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Smart Heritage Practice and Its Characteristics Based on Architectural Heritage Conservation—A Case Study of the Management Platform of the Shanghai Federation of Literary and Art Circles China

Heng Song [1,*], Gehan Selim [1] and Yun Gao [2]

[1] School of Civil Engineering, University of Leeds, Leeds LS2 9LG, UK
[2] Shanghai Historical Building Protection Administration Centre, Shanghai 200003, China
* Correspondence: cnhs@leeds.ac.uk

Abstract: This article aims to find out the process for achieving smartness in urban architectural heritage conservation, maintenance, and operation and identify characteristics of the so-called smartness. It seeks to provide an example of introducing smart ideas into architectural heritage while encouraging more conservation. The discussions among architectural heritage conservation under the smart discourse are scattered in virtual applications, digital involvements, tourism, etc., and an integration method is worth considering. This article selected a platform for architectural heritage conservation and management of the Shanghai Federation of Literary and Art Circles (SFLAC), China. An integrated literature review is conducted to locate knowledge gaps. Thematic analysis is used for data analysis to develop the practising procedure and smart heritage features. Current practices lack a systematic consideration based on the perspective of conservation and management, which details applications for various groups in correspondence to stages. Interviews and policy document analysis were conducted to support the investigation. Smartness for architectural heritage should include policy guidance, digitalisation, platform integration, applications, and optimisations and has the feature of evolvement. Its practice should first promote heritage preservation and consider the benefits of different users, cultural inheritance, and urban regeneration based on different time durations.

Keywords: architectural heritage; heritage conservation; digital heritage; smart heritage; smart cities

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1. Introduction

Architectural heritage may represent an urban or rural space which witnessed a specific civilisation, an important advancement, or a historic event [1]. It differs significantly from other heritage fields in the masses and details, synthesis of materials, structural systems, aesthetic qualities, and spaces suited to support human activities [2]. Architectural heritage in China generally includes nationally listed immovable cultural relic protection units and locally listed historic buildings and monuments.

According to the Venice Charter or the International Charter for the Conservation and Restoration of Monuments and Sites (1964), conservation refers to retaining or preserving heritage fabrics and preventing further loss. Architectural heritage conservation inclines to a comprehensive term over time as cultural, historical, and built contexts need to combine. Recently, it has been defined as a broad concept that comprises plans of heritage safeguarding and promotion, as well as digital technologies and applications like databases, virtual reality (VR), augmented reality (AR), digital museums, social networks, etc. [2].

Smart discourses have risen and evolved in many disciplines in both academia and industry. From the macro perspective, such as smart cities, to smartness in a precise space, such as smart buildings and smart museums, all smart-relevant proposals are seeking innovations from technologies and humanities [3]. Following the penetration of smartness into every urban component, including heritage conservation, the discussion about smart heritage has started and progressed for more than a decade [4,5].

The smart side of smart heritage may highlight the perception and management of heritage-relevant issues via using cutting-edge technologies. This discourse is still novel on both technological and heritage sides. The arrival of digital innovation has contributed to the administration of urban heritage conservation and restoration [6]. Smartness in urban architectural heritage is regarded as linked to smart city understandings and can be interpreted as digitalised historic buildings with 3D modelling technologies for conservation and other applications based on the integration with diverse urban components [5].

The emergence of smart city proposals throughout the world has fuelled ongoing discussions on urban regeneration, which is viewed as a way to revitalise and improve depressed areas to meet sustainable development goals [7,8]. However, it seems that urban architectural heritage has not received enough attention from smart cities. Channels for heritage organisations to contribute to the co-development or co-design of services within smart city initiatives are still missing [9].

As a particular component of urban development, digital to smart heritage conservation needs support at both national and local levels to be practised. The full cover of digital technologies by planning practice affects the conservation of tangible heritage [10]. In academia, there are many relevant smart applications and implementations of architectural heritage conservation. They can be generally summarised as two groups: one is the focus on a single aspect of conservation (e.g., digital reconstruction and display) [11,12], and another is favouring services for tourism or urban renewal [3,13–15].

