, 103849. https://doi.org/10.1016/j.autcon.2021.103849

Pamucar, D., Chatterjee, K., & Kazimieras, E. (2019). Computers & Industrial Engineering Assessment of third-party logistics provider using multi-criteria decision- making approach based on interval rough numbers. *Computers & Industrial Engineering*, *127*(October 2018), 383–407. https://doi.org/10.1016/j.cie.2018.10.023

Pan, L., Zhao, L., Song, A., She, S., & Wang, S. (2021). Research on gear fault diagnosis based on feature fusion optimization and improved two hidden layer extreme learning machine. *Measurement: Journal of the International Measurement Confederation*, *177*(October 2020), 109317. https://doi.org/10.1016/j.measurement.2021.109317

Pan, Y., Ou, S., Zhang, L., Zhang, W., Wu, X., & Li, H. (2019). Modeling risks in dependent systems: A Copula-Bayesian approach. *Reliability Engineering and System Safety*, *188*(March), 416–431. https://doi.org/10.1016/j.ress.2019.03.048

Panteli, C., Kylili, A., & Fokaides, P. A. (2020). Building information modelling applications in smart buildings: From design to commissioning and beyond A critical review. *Journal of Cleaner Production*, *265*, 121766. https://doi.org/10.1016/j.jclepro.2020.121766

Pappas, A., Da Porto, F., & Modena, C. (2016). Seismic Vulnerability Assessment Form for Free-Standing Columns Based on a Simplified Numerical Analysis. *International Journal of Architectural Heritage*, *10*(2–3), 281–299. https://doi.org/10.1080/15583058.2015.1113336

Park, E., Choi, B. K., & Lee, T. J. (2019). The role and dimensions of authenticity in heritage tourism. *Tourism Management*, *74*(August 2017), 99–109. https://doi.org/10.1016/j.tourman.2019.03.001

Park, J. (2022). The real-world challenge and possibility of using Minhwa and applying Lin's cultural levels in fashion design. *The Research Journal of the Costume Culture*, *30*(1), 16–32. https://doi.org/10.29049/rjcc.2022.30.1.16

Pasetto, M., Giordano, A., Borin, P., & Giacomello, G. (2020). Integrated railway design using Infrastructure-Building Information Modeling. the case study of the port of Venice. *Transportation Research Procedia*, *45*(2019), 850–857. https://doi.org/10.1016/j.trpro.2020.02.084

Perera, E. N. C., Jayawardana, D. T., Jayasinghe, P., & Ranagalage, M. (2019). Landslide vulnerability assessment based on entropy method: a case study from Kegalle district, Sri Lanka. *Modeling Earth Systems and Environment*, *5*(4), 1635–1649. https://doi.org/10.1007/s40808-019-00615-w

Philokyprou, M., & Michael, A. (2021). Environmental Sustainability in the Conservation of Vernacular Architecture. The Case of Rural and Urban Traditional Settlements in Cyprus. *International Journal of Architectural Heritage*, *15*(11), 1741–1763. https://doi.org/10.1080/15583058.2020.1719235

Pizzigatti, C., & Franzoni, E. (2021). The problem of conservation of XX century architectural heritage: The fibreglass dome of the woodpecker dance club in Milano Marittima (Italy). *Journal of Building Engineering*, *42*(March). https://doi.org/10.1016/j.jobe.2021.102476

Polo López, C. S., Lucchi, E., Leonardi, E., Durante, A., Schmidt, A., & Curtis, R. (2021). Risk-benefit assessment scheme for renewable solar solutions in traditional and historic buildings. *Sustainability (Switzerland)*, *13*(9), 1–35. https://doi.org/10.3390/su13095246

Rakow, K. (2020). The Light of the World: Mediating Divine Presence through Light and Sound in a Contemporary Megachurch. *Material Religion*, *16*(1), 84–107. https://doi.org/10.1080/17432200.2019.1696561

Rausch, C., Nahangi, M., Perreault, M., Haas, C. T., & West, J. (2017). Optimum Assembly Planning for Modular Construction Components. *Journal of Computing in Civil Engineering*, *31*(1), 04016039. https://doi.org/10.1061/(ASCE)CP.1943-5487.0000605

