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Construction of a Sustainability-Based Building Attribute Conservation Assessment Model in Historic Areas

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Abstract: As important locations that carry the spirit and culture of the city, the conservation and regeneration of historic areas should be a sustainable process. However, in the current Chinese urban historical and cultural heritage conservation system, there is a certain degree of discontinuity in the management of the two-level division between historic districts and heritage protection units, resulting in a lack of control over the renewal of other buildings in the district. The fragmented conservation of historic districts eventually leads to the loss of the historical culture and urban spirit they are supposed to carry, which is not in line with the requirements of sustainable conservation. This study aims to combine sustainability theories with the essential properties of buildings to construct an assessment model to address this issue. Through integrating the discussion on the nature of building and the sustainability assessment dimensions, three aspects of common concern can be identified as economic, cultural, and social. As the ontology for transmitting and preserving culture for future generations, building should take on the three major responsibilities of presenting and inheriting regional culture, improving regional conservation and developing economic functions. Therefore, the three dimensions of sustainability-based building attributes are "Economy of construction, Cultural of form, and Social of benefit". A sustainable assessment model is constructed based on the three dimensions, which can help to dynamically monitor changes in building attributes during implementation. Finally, a case study was analyzed using the proposed model, and the feasibility and applicability of the assessment model were proved. The model provides effective guidance for comparative evaluation before and after the implementation of protecting plans, and corrects deviations to sustainable conservation goals in a timely manner.

Keywords: conservation assessment model; sustainability-based; building attribute; historic areas

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1. Introduction

Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural and natural heritage are both irreplaceable sources of life and inspiration [1]. Adopted in 1972, the Convention Concerning the Protection of the World Cultural and World Natural Heritage proposed that it is incumbent on the international community as a whole to participate in the protection of the cultural and natural heritage of outstanding universal value [2] (p. 1). The significance of World Heritage is defined to be "so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity" [3] (p. 19). The cultural and natural heritage is among the priceless and irreplaceable assets, not only of each nation, but of humanity as a whole. The loss, through deterioration or disappearance, of any of these most prized assets constitutes an impoverishment of the heritage of all the peoples of the world. Parts of this heritage, due to their exceptional qualities, can be considered to be of "Outstanding Universal Value" and, as such, worthy of special protection against the dangers which increasingly threaten them [4] (p. 11). Cultural heritage (CH) is now the most significant medium for transmitting information from the past to the future. CH is considered a key element of city and region identities and uniqueness, potentially contributing to peoples' wellbeing and health, as well as to job creation, environmental regeneration and place attractiveness [5–9]. However, heritage conservation needs large investments, while the resources available are scarce and investment projects are subject to high uncertainties [10–13].

China's current urban historical and cultural heritage conservation system is divided into three levels, including the protection of historical and cultural cities, historical and cultural districts, and heritage protection units [14,15]. As historical and cultural values are increasingly valued by society, the number of historical and cultural cities and towns is increasing, but the preservation quality of the current historical architectural remains in the neighborhoods shows a general trend of decline. Take the first batch of declared historical and cultural districts in China as an example; their core protection area only accounts for 46.9% of the total district area [16]. The reason is that there is a degree of discontinuity in the two-level division between historic districts and heritage protection units in the conservation system. The historical district is composed of all the architectural remains in the district, but the actual architectural protection is only for the buildings of the declared heritage protection units, and there is no holistic and standardized evaluation and control system for other buildings in the district [17]. A sustainable conservation approach should not be a straightforward and restrictive concern for preserving the physical quality of the built heritage, but should take into account the efficiency of the utilization of the built heritage and its symbiotic relationship with the rest of the city [18]. China's greatest shortcoming in the conservation of its historical heritage is that it has not paid attention to the preservation of those dwellings that best reflect the lifestyle of the people and are closely related to their lives. Most of what is protected now are so-called important buildings [19]. Such a "bottom-line" approach for conservation has led to the fragmentation of the protection of historical and cultural heritage in towns and cities, the loss of the overall setting of the historic district, and the gradual loss of the conservation value of neighborhoods [20,21]. UNESCO has elaborated a list with intangible heritage, which should be also protected [22]. It worth a great deal for China to learn from that.

At the same time, in China, the development and implementation period of historical and cultural district protection plans are long. Generally, it takes 1–2 years to prepare the plan and longer to implement it. As a result, the planning and implementation is a static, one-way process. It is difficult to identify problems and make dynamic adjustments in a timely manner during the implementation of the plan. However, urban development, especially the regeneration of historic areas, is a dynamic, changing old to new process. This requires the establishment of an assessment system that can be controlled and dynamically managed in real time, as a way to systematically recognize the historical value of relics and achieve sustainable conservation [23].

Documenting and safeguarding cultural heritage have become increasingly important. With the advancement of technology, conventional documentation approaches were superseded by modernized documentation strategies. Use of digitized tools and technologies in the modeling and representation of the CH was becoming widespread [24]. The "digital humanities" concept has received a lot of attention in Chinese academic circles since about 2009. A variety of ways have lately begun to over visual access to cultural resources and to examine these as complex and extensive information spaces using visualizations, extending further than the traditional representations of search-centric as well as grid-based platforms. Unlike traditional online interfaces, we are seeing an increasing number of novel visualization styles built specifically for rich data from the cultural heritage field. This new category of data visualizations has spawned a wide range of interaction as well as representational strategies [25]. Accurate spatial data are generated through 3D digital documentation. This information can be handled and improved for a variety of uses. Use of 3D data to assist conservation has become more common throughout the cultural heritage field [26].

In addition, another common problem in current research and practice in the conservation of historic and cultural districts is the lack of understanding of the role and value of assessment. The lagging assessment is a major constraint to current historical and cultural district preservation research. From the 'Venice Charter' to the 'Guidelines for the Conservation of Cultural Relics and Monuments in China', one consensus that has gradually emerged is that heritage conservation must be based on a comprehensive assessment of the objects to be conserved. This is not only the procedure and foundation of conservation work, but also an important element of heritage conservation work itself. Its core significance lies in the fact that assessment is a record of the state of heritage conservation at different times, which not only provides a basis for the formulation of conservation measures at present, but also offers the possibility of subsequent scientific research and improvement of conservation methods and is the basis for further development and deepening of subsequent research [16].

2. Literature Review

2.1. Sustainability

The term "sustainability" is derived from the Latin word "sustinere", which means to hold up [27]. Since the 1980s, the concept of sustainability has been frequently mentioned and discussed in different fields. There are various meanings of sustainable development. The most quoted definition is derived from the Brundtland Report (World Commission on Environment and Development 1987), which defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [28]. This definition points out that sustainable development refers to the development form which can satisfy the needs of current society without compromising the requirement of development for the future generation [29]. It contains two key concepts, namely, the needs and limitations. The first one represents, in particular, the essential needs of the world's poor in which prevailing priority should be given, whereas the latter refers to resources imposed by the state of technology and social organization and the environment's ability to meet present and future needs [30]. In order to further clarify the planning and task of sustainable development, specific sustainable development goals and targets were set and explained in the document of the United Nations, committing to achieving better sustainable development by 2030 [31]. The 2030 agenda for sustainable development is shown in Figure 1.

Figure 1. The 2030 agenda for sustainable development [32].

The terms "sustainable development" and "sustainability" are often used interchangeably in the literature. However, some authors argue that sustainability denotes a progression, while sustainable development denotes the end state. Different types of sustainability are included in sustainable development which can be reflected by different fields, such as sustainable agriculture, sustainable architecture, and sustainable supply chain [33,34].

