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ARCHITECTURAL EVALUATION OF HISTORIC SITES THROUGH SITE SURVEYS IN NINGBO CHINA

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Abstract

The preservation and renovation of historic buildings have aroused the public concern in the city of Ningbo, one of the most economically active regions in the south-eastern coast of China. The municipal government of Ningbo has targeted over 2,000 historic sites and been working on creating the database of these sites including building layouts and locations. The research team from the University of Nottingham Ningbo China, in collaboration with the government, had been working on the site survey and follow-up evaluation of a total of 44 historic sites. This study summarizes the site survey results of these historic sites, including building type, structure and construction materials, repair status, historic and architectural values, and present usage. Apart from the follow-up survey data, the research team also conducted further investigation on the retrofitting of a selected case building. Building information modelling, the newly emerged digital technology, was adopted to visualize the case building. The architectural evaluation motivates the exploration of maintaining the historical value and original character meanwhile improving the existing condition of these historic sites. Modern visualization technologies would be a potential tool on modelling the architectural, structural, and building service systems of existing buildings.

Keywords. *Historic buildings, conservation, building survey, building information modelling, visualization.*

1. Introduction of conservation of historic buildings

Under the pressures of a rapid and unprecedented development and urbanization, traditional housing in China has been under a constant threat. Entire neighbourhoods and villages have been demolished making place for contemporary housing aiming to increasing land efficiency and improving the living standard. However, this often results in loss of embodied energy, urban diversity and cultural identity. Although the conservation movement has helped to preserve some traditional housing, the need for old buildings to

meet modern standards of comfort and environmental performance remains a potential economic deterrent to conservation (Phillips and Ding, 2011)

1.1. INTERNATIONAL EXPERIENCE

Conservation of historic heritage has a long history, initially focusing on the repair and amending of buildings and other artefacts for their maintenance and aesthetic quality. The Venice Charter for the Conservation and Restoration of Monuments and Sites, a code of professional standards issued by the 2nd International Congress of Architects and Technicians of Historic Monuments, has been viewed ever since as a fundamental document reflecting the internationally accepted philosophy for protection of architectural heritage, and restoration architects throughout the world have been using it as a guide for their work (ICOMOS, 1964).

In the United States of America, Weeks et al (1995) in their guidelines issued by the Department of the Interior define the following treatment approaches to architectural conservation:

- Preservation "places a high premium on the retention of all historic fabric through conservation, maintenance and repair."
- Rehabilitation "emphasizes the retention and repair of historic materials, but more latitude is provided for replacement."
- Restoration "focuses on the retention of materials from the most significant time in a property's history, while permitting the removal of materials from other periods."

1.2. CONSERVATION OF HISTORIC BUILDINGS IN CHINA

Since the establishment of the People's Republic of China, China has effectively conserved many heritage sites that were in danger of being completely lost and, at the same time, has developed conservation theories and guidelines according to national conditions. The Law of the People's Republic of China on the Protection of Cultural Relics as well as interrelated laws and regulations define the legal framework for conservation practice. The Principles for the Conservation of Heritage Sites issued by China ICOMOS (2004) set the professional guidelines on the basis of these laws and regulations, while drawing upon the 1964 International Charter for the Conservation and Restoration of Monuments and Sites (The Venice Charter).

The case of Xiao He Zhi Jie (Little River Street), located in Hangzhou, China, bears some similarities to this research project. The case is described in Table 1.

Table 1. Xiao He Zhi Jie project outline description. (Source from Wu et al, 2010 and Phillips and Ding, 2011)

Location	Hangzhou City, located on the Xitang River, close to the intersection with the Beijing-Hangzhou Grand Canal)
Residents	120 households with 450 residents, many of them being retired employees
Situation before the renovation	High population density, outdated or no basic sanitation facilities, illegal construction, poor aesthetic condition, lack of neighborhood vitality and other common problems
Age of Buildings	Built in the late 19^{th} -20^{th} century.
Building Type	One or two-storey residential building of stone construction.
Construction	Hard stone and pole framing structures.
Building Category	Historic
Renovation Construction	Original construction retained where possible, some of the houses had to be rebuilt, using masonry walls and stucco.