Ren, Z., Yang, F., Bouchlaghem, N. M., & Anumba, C. J. (2011). Multi-disciplinary collaborative building design—A comparative study between multi-agent systems and multi-disciplinary optimisation approaches. *Automation in Construction*, *20*(5), 537–549. https://doi.org/10.1016/j.autcon.2010.11.020

Sadeqi, S., Ekhlassi, A., & Norouzian-Maleki, S. (2019). An analysis of structural aesthetics in architecture case study: Taj-Ol-Molk Dome, Jāmeh Mosque of Isfahan, Iran. *SN Applied Sciences*, *1*(6), 1–10. https://doi.org/10.1007/s42452-019-0558-5

Said, S. Y., Aksah, H., & Ismail, E. D. (2013). Heritage Conservation and Regeneration of Historic Areas in Malaysia. *Procedia - Social and Behavioral Sciences*, *105*, 418–428. https://doi.org/10.1016/j.sbspro.2013.11.044

Santos, R., Costa, A. A., & Grilo, A. (2017). Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015. *Automation in Construction*, *80*, 118–136. https://doi.org/10.1016/j.autcon.2017.03.005

Shang, Y., Zheng, X., Han, R., Liu, W., & Xiao, F. (2021). Long-term evaluation on urban intensive land use in five fast-growing cities of northern China with GEE support. *Scientific Reports*, *11*(1), 1–14. https://doi.org/10.1038/s41598-021-00285-8

Short, M., & Fundingsland Tetlow, M. (2012). Sunderland. *Cities*, *29*(4), 278–288. https://doi.org/10.1016/j.cities.2010.12.003

Singh, V., Gu, N., & Wang, X. (2011). A theoretical framework of a BIM-based multi-disciplinary collaboration platform. *Automation in Construction*, *20*(2), 134–144. https://doi.org/10.1016/j.autcon.2010.09.011

Sotomayor, G., Hampel, H., & Vázquez, R. F. (2018). Water quality assessment with emphasis in parameter optimisation using pattern recognition methods and genetic algorithm. *Water Research*, *130*, 353–362. https://doi.org/10.1016/j.watres.2017.12.010

Street, K. (2019). *Building Information Modeling and Heritage Documentation BUILDING INFORMATION MODELLING AND HERITAGE*

DOCUMENTATION Carleton Immersive Media Studio , Azrieli School of Architecture and Urbanism ,. June.

Su, K., Hu, B., Shi, K., Zhang, Z., & Yang, Q. (2019). The structural and functional evolution of rural homesteads in mountainous areas: A case study of Sujiaying village in Yunnan province, China. *Land Use Policy*, *88*(September), 104100. https://doi.org/10.1016/j.landusepol.2019.104100

Suh, J., & Cho, J. Y. (2021). A Triangular Relationship of Visual Attention, Spatial Ability, and Creative Performance in Spatial Design: An Exploratory Case Study. *Journal of Interior Design*, *46*(3), 11–27. https://doi.org/10.1111/joid.12194

Sun, C., Zhou, Y., & Han, Y. (2022). Automatic generation of architecture facade for historical urban renovation using generative adversarial network. *Building and Environment*, *212*(September 2021), 108781. https://doi.org/10.1016/j.buildenv.2022.108781

Suryono, A. (2021). Preservation of the manifestation of Balinese cultural traditions in the current architecture of public buildings: a case study of the Mandala Agung building of the Puri Ahimsa resort in Mambal Village–Bali. *Journal of Architectural Conservation*, *27*(1–2), 53–65. https://doi.org/10.1080/13556207.2021.1910402

Systems, G. I., Cloud, P., & Documentation, H. (2022). *Comparison of the Wearable Mobile Laser Scanner (WMLS) with Other Point Cloud Data Collection Methods in Cultural Heritage : a Case Study of Diokaisareia*.