2.2. Sustainability Assessment

There are three pillars often employed to address sustainability issues, including environmental, economic, and social [35]. Cultural, technological, and political aspects are also considered as the sub-domains of sustainable development [36,37]. Recently, a new systematic domain model was proposed consisting of economic, ecological, political, and cultural four dimensions, which accords with the United Nations, UNESCO, and Agenda 21, especially the culture as the fourth dimension of sustainable development [36,38].

Five priorities for the UN sustainable development goals were proposed including the establishment of indicators, the creation of monitoring systems, progress assessment, infrastructure improvement, and data standardization [39]. Sustainability assessment is the key to ensuring sustainable development. For sustainability assessment of any development activities or any socio-economic system, a variety of information and stakeholders' perspectives must be considered and integrated. Therefore, sustainability assessment can be considered as a decision-making problem [40,41]. That requires a technique that can integrate data from the three pillars of sustainability, follow a transparent process, conduct robust analysis and consider stakeholders' opinions on sustainability criteria.

Sustainability assessment must incorporate issues of economic, social and environmental interaction into decision making [41–43] and involve conflicting dimensions of economic, environmental, social, technical, human, and physical issues.

2.3. Sustainability for Historic Conservation

Caring for the historic environment is a dynamic process that involves managing change so that future generations would understand what we value and where they originated. This does not mean keeping everything from the past, but it does involve making careful judgements about value and significance [44]. Conservation is the sustainable management of change. It is not simply an architectural deliberation, but an economic and social issue [45]. Conservation means taking care of a place in order to preserve all the processes of its cultural significance [46]. Therefore, each generation should shape and sustain the historic environment in a way that allows people to use, enjoy and benefit from it without compromising the ability of future generations to do the same [47]. Conservation, at its most basic, involves passing on to future generations what we hold dear. Conservation advisers are there not to stand in the way of change, but to negotiate the transition from the past to the present in ways that minimize the damage that change can cause and maximize the benefits [44]. Sustainable development strategies require the preservation of existing resources of all kinds. Active conservation and sustainable management of urban heritage is a necessary condition for sustainable development. The goal of conserving cultural heritage 'to pass on as much meaning as possible to future generations' coincides with the concept of sustainable development [48].

Conservation of cultural heritage in all its forms and historical periods is rooted in the values attributed to the heritage. Our ability to understand these values depends, in part, on the degree to which information sources about them may be understood as credible or authentic. Knowledge and understanding of these sources of information, in relation to original and subsequent characteristics of cultural heritage and its significance, is a necessary basis for assessing all aspects of authenticity [4]. The understanding of authenticity plays a fundamental role in all scientific studies of the cultural heritage, in conservation and restoration planning. Authenticity judgements may be linked to the value of a great variety of sources of information. Aspects of the sources may include form and design, materials and substance, use and function, traditions and techniques, location and context, spirit and feeling, and other internal and external factors. The use of these sources permits elaboration of the specific artistic, historic, social, and scientific aspects of cultural heritage under examination [49]. According to the review of relevant research and theories presented at the Nara Conference (1994), "Authenticity" can be defined as something that sustains and proves itself, as well as deriving from its own credibility and authority. Authenticity refers to something creative, an authorship, something having a deep identity in form and substance. It means something specific and unique and different from "identical" which refers to universal, representing a class, reproduction, replica, copy, or reconstruction. While in many cases "authenticity" can relate to the "original creative source", it is also a relative concept that, according to modern value judgements, can be related to historical-continuity in the "life" of the heritage resource [50].

The concept of a historic monument includes not only the single architectural work, but also the urban or rural setting in which the evidence of specific civilizations, significant developments or historical events can be found [51]. Preserving cultural heritage and promoting the diversity of cultural expressions, while fostering values and behaviors that reject violence and build tolerance, are instrumental to the social cohesion of societies, peace building and the sustainability of cities.

Summarizing the international laws and regulations [4,49,51–54] on the conservation of historic areas, the core values of historic area conservation focus on the preservation of authenticity, integrity, and diversity.

2.4. Sustainability Assessment for Building Attribute

To analyze the essential properties of building, the key question is "What is a building?" Generally, building refers to a roofed and walled structure built for permanent use. This definition includes the external envelope properties and the enclosed internal space properties. Rudimentary buildings were initially constructed out of the purely functional need for a controlled environment to moderate the effects of climate. These initial buildings were simple dwellings. Early building materials were perishable and often included leaves, branches, and animal hides. These structures did not provide much permanency. Subsequently, more durable natural materials—such as clay, stone, and timber—and, finally, synthetic materials—such as brick, concrete, metals, and plastics—were used, permitting buildings to persist for many decades and even centuries [55].

The ancient Roman architect Marcus Vitruvius Pollio asserted in his book "de Architectura" that "All (architecture) should possess strength, utility, and beauty". This famous quote was initially translated into English by Henry Wotton in 1624 as: "Well building hath three conditions: firmness, commodity, and delight". In modern English, it would be written: "The ideal building has three elements: sturdy, useful, and beautiful" [56]. According to David Smith Capon's research, Vitruvius's three principles of "practicality, solidity and beauty" correspond to the ancient Greek philosopher Plato's three philosophical principles of "truth, goodness, and beauty" [57].

In China, the "principles" originated from the ancient sage King Dayu mentioned in "Shangshu Dayumo", namely "Righteousness, Utilization, Prosperity". The most important ones involved in the three principles are the power of civil engineering and the benefits of water conservancy, so it can be understood as the three principles of ancient Chinese architecture. In the Warring States Period, there were several evaluation criteria for palace architecture, one was "consistency", the other was "integrity", and the third was "beauty". Corresponding to the stage theory of house construction, in the first stage, it is available for preliminary use. In the second stage, the functional space of the house is gradually improved. In the third stage, the house has an aesthetic standard. These three stages correspond to the three different properties of the building. The building structure is firm and can be used initially. The functional space of the building produces appropriate benefits. And the appearance of the building follows the aesthetic principles to produce a sense of pleasure [58].

Sustainability assessment needs to cover economic, social, and cultural aspects. The corresponding building attributes can also be attributed to the economic, social and cultural aspects. Robust construction and appropriate application of materials ensure that the building is economical. Appropriate functional use and spatial efficiency are consistent with the social attributes of the building. The exterior form of the building could reflect the traditional culture of the region. Integrating Western and Chinese discussions on the essential attributes of buildings, the three principles of structural materials, functional space and exterior form of buildings are also in accordance with the three economic, social, and cultural aspects that should be considered in sustainability assessment.

3. Building Attribute Assessment Model Based on Sustainability

When studying the conservation and development of historic areas, it is necessary to discuss both the time and the spatial dimensions. If the attributes of buildings are simplified to the mass points measured by multiple representational dimensions, the process of the generation, change, and destruction, as well as the overall change of buildings in the region can be well analyzed. It is similar to the systematic process of the emergence of particles, the change of trajectory over time, the disappearance, and the simultaneous change of multiple particles in space. Therefore, in this study, building attributes are simplified as the changes of mass points in the cultural space-time coordinate system to construct a sustainable conservation assessment model.

3.1. The Representational Dimension

Integrating the discussion of the nature of building and sustainability assessment dimensions, three aspects of common concern can be identified as economic, cultural, and social. As the ontology for transmitting and preserving culture for future generations, building should take on the three major responsibilities of presenting and inheriting regional culture, improving regional conservation, and developing economic functions. Therefore, the three dimensions of building attributes based on sustainability are "Economy of construction, cultural of form, and social of benefit". The three dimensions correspond to the continuation, improvement, and presentation of the regional history and culture, and, thus, achieve the three stages of "Righteousness, Utilization, Prosperity", then truly realize the sustainable connotation of historical area conservation. Meanwhile, the three dimensions are also consistent with the sustainable requirements of historic district preservation (Figure 2).