According to Phillips and Ding (2011), old buildings in China are generally classified into one of three categories depending on their cultural significance: heritage, intermediate, and historic buildings. For heritage buildings, conservation will be undertaken only with original materials, and the original function of the building will be conserved wherever possible; intermediate buildings can be conserved for a different use from the original, although original materials will generally still be used in conservation works; the conservation of historic buildings can involve both a change of use and the introduction of new materials (Phillips and Ding, 2011). Similar to the case of Xiao He Zhi Jie buildings, targeted buildings for site survey in this research were also classified in the historic category.

This research conducted in the University of Nottingham Ningbo China (UNNC) started from site survey of historic sites in Qiu'ai, a suburban town of Ningbo, followed by data analysis of totally 44 surveyed historic sites. A case building was further explored using Building Information Modelling (BIM) to achieve the 3D visualization which led to discussions on future research.

2. Site survey of historic sites in Ningbo China

In the autumn of 2014, the City Architectural and Planning Bureau of Ningbo (CAPBN) contracted with UNNC on the site survey and database update of historic sites in Qiu'ai Town. Originally 54 historic buildings or infrastructure sites (e.g. bridges) were targeted from the documented

database. The survey work for each targeted historic site was led by one team consisting of one academic staff and three or four students within the Architectural and Environmental Engineering (ABE) department of UNNC. Each survey team was equipped with necessary tools such as laser measurement, scales, and cameras.

The survey report and database required by CAPBN included the building type (e.g., residential, public building such as temple), evaluation of building values (i.e., historic and cultural value, architectural style, construction quality, status of damage), and other general information such as ownership, floor area, and gross floor area, etc.). Each item of building values was divided into A, B, C, and D, with A being the best or least damage, and D being the worst or most seriously damaged. The evaluation criteria for building values were peer-discussed with counterpart researchers in Ningbo and CAPBN to maintain the consistency among different survey teams. An example of the building evaluation according to site survey work is displayed in Table 2.

Table 2. An example of the building value evaluation based on site survey

Photographs*		Description
		A residential house consisting of identical units, built in The Qing Dynasty (from 1636—1912), partly renovated after 1912, is representative of the residential house over a century ago, with certain historic values. The historic value was evaluated as in Category C.
		This building was designed in the courtyard style, with tight layout, consisting of the hall, and flats on both sides as well as the centre as displayed in Figure 1. The architectural style was evaluated as B.
		The courtyard, front door, and roof were mostly well maintained. The wood beam, column, and their joints were built with traditional features. The construction quality was evaluated as B.

		Apparent cracking occurs in the north side of the internal walls. Some wood columns have decayed with weak connections to the concrete support. The status of damage was evaluated as C, damaged at certain level.

*: Only part of photographs is included in Table 1 for demonstration purpose. More photos were taken during the site survey to assist in building value evaluations.

Before the start of each site survey within the rural villages of Qiu'ai town in Ningbo, usually the local contact would be assigned by the CAPBN to assist the UNNC team to find the target sites. The survey team would also identify the target site in the local map. The site tasks of the UNNC survey team were allocated, with the academic staff being the manager communicating with the local contact to collect information such as the site history and existing usage or living condition, one student assistant taking site photos, two or three students collaborating to conduct the site survey with the assistance of the laser measurement tool. The survey team measured the external layout of each site, as well as the internal partition elements such as walls, and other structural elements such as columns. For buildings, window/door locations and sizes were also surveyed. The 2D drawings were generated by Computer Aided Design (CAD) afterwards according to the site survey results. Figure 1 displays the CAD plan drawing of the example building described in Table2. The CAD drawings (only in 2D plan views) for each surveyed site became part of the database provided to CAPBN as one project deliverable.