Tang, C. S., & Veelenturf, L. P. (2019). The strategic role of logistics in the industry 4.0 era. *Transportation Research Part E: Logistics and Transportation Review*, *129*(June), 1–11. https://doi.org/10.1016/j.tre.2019.06.004

Tang, P., Huber, D., Akinci, B., Lipman, R., & Lytle, A. (2010). Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. *Automation in Construction*, *19*(7), 829–843. https://doi.org/10.1016/j.autcon.2010.06.007

Tobi, H., & Kampen, J. K. (2018). Research design: the methodology for interdisciplinary research framework. *Quality and Quantity*, *52*(3), 1209–1225. https://doi.org/10.1007/s11135-017-0513-8

Turnpenny, M. (2004). Cultural heritage, an Ill-defined concept? A call for joined-up policy. *International Journal of Heritage Studies*, *10*(3), 295–307. https://doi.org/10.1080/1352725042000234460

Uzun, Z., Köse, C., & Köse, N. (2018). A multidisciplinary study to reveal the historical value of wooden structures and to develop a conservation approach: Dere and Karlı Mosques in Samsun, Turkey. *Journal of Cultural Heritage*, *32*, 60–72. https://doi.org/10.1016/j.culher.2018.01.010

Veller, C., Edelman, N. B., Muralidhar, P., & Nowak, M. A. (2020). Variation in genetic relatedness is determined by the aggregate recombination process. *Genetics*, *216*(4), 985–994. https://doi.org/10.1534/genetics.120.303680

Verdini, G., Frassoldati, F., & Nolf, C. (2017). Reframing China's heritage conservation discourse. Learning by testing civic engagement tools in a historic rural village. *International Journal of Heritage Studies*, *23*(4), 317–334. https://doi.org/10.1080/13527258.2016.1269358

Versaci, A. (2016). The Evolution of Urban Heritage Concept in France, between Conservation and Rehabilitation Programs. *Procedia - Social and Behavioral Sciences*, *225*(November 2015), 3–14. https://doi.org/10.1016/j.sbspro.2016.06.003

Vodopivec, B., Žarnić, R., Tamošaitiene, J., Lazauskas, M., & Šelih, J. (2014). Renovation priority ranking by multi-criteria assessment of architectural heritage: the case of castles. *International Journal of Strategic Property Management*, *18*(1), 88–100. https://doi.org/10.3846/1648715X.2014.889771

Wang, B., Yin, C., Luo, H., Cheng, J. C. P., & Wang, Q. (2021). Fully automated generation of parametric BIM for MEP scenes based on terrestrial laser scanning data. *Automation in Construction*, *125*(May 2020), 103615. https://doi.org/10.1016/j.autcon.2021.103615

Wang, J., Yuan, Z., He, Z., Zhou, F., & Wu, Z. (2021). Critical factors affecting team work efficiency in BIM-based collaborative design: An empirical study in China.

In *Buildings* (Vol. 11, Issue 10). https://doi.org/10.3390/buildings11100486

Wang, L., & Bi, X. (2021). Risk assessment of knowledge fusion in an innovation ecosystem based on a GA-BP neural network. *Cognitive Systems Research*, *66*, 201–210. https://doi.org/10.1016/j.cogsys.2020.12.006

Wang, R. P., & Cai, Z. Y. (2006). An ecological assessment of the vernacular architecture and of its embodied energy in Yunnan, China. *Building and Environment*, *41*(5), 687–697. https://doi.org/10.1016/j.buildenv.2005.02.023

Wang, S., Zhang, N., Wu, L., & Wang, Y. (2016). Wind speed forecasting based on the hybrid ensemble empirical mode decomposition and GA-BP neural network method. *Renewable Energy*, *94*, 629–636. https://doi.org/10.1016/j.renene.2016.03.103

Wen, Z. (2019). Application Research of BIM Technology in Engineering Cost Management. *IOP Conference Series: Earth and Environmental Science*, *295*(4), 042037. https://doi.org/10.1088/1755-1315/295/4/042037

Whitley, D. (1994). A genetic algorithm tutorial. *Statistics and Computing*, *4*(2), 65–85. https://doi.org/10.1007/BF00175354

Woodward, A., & Heesom, D. (2021). Implementing HBIM on conservation heritage projects: Lessons from renovation case studies. *International Journal of Building Pathology and Adaptation*, *39*(1), 96–114. https://doi.org/10.1108/IJBPA-06-2019-0054

Wu, E., Chen, C. W., Intra, R., Anusawari, K., & Bang Khen, K. (2021). The Dwellings Spatial Form Of Traditional Village Based On The Tunup-Culture In The Minority Area-The Case Study Of Longli Village. In *Turkish Journal of Computer and Mathematics Education* (Vol. 12, Issue 11).