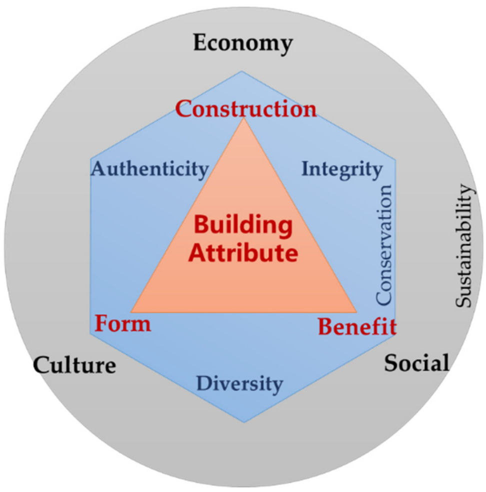


Figure 2. The three dimensions of building attributes based on sustainability.

One or more elements are included under each dimension of the sustainable assessment model of building attributes. In China's current historical district protection planning, the age, style, quality, structure, number of floors and the published grade of protected buildings are the main factors for evaluating and delimiting the scope of core protection areas in historic districts. By making certain modifications to the elements in the current protection evaluation criteria, other elements are appropriately added and integrated to form seven influential elements under the three representational dimensions (Figure 3).

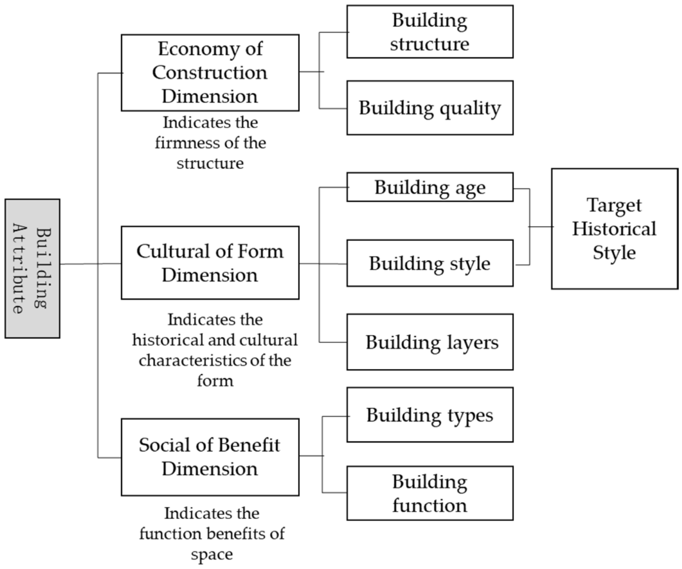


Figure 3. The elements under each dimension.

For economy of construction dimension, the influencing factors include the structure and quality of the building, which can reflect the solidity of the building construction.

For cultural of form dimension, the influencing factors are the three elements of building layers, age, and style. In the meantime, the judging criteria are revised. The concept of "target historical style" is proposed, which refers to clarifying the amount of historical information that can be conveyed by different patches in the historical area based on regional historical data. As a result, the historical information characteristics of each building can be identified, which can be referred to and preserved. This feature includes both the target chronological aspect and the target functional aspect of the building. The age and style of the building are judged together. The closer it is to the "target historical style", the higher the score. On this basis, the spatial scale changes reflected by building layers are also considered.

The social of benefit dimension reflects the function benefit of space through a comprehensive judgment of building types and functions.

Each specific element in the three evaluation dimensions has a relevant scoring criterion, and the dimension scores are integrated based on the scores of the included elements.

3.2. Bipolar Value Orientation

In order to facilitate research, analysis, and graphic expression, a three-dimensional coordinate system is established by referring to the construction method of the three-dimensional coordinate system in analytic geometry. Each of the three evaluation dimensions are respectively corresponded and perpendicular to each other in the graphic expression. The system is constructed for the evaluation of architectural attributes in historical areas. The coordinate x-axis is the economy of construction dimension, the coordinate y-axis is the cultural of form dimension, and the coordinate z-axis is the social of benefit dimension. The origin of the three-dimensional coordinates is at (0, 0, 0). The positive and negative coordinate systems of the three dimensions constitute eight spatial quadrants, called quadrant one to eight. In this way, the distribution of building attribute particles in the three-dimensional coordinate system is intuitively depicted, and the change trajectory of building property particles over time can be represented by a trend line of attribute changes in the three-dimensional coordinate system (Figure 4).

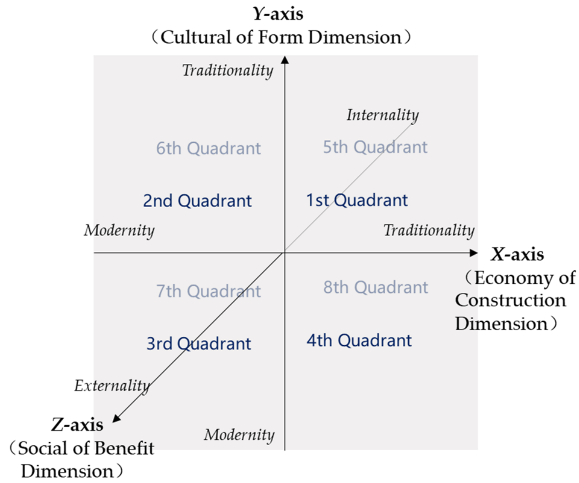


Figure 4. Three-dimensional Evaluation coordinate system diagram.

The value orientation of buildings in historical areas has two polarities, namely, traditionality and modernity. In the three-dimensional coordinate system of sustainable conservation assessment, the positive and negative directions of each dimensional axis represent the traditional and modern orientation, respectively. In the value evaluation criteria, a score of 5 represents the highest attribute value, while a score of 1 represents the lowest attribute value.

The X-axis represents the economy of construction dimension, the positive direction of the coordinate axis represents the firmness of traditional structures, such as wood and brick-wood, and the negative direction represents modern structures, such as brick-concrete and steel-concrete. The higher the score value, the higher the firmness and vice versa.

The Y-axis represents the cultural of form dimension. The positive direction of the coordinate axis represents that the building has a traditional cultural style. The higher the fit between the architectural form and the "target historical style", the higher the score, and vice versa. The negative direction indicates that the building has a modern cultural style. The more regional historical information reflected in the building form, the higher the score, and vice versa.

The Z-axis represents the social of benefit dimension. The positive and negative directions of the coordinate system represent the externality and internality of building functions respectively. The externality of functional benefits refers to the use function of the building serving the outside of the region, usually with a stronger cultural display function, serving the city or even a larger area. The internality of functional benefits means that the use function of the building serves the local population within the historical area, either as a residential function or as a regional service function. The positive direction of the coordinate axis represents that the building function has external benefits. The negative direction represents internal benefits. The higher the service level and the less damage to the health of the building, the higher the score, and vice versa.

In the three-dimensional space-time coordinate system, each building's attribute score corresponds to a unique attribute particle in the coordinate system, and the trajectory change of the particle represents the conservation practice process of the building.

3.3. Building Classification Guidance

In the practice of historic area conservation, buildings are divided into two categories: "historical buildings" [59], which are legally protected as cultural relics, and "other buildings". Historical buildings have strict legal meanings and mandatory protection regulations and shoulder more important values and responsibilities in the protection and inheritance of regional history and culture. The conservation of other buildings is relatively flexible, and the historical culture can be displayed in a variety of ways. Therefore, the two types of buildings are classified and controlled with different orientations of scoring values (Figure 5).