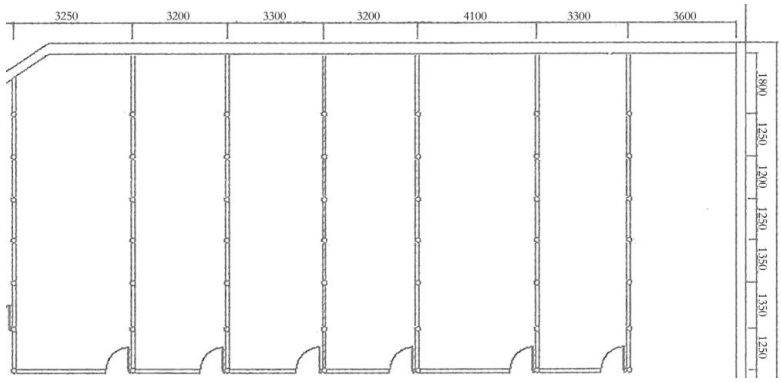
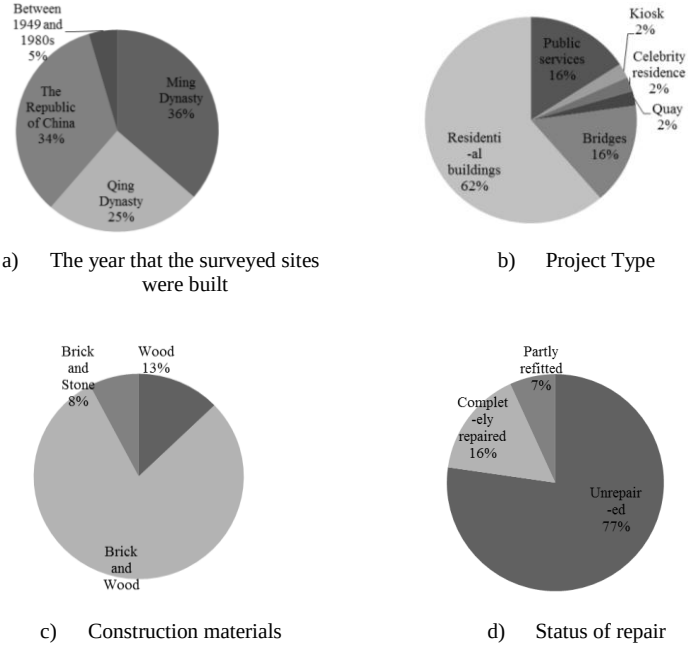


Figure 1. CAD drawing of the building's plan view according to the site survey

By the end of May 2015, in total 44 historic sites within 17 villages of Qiu'ai Town were visited during this period. Another ten targeted buildings

had been demolished due to various reasons including providing spaces for new building construction, new railway, new pavement, or land under the new development plan. The site survey report is summarized statistically in Figure 2.



a) The year that the surveyed sites were built

b) Project Type

c) Construction materials

d) Status of repair

Note: the year that buildings were constructed could only be identified within a certain historic period: Ming Dynasty (between 1368 and 1644), Qing Dynasty (between 1636 and 1912), The Republic of China (between 1912 and 1949), and People's Republic of China (after 1949).

Figure 2. Statistical report of the building survey

The statistical analysis of the surveyed historic sites displayed in Figure 2 includes the year that the building or infrastructure project was constructed, the status of repair, original construction materials used, and the type of projects. The majority (95%) of the sites surveyed were built before 1949, and 61% of sites were built over a century ago. The majority (80%) of surveyed sites were buildings, including residential buildings, public services buildings such as temple, celebrity residence, leaving the remaining 20% being infrastructure sites including bridges, kiosk, and quay. Wood and brick were the most frequently used construction materials among these surveyed buildings, accounting for almost 80% of the survey sample. Only 16% of sites had been completely repaired. Figure 3 provides an example showing the status of repair of a single residential unit displayed in Figure 1.

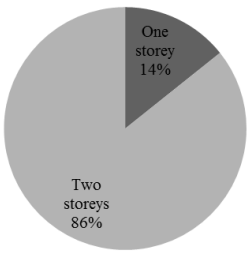
The original weakened wood structure had been replaced with modern reinforced concrete materials.

a) Replacement of the original wood column with reinforced concrete structure

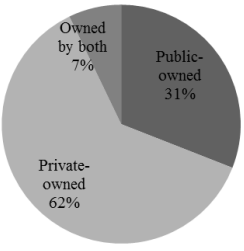
b) Replacement of the original wooden panel wall with masonry / concrete

Figure 3. An example showing the repair status of a surveyed historic building

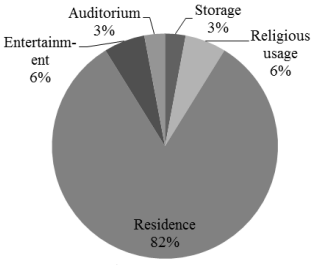
Apart from the statistical summary of the survey sample in Figure 2, the usage and ownership related data was also one of the research deliverables. Based on the site survey information collected, further data summary is provided in Figure 4 displaying the buildings' storey, type of current ownership, and the current usage.