Wu, Y., Gao, R., & Yang, J. (2020). Prediction of coal and gas outburst: A method based on the BP neural network optimized by GASA. *Process Safety and Environmental Protection*, *133*, 64–72. https://doi.org/10.1016/j.psep.2019.10.002

Xiao, Y., & Bhola, J. (2022). Design and optimization of prefabricated building system based on BIM technology. *International Journal of System Assurance*

Engineering and Management, *13*(S1), 111–120. https://doi.org/10.1007/s13198-021-01288-4

Xu, C., Zhao, Y., & Wu, C. (2022). 'Sustainable' Recording and Preservation of Zangniang Stupa and Sangzhou Lamasery in Qinghai, China with Heritage Building Information Model. *Sustainability*, *14*(8), 4549. https://doi.org/10.3390/su14084549

Xu, J., & Dang, C. (2019). A novel fractional moments-based maximum entropy method for high-dimensional reliability analysis. *Applied Mathematical Modelling*, *75*, 749–768. https://doi.org/10.1016/j.apm.2019.06.037

Xu, Z., Shen, X., Cao, L., Coops, N. C., Goodbody, T. R. H., Zhong, T., Zhao, W., Sun, Q., Ba, S., Zhang, Z., & Wu, X. (2020). Tree species classification using UAS-based digital aerial photogrammetry point clouds and multispectral imageries in subtropical natural forests. *International Journal of Applied Earth Observation and Geoinformation*, *92*, 102173. https://doi.org/10.1016/j.jag.2020.102173

Yan, C., Li, M., Liu, W., & Qi, M. (2020). Improved adaptive genetic algorithm for the vehicle Insurance Fraud Identification Model based on a BP Neural Network. *Theoretical Computer Science*, *817*, 12–23. https://doi.org/10.1016/j.tcs.2019.06.025

Yang, L., & Wall, G. (2008). The evolution and status of tourism planning: Xishuangbanna, Yunnan, China. *Tourism and Hospitality, Planning and Development*, *5*(2), 165–182. https://doi.org/10.1080/14790530802252818

Yang, L., & Wall, G. (2009). Minorities and tourism: Community perspectives from Yunnan, China. *Journal of Tourism and Cultural Change*, *7*(2), 77–98. https://doi.org/10.1080/14766820902849971

Yang, X., Grussenmeyer, P., Koehl, M., Macher, H., Murtiyoso, A., & Landes, T. (2020). Review of built heritage modelling: Integration of HBIM and other information techniques. *Journal of Cultural Heritage*, *46*, 350–360. https://doi.org/10.1016/j.culher.2020.05.008

Yousif, N., Cole, J., Rothwell, J. C., Diedrichsen, J., Zelik, K. E., Winstein, C. J., Kay, D. B., Wijesinghe, R., Protti, D. A., Camp, A. J., Quinlan, E., Jacobs, J. V, Henry, S. M., Horak, F. B., Jacobs, J. V, Fraser, L. E., Mansfield, A., Harris, L. R., Merino, D. M., … Dublin, C. (2018). No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title. *Journal of Physical Therapy Science*, *9*(1), 1–11. http://dx.doi.org/10.1016/j.neuropsychologia.2015.07.010%0Ahttp://dx.doi.org/10.1016/j.visres.2014.07.001%0Ahttps://doi.org/10.1016/j.humov.2018.08.006%0Ahttp://www.ncbi.nlm.nih.gov/pubmed/24582474%0Ahttps://doi.org/10.1016/j.gaitpost.2018.12.007%0Ahttps:

Yuan, M., & Li, C. (2021). Research on Global Higher Education Quality Based on BP Neural Network and Analytic Hierarchy Process. *Journal of Computer and Communications*, *09*(06), 158–173. https://doi.org/10.4236/jcc.2021.96009