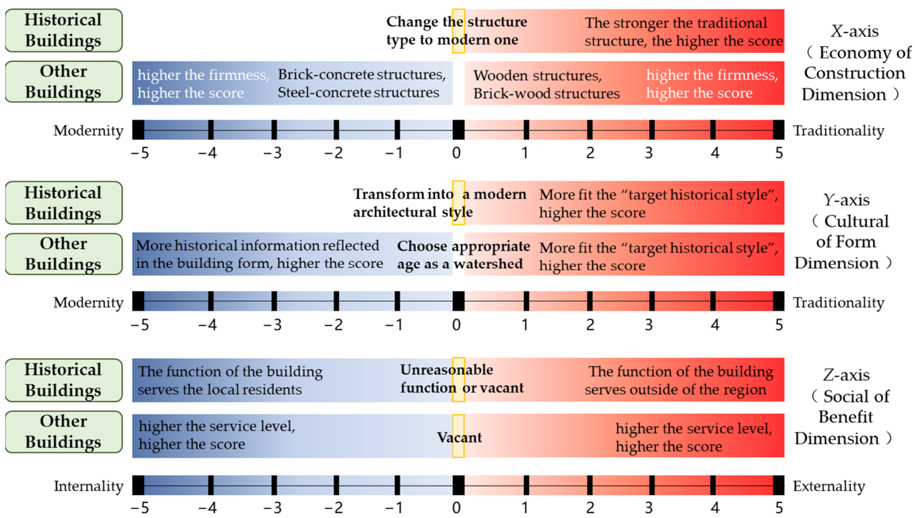


Figure 5. Building classification guide diagram.

For economy of construction dimension, due to the need for authenticity, historical buildings must guarantee the traditional orientation of the building structure and must not change the structure type to a modern one. This requirement does not apply to other buildings.

When evaluating the culture of form dimension, the building's state of preservation is judged by the layers, age, and style of the building in a comprehensive way that fits with the target style. As historical buildings are of significant high value, their building style should not lead to modernity. Therefore, in the evaluation process, if the historical building is updated to a modern style, the score is zero. When other buildings are oriented towards modern style, the more historical information of the area reflected in the building form, the higher the score, and vice versa. The greater the deviation between the traditional form and the target historical style, the lower the score. The less historical and cultural elements reflected in the modern architectural form, the lower the score. Among them, if a historical building conveys the wrong modern information, the score is 0.

The social of benefit dimension score considers not only whether the building is functional, but also measures the service level of function and the impact on the health of the building itself. If the building is vacant, the score is zero. When the functional benefit of the building is external, the score is in the positive direction of the *z*-axis; when the functional benefit is inward, the score is in the negative direction. The score is also zero if the function use is unreasonable or seriously affects the health of the building itself. During the evaluation process, the score is gradually reduced from 5 to 1 depending on the level of service benefits of the building function.

4. Case Study

To demonstrate the application of the proposed sustainability-based building attribute assessment model, a suitable project was analyzed using the proposed model.

4.1. Project Background

The Xijindu Historic District is in the northwest corner of Zhenjiang City, bordering the Yangtze River to the north, and the Yuntai Mountain to the south. It is located in the "Historical and Cultural Expo Area" as defined in the protection plan of the famous historical and cultural city, and is the most concentrated, numerous, and well-preserved area of cultural relics and monuments in Zhenjiang. The area was formed during the Three Kingdoms period and gradually became a complete ferry port in the Tang Dynasty, becoming a transportation hub for China's north-south water transport. During the Qing Dynasty, the Xijindu area was connected to two major shipping arteries, the Yangtze River and the Beijing-Hangzhou Grand Canal. After the Opium War, Zhenjiang was officially opened as a port in 1861 and the Xijindu area was designated as a British Concession. With the northward shift of the Yangtze River shoreline and the construction of the regional railway, the freight function of the district was gradually transferred to the area around Xijin bay, and the Xijindu historic area gradually declined.

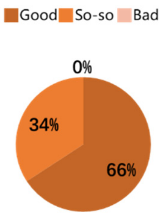
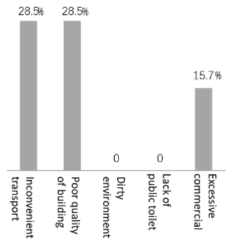
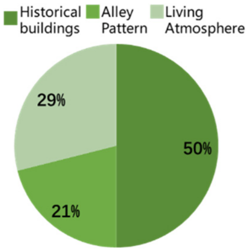
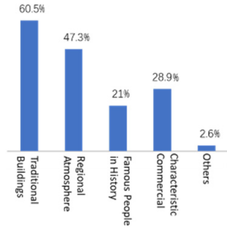
In this research, the boundary of Xijindu historic area is from Yingjiang Road in the east, to Heping Road in the west, to the northern foot of Yuntai Mountain in the south and to Changjiang Road in the north. The total area is approximately 16.05 hectares, with a current built-up area of 122,800 m^2 (2018) (Figure 6).

Figure 6. The boundary of Xijindu historical area.

Zhenjiang was approved as a national historical and cultural city in 1986. Since the adoption of the Protection Plan for Zhenjiang Historical and Cultural City in 1989, the preparation of a protection plan for the Xijindu area, an important cultural heritage site in Zhenjiang, has been on the agenda. In 1998, the Zhenjiang Government approved the Protection Plan for the Xijindu Historical District, focusing on the physical authenticity of the area and on the buildings declared as heritage protection units and traditional dwellings. Between 2000 and 2005, a series of plannings and restoration design schemes were completed in relation to the conservation and improvement of this historic district. Around 2008, the conservation plan was basically completed. During this period, it won a number of domestic and international awards, including the UNESCO Award for Excellence in Historical and Cultural Heritage Conservation in the Asia-Pacific region and the China Habitat Award. In 2010, Xijindu was ranked as one of the top 20 most popular "Expo Experience Tour Demonstration Sites" and was successfully established as a "National AAAA Grade Tourist Attractions", receiving a total of over one million visitors, including about 30,000 visitors from abroad.

Theoretically, after nearly 20 years of conservation planning and implementation, the Xijindu historical district should have entered a good state of conservation. However, the author visited the renewed Xijindu area several times between 2016 and 2018 and found that the buildings in the area suffer from a series of problems such as grotesque appearance, homogeneous forms, loss of characteristics, and vacant functions. In the visitor questionnaire survey (Table 1), it was found that nearly 34% visitors had a just so-so experience of visiting this area, especially on its history and culture exhibition aspect. The heavy commercial atmosphere of tourism overshadowed the original traditional historical atmosphere of the district, and the intricate building forms resulted in visitors being unable to identify the historical chronological features of this area or to understand the real culture of the ferry. It is difficult to leave a lasting memory for visitors after a single visit to the Xijindu area. Most visitors found it difficult to match the many awards the area has received with its conservation status.

Table 1. Visitor questionnaire survey and problems in Xijindu area.

<table>
<tr><th colspan="5">Visitor Questionnaire Survey and Problems in Xijindu Area</th></tr>
<tr><td>Questions</td><td>Evaluation of the conservation status</td><td>Shortcomings in protection planning</td><td>What should be retained?</td><td>Area-specific attractions</td></tr>
<tr><td>Answers</td><td>
</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Building Problems</td><td>Grotesque Appearance</td><td>Homogeneous Forms</td><td>Loss of Characteristics</td><td>Vacant Functions</td></tr>
<tr><td>Photos</td><td></td><td></td><td></td><td></td></tr>
</table>

What are the key problems for conservation practice in the Xijindu area? The following will attempt to discuss this question using the Sustainability-based Building Attribute Assessment model.

4.2. Research Process

Unlike traditional protection planning for historic districts, there is a step of dynamic evaluation and continuous adjustment in the sustainable building attributes assessment model proposed in this paper (Figure 7). By simplifying the building attributes before and after renovation into spatial qualitative points, the renovation process, the degree of attribute value enhancement and the type of building conservation can be summarized visually. By constantly comparing the building attribute particles with the sustainable value orientation, the position of the spatial particles can be changed by adjusting the corresponding elements of the building attributes dimension to approach the area with the highest overall value as closely as possible. In this way, the process of conservation practice in historic areas will no longer be a single, static process, but a sustainable process that can be constantly and dynamically compared and reflected upon.