Rapid urbanisation, urban regeneration, and the need for continuous economic growth have attracted increasing attention to smart issues. Whether these concerns can be meticulously applied to urban heritage conservation remains to be further verified. The intervention of digital means in heritage conservation has opened up the discussion of smart heritage. However, this process also faces problems such as data fragmentation and complicated systems with poor usability [6].

To prevent architectural heritage from being ignored by rapid urban development and to solve problems in conservation and management, this study seeks to deepen discussions in the smart heritage discourse. Currently, understandings about heritage smartness in both tangible and intangible aspects have evolved for some years; however, detailed interpretations and implementations in smart heritage, especially for urban architectural heritage, seem in need of investigation.

This research aims to bridge the gap in the method of achieving smartness in urban architectural heritage conservation, management, and operation with necessary considerations. Research objectives can be listed as proposing a smart method for urban architectural heritage conservation and promotion, investigating supports for innovative urban architectural heritage preservation and management, and finding out characteristics of heritage smartness, with the hope of evoking similar developments to better preserve architectural heritage in a city.

Smart heritage development comprehensively serves urban administrators, heritage conservation professionals, planners, etc., to conduct their work and corresponds to urban digital, as well as smart, transformation. It is anticipated to answer how to develop smartness in urban architectural heritage conservation and management, why it should be developed, what initiatives have been implemented, and what the features are.

This research takes the management platform of the Shanghai Federation of Literary and Art Circles (SFLAC), China, as a case study. This platform provides fundamental functions for digitalisation and interaction while integrating various sources. As a historical and economically developed city in China, there are many examples of architectural heritage scattered throughout Shanghai. National and local authorities attach great importance to conservation via various modes, including restoration, relocation, reconstruction, etc. [16,17].

Insights from urban operation and heritage conservation in Shanghai under China's evolving smart approaches hope to offer valuable perspectives of innovative heritage preservation in the increasingly urbanised world. An integrated literature review is included in Section 2 to consolidate the conceptual foundation and identify the knowledge gaps according to relevant developments. Following this, the case study and methodology are illustrated, respectively. Section 3 demonstrates the results of the analysis, after which are the Discussions and final Conclusions sections.

2. Materials and Methods

2.1. Conceptual Foundation and Relevant Developments

2.1.1. Architectural Heritage Conservation in the Digital and Smart Contexts

There are different levels of intervention and classification for architectural heritage conservation around the world. For different situations, the more common ones are documentation, preservation, stabilisation, repair, strengthening, reconstruction, relocation, and adaptive reuse [18]. The increasing highlighting of sustainability in the architecture, engineering, and construction (AEC) field reminds us that pure conservation may not match sustainable requirements in heritage aspects, while sustainable utilisation of the built heritage should be considered for redevelopment.

In the heritage discourse, the virtual record creates a novel background for heritage conservation. Heritage smartness tends to integrate technologies, history, and people in the whole process of conservation. An online–offline on-site heritage operation system based on service data analysis of the Chinese national archaeological site and park Yuan Ming Yuan was developed by [19] for heritage conservation and operation. The highlight of smartness starts from digital display to heritage management and services for various end users. Dissemination of history and culture for tourists is the main focus of the system.

Heritage, conservation, and smartness can all be seen as broad terms which comprise various aspects and details. Digital technology for modelling, representation, and surveying has resulted in significant evolvements in heritage conservation as the use of technologies such as laser scanning, photogrammetry, AR, VR, and IoT facilitates data collection. These adoptions in heritage consolidate the development of digital documentation, which records the current state and provides the required context for both past and future research while preserving heritage [20].

Digitalisation for heritage is one of the most relevant representatives of heritage conservation and smartness. A three-dimensional (3D) archive system to store and report all information of each desert palace in Jordan was proposed by [21], in which digital cameras and terrestrial laser scanners (TLS) are proposed to be combined to maximise the efficiency of data collection, image quality, and geometric accuracy of the palace [21]. Virtual environments of heritage buildings are anticipated to be created to enable people such as archaeologists to see and conduct their simulations.