a) Buildings' number of storeys



b) Current ownership



c) Status of current usage

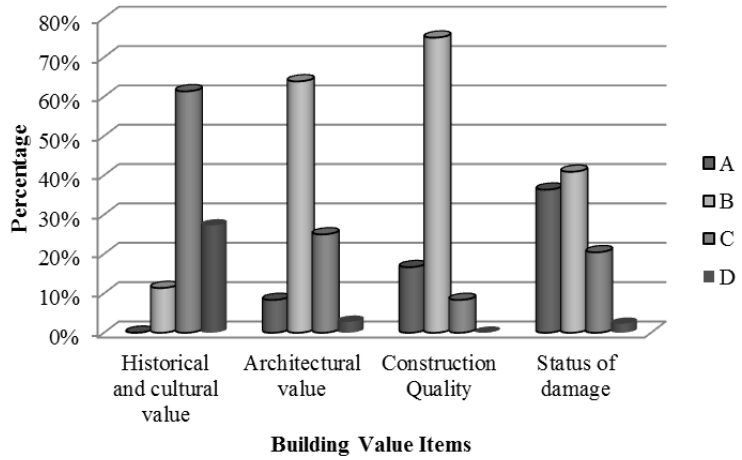
Note: the data sample of storey number and current usage excluded bridges, kiosk, and quay. But the type of ownership was analysed within the whole sample of 44 sites.

Figure 4. Further data summary of the surveyed buildings

Most buildings in this survey were constructed in the two-storey type, and over 80% of them had been used for residential purposes providing the living spaces for lower-income families. For example, each single residential

unit of the residential community shown in Figure 1 was rented to a family consisting of two to three residents.

The evaluation of surveyed sites categorized by four different levels was analysed in Figure 5.



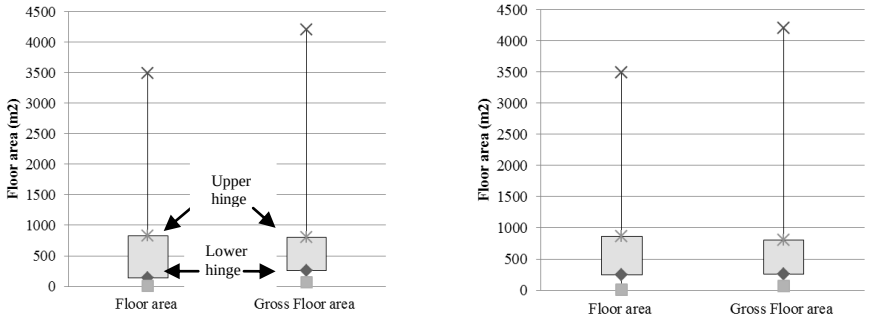
Note: for evaluation of the historic and cultural value and status of damage, all the 44 surveyed sites were included. For the evaluations of architectural and construction quality, only the 35 buildings were included for the data analysis.

Figure 5. Statistical summary of buildings' evaluation results

Apart from Table 2 describing the categorization of an example surveyed site's evaluation results, images for different categories in Figure 5 were further added in the appendix. The majority of the surveyed sites were categorized as B or C level in terms of historic and cultural value, and architectural value. Over 70% of the surveyed sites were found falling into the category of B in terms of construction quality. Only 36% of the surveyed sites were found with the minimum level of damage, and over 60% of surveyed sites were in the Levels B or C considering their damage status. Noticing that most surveyed buildings were being used as residential flats, there should be concerns raised on renovating the existing buildings for the safety and comfort living conditions for residents. Some of the surveyed residential buildings were found with inappropriate window orientations or lacking shading devices in the summer, which resulted in high indoor temperature in the summer and low solar gain with high humidity in the winter.

Further statistical analysis was conducted as part of the research project deliverables to summarize the sizes of the surveyed buildings or infrastructures. Floor areas and gross floor areas were the two measurements

of project sizes. The data is analysed in Figure 6 using box plots, which conveys the data information regarding surveyed site size distribution in terms of the minimum, first quartile, median, third quartile, and maximum values of floor areas and gross floor areas.



a) Box plot of data including all surveyed sites

b) Box plot of data excluding bridges, kiosk, and quays

Note: the data sample of floor area covers the whole sample of the 44 surveyed sites, but the data analysis of gross floor area (i.e., total floor area of all storeys) only included the 35 buildings.