4.3. Application of Sustainable Attribute Assessment Models

4.3.1. Three Dimensions of Building before and after Renovation

There are four types of building structures in Xijindu area: wood structure, brick-wood structure, brick-concrete structure, and steel-concrete structure. Among them, wood and brick-wood structures are traditional types, and are scored in the positive direction on the x-axis; brick-concrete and steel-concrete structures are modern building structure types, and are scored in the negative direction on the x-axis. According to the above criteria, a chart of the economy of construction dimension scores was drawn. The darker the red in the graph, the stronger the traditional structure of the building; the darker the blue, the stronger the modern building structure. Comparing the score charts before and after the renovation, it is intuitively clear that the number of red buildings in the area has decreased sharply, which means that the number of buildings with traditional structures has decreased a lot.

Both red and blue buildings have deepened in color, indicating that both traditional and modern structure buildings are more robust (Table 2).

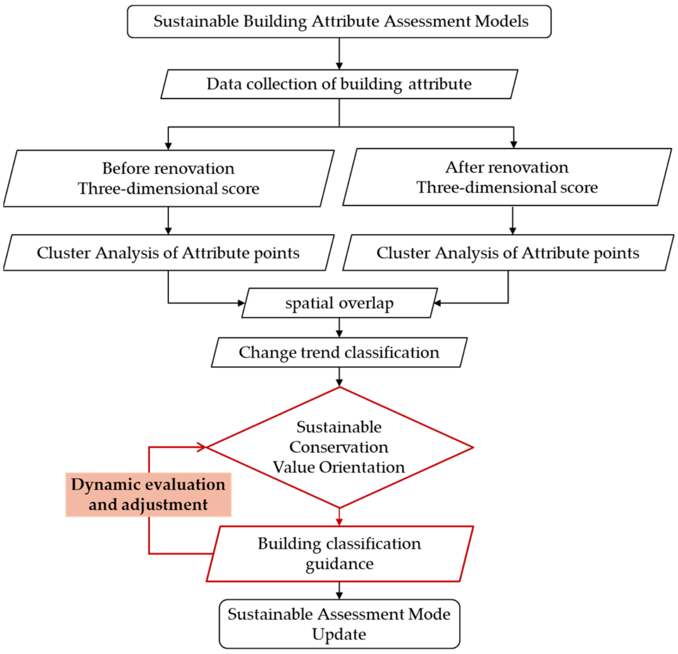
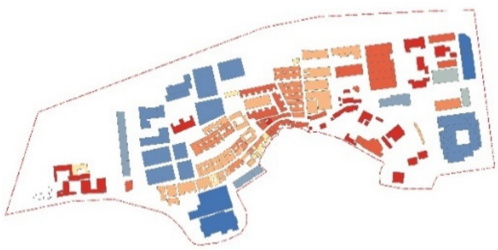


Figure 7. The research process in sustainable building attribute assessment model.

Table 2. Building attribute dimensions score chart.

Building Attribute Dimensions Score Chart		
	Before renovation	After renovation
X-axis Value		
Y-axis Value		
Z-axis Value		

The "target historical style" of the buildings in the Xijindu area are grouped into blocks to form a "target historical style" orientation map, taking into account the heritage remains and information mining in the history (Figure 8). Each block of buildings in the region corresponds to its own target historical style and functional information features. During the scoring process, the higher match between the buildings in the block and their respective "target historical style", the more authentic the historic information conveyed, and the higher their value.

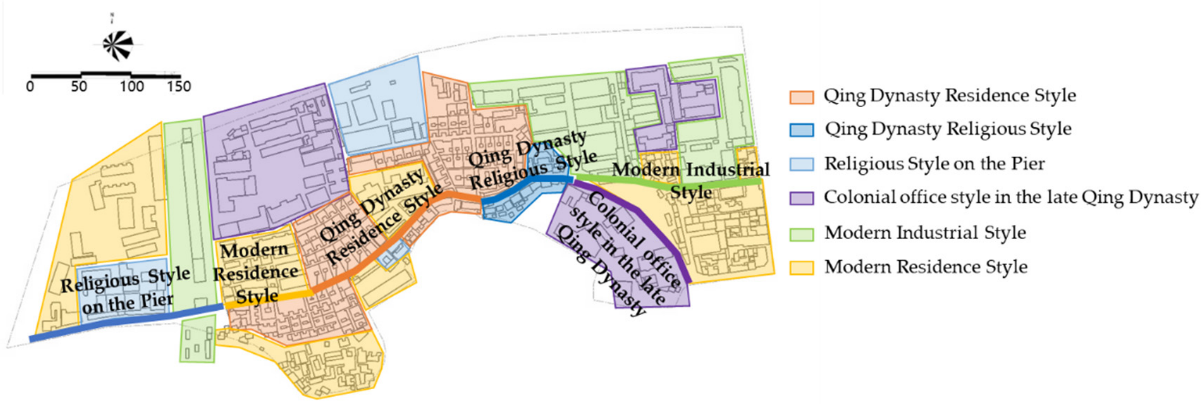


Figure 8. The "target historical style" diagram of Xijindu area.

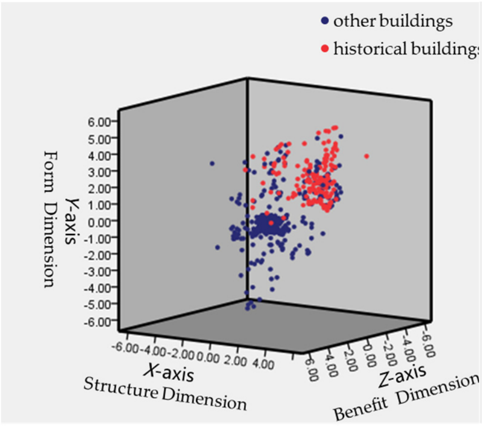
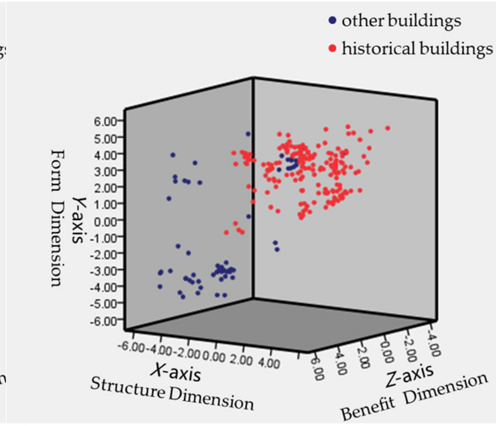
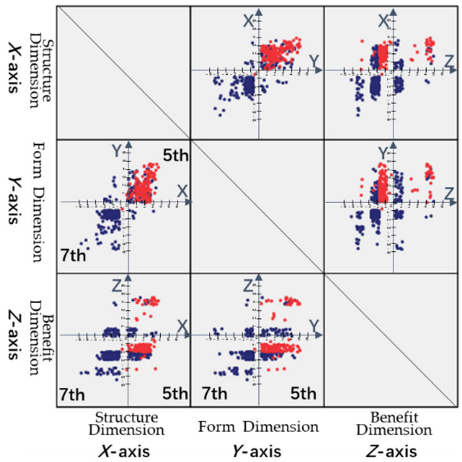
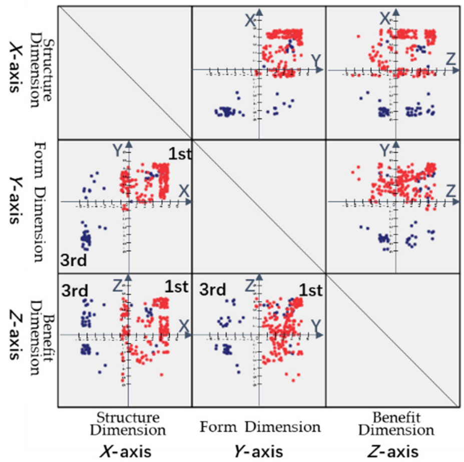
In the cultural of form dimension scoring chart, the darker the red color of the building, the higher the match between the traditional building style and the "target historical style". The darker the blue color, the more historical information reflected in the modern style building. Among them, the white building represents the transformation of cultural heritage building into a modern one. Comparing the score charts before and after the renovation, the proportion of red and blue buildings after the renovation is approximately the same as before the renovation, indicating that the authenticity of the buildings in the area has been well maintained. The chromaticity of both red and blue buildings has deepened, indicating a clear trend towards polarization of building form. The absence of white buildings indicates that the traditional style of historical buildings was well preserved, and the formal attributes have not changed.