The more frequent the use of applications, including photogrammetry, TLS, 3D modelling, VR, AR, geographic information system (GIS), building information modelling (BIM), Internet of Things (IoT), and wireless sensor network (WSN), etc., the more contributions to surveying, modelling, visualising, and management of architectural heritage. A VR model for heritage digitalisation and interactive simulation was proposed in 2010, in which innovative haptic devices were included to support successful collision detection and users' interactions with heritage [22].

The feasibility and challenge of AR via a simulation in a block in Cagliari, Italy, was tested by [15] in 2014. The case study demonstrates the benefits of using AR on mobile devices, including dynamically bringing attractive solutions for heritage conservation and cultural promotion via heritage tourism. However, historical sites may be increasingly in danger of being lost due to greater exposure to tourism [23].

The emergence of BIM in heritage brings new chances for information documentation and conservation. Murphy et al. (2009) detailed the procedure from remote historic building data collection via laser scanning to developing engineering drawings in CAD and 3D models [24]. They first proposed using BIM technology in historic buildings, known as heritage/historic BIM (HBIM).

The involvement of BIM technology in heritage brings potential for conservation. On the side of supporting heritage building rehabilitation, Del Giudice and Osello (2013) investigated how BIM can be used to refurbish architectural heritage via the case study of the old thermal power of Politecnico di Torino. Such technology enables professionals to handle heritage data and query 3D models [25].

For heritage documentation, López et al. (2017) presented architectural heritage virtual reconstruction via manual modelling using BIM and developing parametric elements library under HBIM. The development of the HBIM library is regarded as a supplement to BIM software platforms within a broader context of smart heritage [26]. The storing of cultural and historical documents, as well as monitoring and simulating data for conservation, is a gap in the BIM capacity [27].

The technological adoption is advanced via the combination of unmanned aerial vehicle (UAV) photogrammetry with TLS for data collection in the study of [28]. The Cortijo del Fraile case study in Njar, Almera, Spain, was evaluated using HBIM for ancient structures in a ruined state. The HBIM model from this study presents a great example of digital involvement in architectural heritage for visualisation and documentation.

On the other hand, IoT and WSN are widely applied to structural health monitoring of both archaeological sites [29] and historic structures [30]. For architectural heritage, the study of Lerario and Varasano (2020) was devoted to finding a solution towards the threat to heritage buildings posed by unexpectedly high visitor volumes based on WSN and IoT. The practised smart sensing infrastructure benefits structural safety monitoring and even affects future applications with the involvement of more advanced technologies to conduct simulation and prediction [31].

The technology-driven preservation of architectural heritage makes researchers wonder how to sustainably store, integrate, and use information obtained via different cutting-edge technologies. According to the above studies, smartness in architectural heritage conservation requires digitalisation as a foundation and relies on integration and coordination of technologies and services via a system or platform.

2.1.2. Platform Developments Associated with Smart Heritage

The use of a platform to integrate heritage data and coordinate actions may detail different sub-themes in heritage. A platform for achieving interactions in teaching and training is developed by [32] based on the visualisation of complicated architectural heritage objects. A World Cultural Heritage site of an urban area in Segovia, Spain, and severely damaged churches are selected as examples to see the roles of advanced visualisation technologies and the learning software platform in the evaluation of damaged heritage rescuing plans.

Professionals and technicians in architectural heritage and construction consist of two focused groups for the application of the introduced platform. The compatibility of this platform helps to develop connections with general GIS applications for urban buildings and areas, under which urban managers or planners can track and identify measures taken for heritage restoration [32].

To manage, protect, and transmit information about both tangible and intangible cultural heritage reliably in the smart city context, the design and realisation of a multifunctional and multidisciplinary digital platform is introduced [33]. While digitally managing heritage content, the platform presents a great example of extending digitalisation to numerous data sources and integrating them to solve corresponding problems that smart city development is struggling with.