Yung, E. H. K., Langston, C., & Chan, E. H. W. (2014). Adaptive reuse of traditional Chinese shophouses in government-led urban renewal projects in Hong Kong. *Cities*, *39*, 87–98. https://doi.org/10.1016/j.cities.2014.02.012

Zhang, A., Bokel, R., van den Dobbelsteen, A., Sun, Y., Huang, Q., & Zhang, Q. (2017). Optimization of thermal and daylight performance of school buildings based on a multi-objective genetic algorithm in the cold climate of China. *Energy and Buildings*, *139*, 371–384. https://doi.org/10.1016/j.enbuild.2017.01.048

Zhang, B. jun, & Chen, Y. hua. (2021). Traditional Village Planning under the Theory of Actor Network: A Case Study of Village Planning in the Jingmai Mountain, Pu’ er, Yunnan Province. *Journal of Landscape Research*, *2021*(2), 29–35. https://doi.org/10.16785/j.issn

Zhang, Y. (2008). What is Going on in China? A Cultural Analysis on the Reappearance of Ancient Jili and Hanfu in Present-Day China. In *Intercultural Communication Studies XVII* (Vol. 1, pp. 2004–2009). https://web.uri.edu/iaics/files/22-Yan-Zhang2.pdf

Zhao, Q. (2020). BIM Design for Reconstruction of Old Factory Building based on Sustainable Perspective. *Proceedings - Companion of the 2020 IEEE 20th*

International Conference on Software Quality, Reliability, and Security, QRS-C 2020, 522–526. https://doi.org/10.1109/QRS-C51114.2020.00092

Zhao, Y. Q., Ponzini, D., & Zhang, R. (2020). The policy networks of heritage-led development in Chinese historic cities: The case of Xi'an's Big Wild Goose Pagoda area. *Habitat International*, *96*(December 2019), 102106. https://doi.org/10.1016/j.habitatint.2019.102106

Zhou, Q. (Bill), Zhang, J., & Edelheim, J. R. (2013). Rethinking traditional Chinese culture: A consumer-based model regarding the authenticity of Chinese calligraphic landscape. *Tourism Management*, *36*, 99–112. https://doi.org/10.1016/j.tourman.2012.11.008

Zhou, Y. W., Hu, Z. Z., Lin, J. R., & Zhang, J. P. (2020). A Review on 3D Spatial Data Analytics for Building Information Models. *Archives of Computational Methods in Engineering*, *27*(5), 1449–1463. https://doi.org/10.1007/s11831-019-09356-6

Zhu, C., Zhang, J., Liu, Y., Ma, D., Li, M., & Xiang, B. (2020). Comparison of GA-BP and PSO-BP neural network models with initial BP model for rainfall-induced landslides risk assessment in regional scale: a case study in Sichuan, China. In *Natural Hazards* (Vol. 100, Issue 1). Springer Netherlands. https://doi.org/10.1007/s11069-019-03806-x

Zhu, J., Zhang, H., & Wen, Y. (2014). A New Reconstruction Method for 3D Buildings from 2D Vector Floor Plan. *Computer-Aided Design and Applications*, *11*(6), 704–714. https://doi.org/10.1080/16864360.2014.914388

Zhuang, C., Liu, J., & Xiong, H. (2018). Digital twin-based smart production management and control framework for the complex product assembly shop-floor. *The International Journal of Advanced Manufacturing Technology*, *96*(1–4), 1149–1163. https://doi.org/10.1007/s00170-018-1617-6

Žlender, V. (2021). Characterisation of peri-urban landscape based on the views and attitudes of different actors. *Land Use Policy*, *101*(October 2020), 105181. https://doi.org/10.1016/j.landusepol.2020.105181

Zou, Z. H., Yun, Y., & Sun, J. N. (2006). Entropy method for determination of weight of evaluating indicators in fuzzy synthetic evaluation for water quality assessment. *Journal of Environmental Sciences (China)*, *18*(5), 1020–1023. https://doi.org/10.1016/S1001-0742(06)60032-6