In the Z-axis value chart, the darker the red, the higher the external benefit of the building; the darker the blue, the higher the internal benefit; the white building indicates vacant building, or the function use seriously affects the health of the historical building. Comparing the score charts before and after the renovation, the buildings in the area have changed a lot from blue to red, indicating that the dominant function of the buildings in the Xijindu historic area has shifted from internal to external, from serving the community internally to serving the city or even a larger region. The number of white buildings has increased significantly after the renovation, indicating a significant increase in the number of vacant buildings as of the time of the survey. Approximately 1/3 of the buildings in the area failed to exert any functional benefits, seriously affecting the vitality of this area and the sustainable conservation of the buildings. This issue needs to be addressed urgently (Table 2).

4.3.2. Cluster Analysis of Attribute Points

In the assessment model, each building corresponds to a unique three-dimensional value of x, y, and z, and the attribute particles are placed in the three-dimensional coordinate system. The red dots in the diagram represent the attribute points of the historical buildings and the blue dots represent other buildings (Table 3).

Table 3. Three-dimensional coordinate space expression of scattered points of building attributes in Xijindu area.

<table>
<tr><th></th><th colspan="2">Scattered Map of Building Properties in Xijindu Historic Area</th></tr>
<tr><th></th><th>Before renovation</th><th>After renovation</th></tr>
<tr><td>3D distribution of building attribute points</td><td>
</td><td>
</td></tr>
<tr><td>Matrix distribution of building attribute points</td><td>
</td><td>
</td></tr>
</table>

Before the renovation, most attribute points of the historical buildings are located in the fifth quadrant, indicating that the building structures are traditional and firm, the building forms are traditional and close to the "target historical style", and the building benefits are internal. The other building attribute points are mostly distributed in the seventh quadrant, representing buildings with modern and robust structures, modern forms and internal benefits.

After the renovation, the majority of the attribute points of the historical buildings are in the first quadrant, indicating traditional and solid building structures, traditional building forms closer to the "target historical style", and external the building benefits. The points of other building attributes are mostly distributed in the third quadrant, representing that the building structures are modern and firmer, the building forms are modern and more cultural, and the building benefits are external.

To analyze the aggregation distribution and changes of building attribute points quantitatively and rationally, a scientific analysis using cluster analysis method in statistics is required.

In the analysis of building attribute scatter, the number of clusters of building attribute points was first analyzed using the hierarchical clustering method. After determining the number of clusters of building attribute points, the K-means fast clustering method was used to analyze the coordinates of the centroids of each cluster to represent the common attributes of each clustered buildings.

Hierarchical cluster analysis was carried out on the building attribute points before the renovation. The historical building attribute clusters were divided into two categories and three subcategories, while the other building attribute clusters were divided into two categories and four subcategories.

The K-means fast clustering method was applied to the attribute points of the historical buildings, and three cluster centers were obtained after iteration. The coordinate points are (3, 4, 5), (2, 2, −1), and (3, 4, −1), and the number of building attribute points per cluster is 26, 89, and 46 respectively. The three cluster centers are located in the first, fifth, and fifth quadrants in that order (Figure A1).

The K-means fast clustering method was applied to the attribute points of the other buildings, and four cluster centers were obtained after iteration. The coordinate points are (−2, −1, −2), (2, 2, −1), (−2, −3, −4), and (2, 3, 5), and the number of building attribute points in each cluster is 238, 79, 34, and 9 respectively. The four cluster centers are in the seventh, fifth, seventh, and first quadrants in sequence (Figure A2).

The building attribute table was imported back into GIS, and the building cluster attributes were linked with the spatial location. In the building attribute type map, the building color indicates the cluster type to which the attribute belongs (Figure 9).

Figure 9. Building attributes clusters before renovation.

Hierarchical cluster analysis was performed on the building attribute points after the renovation. Both historical and other building attribute clusters were divided into two categories and four subcategories.

The K-means fast clustering method was used for the attribute points of the historical buildings, and four cluster centers were obtained after iteration. The coordinate points are (5, 3, 2), (1, 2, −1), (0, 3, 3), and (5, 5, 5), and the number of building attribute points in each cluster is 74, 30, 44, and 45 respectively. The four cluster centers are in the first, fifth, y-z plane, and first quadrant in order (Figure A3).

The K-means fast clustering method was applied to the attribute points of the other buildings, and four cluster centers were obtained after iteration. The coordinate points are (−4, 2, 4), (3, 4, 4), (−5, −4, 0), and (−5, −4, 4), and the number of building attribute points in each cluster is 9, 14, 22, and 16 respectively. The four cluster centers are in the second, first, x-y plane, and third quadrant in sequence (Figure A4).

The building attribute table was imported back into GIS and the building cluster attributes were linked with the spatial location. In the building attribute type map, the building color indicates the cluster type to which the attribute belongs (Figure 10).

Figure 10. Building attributes clusters after renovation.

4.3.3. Change Trend Classification

The building attributes were spatially overlaid in to obtain the cluster types of buildings before and after renovation in the same spatial location. The table of historical building and other building attributes was imported into SPSS, and the two groups of cluster type data before and after renovation were used as variables for systematic cluster analysis. The number of clusters for the change trend of historical building attributes was 10, and the change trend of other building attributes was 16.

Summarizing the 10 different ways in which historical building attributes have changed, there are three trends in total (Figure A5): (Figure 11)

Figure 11. Changing trend of building attributes.

- Trend I: Increasing both scores of form and structure and improving the external functional benefits of the building while the building maintains its traditional form and structure, including 84 buildings;
- Trend II: Some buildings with traditional structures and forms were seriously damaged. Fifty-five of these buildings have been converted to modern structures due to difficulties in maintaining their traditional nature or for other reasons. Such practice undermined the responsibility of historical buildings to convey authentic historical information;
- Trend III: Some buildings with traditional structure and form have not been properly protected. Their structural and formal conditions have become increasingly dilapidated over time, including 19 buildings. Such buildings are in urgent need of further conservation measures.

Summarizing the 16 different ways in which the properties of other buildings have changed, there are 6 trends in total, excluding demolishing building behavior (Figure A6): (Figure 11)

- Trend I: The modern building structure was strengthened with the form showing more cultural expression, including 103 buildings;
- Trend II: The traditional building structure was reinforced, and the building form was closer to the target historical style, including 19 buildings;
- Trend III: The traditional building structure was transformed into a modern structure with increased solidity and unchanged building form, comprising nine buildings;
- Trend IV: Traditional buildings have been shifted into modern ones with increased structural solidity and cultural features, including 25 buildings;
- Trend V: The firmness of the modern building structure was enhanced, and the facade form was transformed into an antique building, including seven buildings;
- Trend VI: Modern buildings have been renewed to antique buildings with traditional structural and historical form, including three buildings.