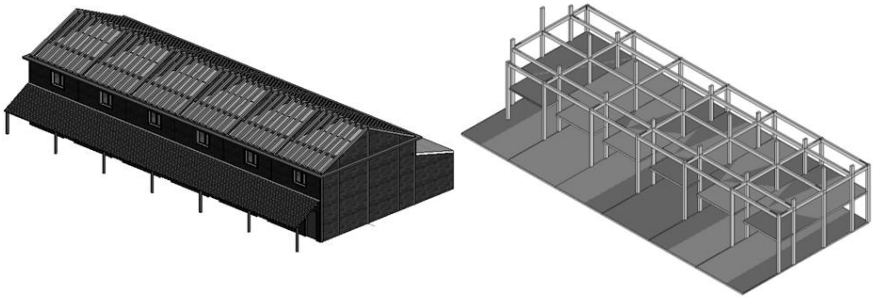
Figure 6. Box plot of surveyed buildings' floor areas

The upper and lower hinges in Figure 6 show the first and third quartiles of the data sample. The centreline between the upper and lower hinges indicates the median value of site sizes. It can be read from Figure 6 that the median values of project size with all 44 sites included were 304 m^2 and 489 m^2 respectively for floor areas and gross floor areas. When the infrastructure projects were excluded, these median values for the 35 buildings became 427 m^2 and 489 m^2 respectively. The minimum values in both Figure 6-a) and Figure 6-b) were the same at 7 $m^2$and 60 m^2 respectively. It can be found from Figure 6 that in both cases, whether the floor area data of infrastructure sites were included or not, the floor area and gross floor areas were highly skewed from the normal distribution due to the large sizes of some sites with maximum values of areas at 3491 m^2 and 4204 m^2 respectively.

3. Case study of a historic building

As the continued work from historic site survey and data collection which ended in May 2015, BIM technology was adopted in visualizing the current building's architectural details. The residential building illustrated in Table 1 and Figure 1 had the typical architectural style within Ming and Qing dynasties of China. It fell into the category of residential usage, constructed by bricks and wood with its damages unrepaired. Based on its representativeness of its project type, construction materials, status of repair, as well as its cultural, architectural, and construction values according to

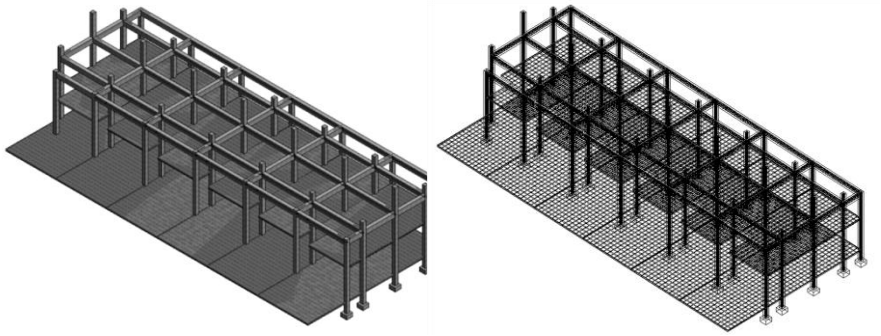
Figure 2 and Figure 5, it was selected as the BIM case study. Figure 7 visualized the building in Figure 1 by displaying the continuous six residential units in the Revit Architecture Template.



a) Visualization of the current building b) Wood structure model

Figure 7. Visualization of the six identical residential units in the case study

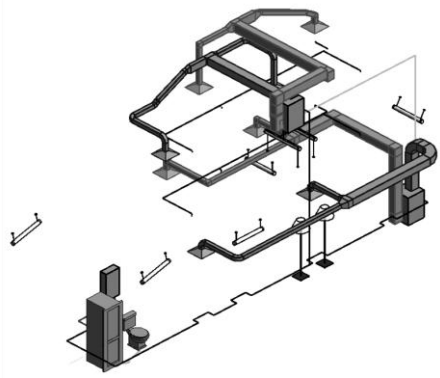
The existing residential units in Figure 7 used wood framing structure, which had been decayed and weakened. The reinforced concrete framing structure was modelled in the Revit Structure template as displayed in Figure 8.