4.3.4. Sustainable Conservation Value Orientation

In the assessment model, the above trends in building attribute change were superimposed on the reconstructed building map through the spatial position to analyze the types of conservation practice.

The three changing trends of historical buildings all reflect that the properties are approaching the first quadrant. It shows that in the real renovation process, no matter how many trends of attribute changes there are in historical buildings, there is only one goal for their conservation practice, and that is to maintain authentic traditional buildings with traditional structure, traditional form, and external building benefits. This corresponds to the responsibility of historical buildings to pass on the authenticity of historical culture. The three dimensions of building structure, form, and benefit should converge on the coordinates (5, 5, 5). It means that the building should improve the structural firmness while maintaining its traditional structure, the architectural form should show the authenticity of the "target historical style" and the functional benefits of the building should be as external as possible. As historical buildings have statutory mandatory protection requirements, there is little scope for flexibility guidance on sustainable conservation, so the guidance and control is focused on other buildings and special cases of historical buildings in the area.

Among the six attribute change trends of other buildings, I and IV indicate that the three-dimensional attributes of the building are approaching the third quadrant, II is approaching the first quadrant, III and V are approaching the second quadrant, and VI is excluded because this change is caused by errors. Under the orientation of sustainable conservation values, for other buildings in the area, the three dimensions of building structure, form and benefit should converge to the coordinate points $(5, 5, \neq 0)$, $(-5, -5, \neq 0)$, $(-5, 5, \neq 0)$, or $(5, -5, \neq 0)$. They respectively indicate that:

① The structural firmness of the building has been improved by maintaining the traditional structure, the form of the building displays the authenticity of the "target historical style" and the building space has a productive functional benefit;

② The building has been modernized and made structurally stronger. The building takes on a modern form while presenting as much historical and cultural information as possible. At the same time, the building space has a useful function that generates benefits;

③ The building is constructed in a modern structure, but the facade displays historical and cultural information, or the building is constructed in a traditional antique structure but the form displays a modern style, and the building space has a productive functional benefit.

Comparing the changing trend of building attributes in conservation practice types and the sustainable conservation value orientation, three categories and five sub-categories of buildings were obtained:

1. Type A—Authenticity-oriented type, oriented towards increasing authenticity:

This type of building is an authentic historical building in the original location with the attribute three-dimensional orientation score of (5, 5, 5). The control elements include the reinforcement of the traditional building structure, the maintenance of the building scale and the number of floors, the conformity of the building form to the "target historical style", the overall improvement of the facade style and the introduction of appropriate use functions for sustainable conservation.

2. Type B—Image-display type, oriented towards improving the façade appearance:

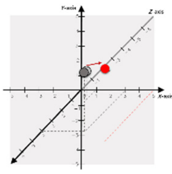
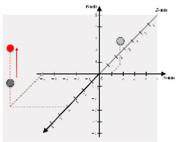
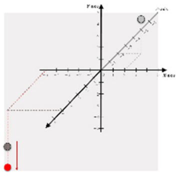
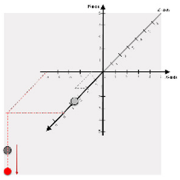
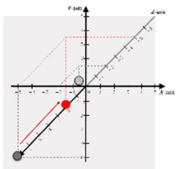
It means that the structure and form dimensions of the building show an inconsistency between traditional and modern orientation, and the attribute three-dimensional orientation score is (5, -5, $\neq 0$) or (-5, 5, $\neq 0$). The guiding elements include structural reinforcement, slightly variable scale and number of stories, and emphasis on displaying historical information on the facade's image. At the same time, restore and increase the cultural information displayed in the style according to the "target historical style" as much as possible and introduce appropriate using functions.

3. Type C—Cultural-oriented type, the guiding goal is to improve diversity:
    (1) Sub-category C-1, Reconstruction building. It refers to buildings that have been rebuilt on their original site, and the attribute three-dimensional orientation score is (-5, -5, $\neq 0$). The guiding elements are that the scale and shape of the building should be close to the original building, and the exterior facade and interior form should continue the target historical features as much as possible;
    (2) Sub-category C-2, Reproduction building. It refers to the reproduction of unreserved buildings based on historical data or displaced historical buildings, and the attribute three-dimensional orientation score is (-5, -5, $\neq 0$). The controlling elements, including the building form and style, should be consistent with the chronological or functional information verified by historical data; the scale and the number of floors are not required, and the architectural style is not abrupt;
    (3) Sub-category C-3, Deductive building. It refers to new modern buildings or antique buildings with an attribute three-dimensional orientation score of (-5, -5, $\neq 0$). The guiding elements include the external form and characteristic elements need to reflect the diversity of regional history and culture, with a flexible scale and number of layers. The building form does not need to strictly follow the target historical style, but can interpret traditional cultural elements with modernity. At the same time, the form should add characteristic components and elements that are conducive to demonstrating the overall historical and cultural values of the area as far as possible, so as to display the culture of Xijindu area.

5. Discussion

In the conservation process of the Xijindu historic area, the six changing trends of architectural attributes are consistent with the three major categories and five sub-categories of sustainable conservation value-oriented building types. To illustrate the specific requirements and control elements of the classification guidance for each building type, five typical buildings were selected as examples to illustrate (Table 4).

Table 4. Suggestions on building classification guidance.

Suggestions on Building Classification Guidance				
Guidance Type	Attribute change trend	Coordinate guidance	Photos before and after renovation	Guidance target
A Authenticity-oriented type		(1,2,1) → (3,4,4) → (5,5,5)		Improve authenticity
B Image-display type		(1,2,−1) → (−5,2,4) → (−5,5,4)		Enhance Image style
C-1 Reconstruction building		(2,3,−2) → (−5,−3,5) → (−5,−5,5)		Increase cultural diversity
C-2 Reproduction building		(−1,−1,2) → (−5,−3,5) → (−5,−5,5)		Increase cultural diversity
C-3 Deductive building		(−2,−1,−2) → (−5,−5,0) → (−5,−5,−5)		Increase cultural diversity

- In 1966 the filter factory building belonged to type A. The building retained the original industrial architecture of the filter factory. Control elements should include the reinforcement of the brick-concrete structure without changing the scale or number of layers. While increasing a sense the 1966 period, the facade and interior of the building should also incorporate the characteristic elements of the industrial relics of the filter factory. The using function could be appropriate to add a section of the exhibition open to the public based on the restaurant and bar;
- The Old Quay Restaurant building belongs to the type B. The internal frame structure of the building has been changed, integrating several traditional buildings with a good exterior form. Guiding elements include strengthening the modern structure without changing the scale or the number of floors, adding characteristic elements of residential buildings in the Qing Dynasty, and the façade and surrounding landscape features showcasing the history and culture of Xijindu;
- The old railway station building belongs to the type C-1. The original building was demolished and rebuilt. The current building is not original. The controlling elements include that the scale and nature of the building should be close to the original building, while the exterior facade and internal form should show as many characteristic elements of a modern industrial railway station as possible. And the

building should be in harmony with the style and appearance of the train square on the west side, with appropriate inclusion of landscape elements for interaction;

- The Yushan Grand Quay Ruins Museum belongs to type C-2. The Yushan Grand Quay has already disappeared, and only the ruins and historical materials excavated underground remained. The architectural control elements include reproducing of the cultural characteristics of Yushan Grand Wharf, the building skin and facade appropriately reflecting the Qing Dynasty residential style and wharf characteristics, and the surrounding landscape works together showing the culture of Xijindu Ferry;
- The renovation residential building next to the mountain belongs to the type C-3. The original dwellings were demolished, and large-scale antique buildings were built. Guiding elements include flexibility in the scale and the number of floors, with external form reflecting a certain living style in the Qing Dynasty or modern living style. The cultural characteristics of the hillside dwellings can be interpreted using modern architectural techniques, or other cultural elements can be added depending on the function of use.

6. Conclusions

The conservation and regeneration of buildings in historic areas is an inherently sustainable issue that requires realistic conservation objectives for the future. The conservation goal should, on the one hand, correspond to the actual development of the area and, on the other hand, measure the degree of inheritance of historical information.

In this study, a sustainable assessment model with three-dimensional evaluation is constructed by reviewing sustainability theories and combining the essential attributes of buildings. The model provides an effective guide for comparative evaluation before and after the implementation of protecting plans, helps to dynamically monitor changes in building attributes during the implementation, and corrects deviations to sustainable conservation goals in a timely manner. This study advances previous studies as follows. Firstly, it is a better integration of the problematic aspects of sustainability theory and the dimensions of the essential building properties, dividing the assessment into three dimensions, each with two orientations. The evaluation of each dimension is further subdivided into several evaluation elements to provide a relatively more integrated and scientific understanding of the factors affecting the sustainability of building properties. Secondly, by introducing a temporal dimension into the model, the problem of static, one-off in protection planning has been corrected. By placing the building attribute particles in a three-dimensional space-time coordinate system, their trajectory of changes, orientation targets and timely correction of deviations can be dynamically observed. The model could not only improve the accuracy of the building assessment, but also predict the development trend of building attributes. Thirdly, the evaluation in this study includes both historical buildings and other buildings, both as a comprehensive evaluation for historic area and for differentiated characteristic building in a proper way, reducing the fragmentation conservation problems caused by focusing only on historical buildings. The objectivity and integrity of the evaluation results are ensured.

The proposed model in the study is a practical tool to help management teams to improve the sustainable attributes of buildings in different types of historic district conservation projects. It can help managers to (1) identify the factors affecting building attributes, (2) measure the impact of the influencing factors on sustainable conservation, (3) predict changing trends in building attributes, and (4) categorize and control the main issues for improvement in different types of buildings to improve sustainability of the historic area as a whole.

The case analysis shows that the six changing trends in building attributes during the actual renovation of the Xijindu historic district are consistent with the three guidance types under sustainable values. The sustainable guiding building types include three categories and five sub-categories, named Type A—Authenticity-oriented type, Type B—Image-display type, and Type C—Cultural-oriented type. Under Type C, there are Sub-category

C-1, called Reconstruction building; Sub-category C-2, called Reproduction building; and Sub-category C-3, called Deductive building. Each type of building can be classified and guided in a sustainable targeted way.

Although the assessment model developed can be applied to the Xijindu Historic District to identify sustainability issues in the current project implementation, this project is not representative of all similar projects in China. In the future, more case samples could be used to obtain information on the sustainability of building attributes in the conservation process of historic districts. Meanwhile, the application of the model in this paper is not limited to sustainable conservation assessment of buildings in historic areas, but can also be transferred to assessment projects of building attributes in more complex and uncertain areas.

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Appendix A

Final Cluster Center

	Cluster		
	1	2	3
Structure	3	2	3
Form	4	2	4
Benefit	5	−1	−1

Number of cases in each cluster

Cluster	1	26.000
	2	89.000
	3	46.000
Efficient		161.000
Missing		0.000

Distance between the final cluster centers

Cluster	1	2	3
1		6.129	5.844
2	6.129		2.108
3	5.844	2.108	

Figure A1. K-means clustering analysis of historical buildings before renovation.

Final Cluster Center

	Cluster			
	1	2	3	4
Structure	−2	2	−2	2
Form	−1	2	−3	3
Benefit	−2	−1	−4	5

Number of cases in each cluster

Cluster	1	238.000
	2	79.000
	3	34.000
	4	9.000
Efficient		360.000
Missing		0.000

Distance between the final cluster centers

Cluster	1	2	3	4
1		4.695	2.859	8.276
2	4.695		6.885	5.938
3	2.859	6.885		11.039
4	8.276	5.938	11.039	

Figure A2. K-means clustering analysis of other buildings before renovation.

Final Cluster Center

	Cluster			
	1	2	3	4
Structure	5	1	0	5
Form	3	2	3	5
Benefit	2	−1	3	5

Number of cases in each cluster

Cluster	1	74.000
	2	30.000
	3	44.000
	4	45.000
Efficient		193.000
Missing		0.000

Distance between the final cluster centers

Cluster	1	2	3	4
1		4.252	4.611	3.446
2	4.252		3.977	6.941
3	4.611	3.977		5.109
4	3.446	6.941	5.109	

Figure A3. K-means clustering analysis of historical buildings after renovation.

Final Cluster Center

	Cluster 1	2	3	4
Structure	–4	3	–5	–5
Form	2	4	–4	–4
Benefit	4	4	0	4

Number of cases in each cluster

Cluster	1	9.000
	2	14.000
	3	22.000
	4	16.000
Efficient		61.000
Missing		0.000

Distance between the final cluster centers

Cluster	1	2	3	4
1		7.999	7.632	6.294
2	7.999		12.062	11.399
3	7.632	12.062		3.691
4	6.294	11.399	3.691	

Figure A4. K-means clustering analysis of other buildings after renovation.

Initial Cluster Center

	Cluster 1	2	3	4	5	6	7	8	9	10
Cluster Before Renovation	3	2	2	2	1	1	2	3	3	3
Cluster After Renovation	4	3	4	2	1	4	1	2	1	3

Iteration history [a]

Iterate	Changes within cluster centers 1	2	3	4	5	6	7	8	9	10
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

a. Convergence is reached due to no or small changes within the cluster centers. The maximum absolute coordinate of any center is changed to .000. The current iteration is 1. The minimum distance between initial centers is 1.000.

Final Cluster Center

	Cluster 1	2	3	4	5	6	7	8	9	10
Cluster Before Renovation	3	2	2	2	1	1	2	3	3	3
Cluster After Renovation	4	3	4	2	1	4	1	2	1	3

Number of cases in each cluster

Cluster	1	16.000
	2	44.000
	3	8.000
	4	16.000
	5	3.000
	6	18.000
	7	25.000
	8	3.000
	9	14.000
	10	11.000
Efficient		158.000
Missing		0.000

Figure A5. K-means clustering analysis of changes in the attributes of historical buildings.

Initial Cluster Center

	Cluster 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cluster Before Renovation	6	5	6	5	4	5	4	6	5	4	4	7	4	5	7	7
Cluster After Renovation	8	6	7	0	7	5	0	0	8	8	5	0	6	7	7	6

Iteration history [a]

Iterate	Changes within cluster centers 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

a. Convergence is reached due to no or small changes within the cluster centers. The maximum absolute coordinate of any center is changed to .000. The current iteration is 1. The minimum distance between initial centers is 1.000.

Final Cluster Center

	Cluster 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cluster Before Renovation	6	5	6	5	4	5	4	6	5	4	4	7	4	5	7	7
Cluster After Renovation	8	6	7	0	7	5	0	0	8	8	5	0	6	7	7	6

Number of cases in each cluster

Cluster	1	6.000
	2	14.000
	3	13.000
	4	30.000
	5	68.000
	6	9.000
	7	142.000
	8	15.000
	9	10.000
	10	16.000
	11	7.000
	12	8.000
	13	3.000
	14	14.000
	15	1.000
	16	5.000
Efficient		361.000
Missing		0.000

Figure A6. K-means clustering analysis of changes in the attributes of other buildings.

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