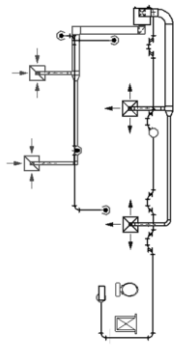
a) Alternative plan for the structural model b) Reinforcement details for the alternative structural model

Figure 8. Alternative plan for structural renovation

Based on the site survey work of these six residential units including the investigation of the existing building services systems, the newly proposed building service facilities were modelled in the template of Revit MEP (i.e., mechanical, electrical, and plumbing) template as displayed in Figure 9.



a) The proposed plan for building services systems for a single unit



b) Plan view of the building services in one residential unit

Figure 9. Suggested plan for the improvement of building services system within a single residential unit

The proposed building services included lighting, water supply, air conditioning, and fire sprinklers to be added to the existing residential unit. The fluorescent lamps were suggested due to the higher efficiency and energy saving potential. Apart from the existing water pipeline added in Figure 6 to supply water, fire sprinklers were suggested. The site survey revealed that the old wood building is vulnerable to fire. Fire sprinklers could be designed at working temperature of 57℃. The air conditioning system was proposed to maintain the humidity of the wood building, to prevent decomposing due to the tropical climate in Ningbo, and to improve the indoor comfort of human-beings.

4. Summaries and Discussion

The statistical analysis of the surveyed historic site sample provided the data on the current status of the reservation of historic sites in Qiu'ai Ningbo. Further suggestions would be necessary for the local government to weight between maintaining the cultural heritage and allowing spaces for new construction. It had been found from the survey that ten out of 54 original targeted historic sites had been demolished given space to new construction. Although most residential buildings had still been in use today, there were problems remaining to be solved in the near future. For example, as the data indicated, most buildings had not been repaired and could cause emergency in case of natural disaster. Even for some of the repaired structures, the reinforced concrete materials were not in harmony with the original wood construction in terms of architectural aesthetics.

Apart from the building site survey and data analysis, further study of utilizing BIM as the digital tool was conducted to visualize the current architectural and structural models, as well as the proposed improvement plan to strengthen the existing structure. The BIM work provides the learning opportunities for undergraduate students in the ABE and CE departments of UNNC in digital modelling practices. BIM would display higher potential in larger-sized building design and construction in detecting spatial conflicts. The application of BIM in a smaller building in this case study is the starting point for follow-up studies of digitalization applied in the reservation of historic buildings.

BIM, as the emerging digital tool in today's architectural, construction, and engineering industries, could be more widely adopted in the future research projects of historic buildings. The benefits of BIM application include accurate geometrical representation of building elements and better control of cost, environmental, and lifecycle data (CRC Construction Innovation, 2007). BIM enables the multidisciplinary collaboration starting from the project designs of architectural, structural, and building services. According to AIA California Council (2007), using BIM in the project criteria design stage could allow different options to be evaluated, tested, and decided. In a project using BIM, the model can be used to test "what if" scenarios (AIA California Council, 2007).

5. Conclusion

The historic site survey research project in the suburban area of Ningbo China provided the local government with updates in light of current repair status, cultural and architectural values, current usage, as well as other information such as years of history, construction materials, and floor areas. The data generated from this project would lead to further decisions on reservation, renovation, or demolition of these existing buildings. Strengthening the weakened wood structure and improving the indoor living condition would be two suggestions from this research. Apart from the data summary report as well as the 2D CAD drawings provided as the research project deliverables, this study further adopted visualization tools in BIM starting with a case study from one surveyed residential site. BIM has demonstrated its potential in visualizing the existing architecture, proposing alternative plan for renovation, and advising the improvements of building services systems.

6. Recommendations for future research

Based on the current work, the future research of historic site survey and evaluation could focus on two areas related to the 3D visualized historic building database and renovation targeting on energy efficiency:

- Apart from extending the visualized model from single residential units to cover the whole community, other historic buildings, especially those with high cultural and architectural values could be created with visualized models by adopting BIM. Therefore, the 2D CAD database could be updated with the 3D platform.
- Some of the residents in surveyed residential buildings were suffering from poor daylighting, high indoor humidity, and uncomfortable living condition due to improper ventilation. BIM could be linked to building energy analysis tools to perform renovation study of improving the energy efficiency and indoor living condition of the residents. The study of achieving the architectural renovation, structural strengthening, and energy efficiency while maintaining the cultural features of these historic buildings would motivate cross-disciplinary collaboration by adopting BIM and building analysis tools for the future study.

Acknowledgement

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Appendix: Images of Different Categories in the Historic Site Evaluation

Category	A	B	C	D
Historical and Cultural Value	**N/A**			
Architectural Value				
Construction Quality				
Status of Damage				

Note: 1: No example of category A in the evaluation of historical and cultural value from the surveyed sites as indicated in Figure 5; 2: The evaluation of each site's values were based on a comprehensive review and discussion among research team members, and one single image in the appendix may not be fully representative of each category.