The ultimate goal of developing this platform is to create an online virtual space for researchers, professionals, artists, children, parents, and technicians to gain different information and participate in heritage conservation. It consolidates the potential of expanding ideas, technologies, and applications from smart cities to urban heritage while combining various people and services to create a particular heritage community and result in education [33].

For the archaeological presentation and historical reappearance, an open-public website integrating research, archives, and survey datasets is developed for the world heritage site Umm Qais to restore history and enable virtual touring and learning [34]. With similar functions, a WebGIS system providing remote visiting based on multimedia files, 360° panoramas, 3D models, and 2D historical evolution schemes is analysed [35]. The direct beneficiaries of these platforms can be generally understood as heritage professionals and tourists.

With similar considerations among visitors, a novel multimedia platform tailored to user preferences has been developed and applied to an industry-related cultural heritage site, Strijp-S, in Eindhoven, Netherlands [36]. Through the use of 3D models and VR, this suggested platform offers a perspective on multimedia platform system design and has the potential to improve public awareness of heritage preservation. With a map-based metaphor, the multimedia platform enables users to access various contents, including 3D models, texts, and videos, by retrieving information filtered by their interests [36].

Furthermore, this platform in Strijp-S allows users to upload information based on their experiences, aiming to enrich the database. For instance, a user can attach the experience that corresponds with a chosen heritage object in the 2D map. According to a specific format that is compatible with the formats of VR and 3D models, the user can upload related texts, photos, or videos to share the experience. Although there are drawbacks to this platform, such as the platform being more interactive and the 3D model not working properly, it is a great addition to receiving information about the heritage, events, and other details [36].

For cooperation, an online platform enabling interdisciplinary professionals to communicate and collaborate is developed by [37], which is used to integrate and administrate projects of heritage registration. The platform first addresses the problem that HBIM is facing: inadequate historical records and challenges in coordinating information of various participants. It stores heritage information in the cloud and enables relevant people to work in the same virtual environment. This study innovatively integrates HBIM with traditional registering modes to ensure the accuracy and non-repeatability of heritage data, though it did not pay attention to 3D modelling based on HBIM [37].

To promote interactions between different stakeholders of architecture heritage conservation and management, the Qatar Historic Buildings Information Modeling (Q-HBIM) platform was developed based on digitalisation for architectural heritage sustainable and interactive archiving [38]. Through the development and practice of the Q-HBIM platform, it can be seen that conservation policies in line with constant refinement and particular conservation authorities are decisive for transferring the semantics of cities and architectural heritage into a structured digital database [38].

Based on manual investigation, the data collected according to the current status, materials, and history are categorised, after which 2D drawings and 3D models are subsequently developed [38]. Linkages between relevant semantic data and 3D models are anticipated to be conducted at the final stage. The Q-HBIM platform provides functions including classifying and analysing information while seeking to meet the need for interactive and publicly accessible historical information.

In conservation state analysis, digital analytical techniques are combined in building restoration with 3D documentation, under which investigations of advantages in multi-scale and discipline digitalisation for architectural heritage restoration are carried out [39]. A platform based on HBIM is developed to emphasise potential effect of data integration, methodologies, and workflows on renovation and updates. The proposed paradigm has to cope with challenges from rapid urbanisation and issues caused by climate change, though it is a good example of innovative vernacular architectural heritage conservation [39]. The successful implementation of heritage management and conservation platforms in a city needs to become compatible with the requirements of urban development in time.

2.1.3. Relevant Developments in China

The techniques relevant to digitalisation and conservation, including 3D scanning and high-precision measurement, have notably improved the quality of architectural heritage conservation in China [40]. Innovative heritage conservation has evolved from traditional digitalisation to remote real-time monitoring and detection based on the interventions of digital mapping, IoT, WSN, photogrammetry, reverse modelling, etc.

Detailed models can be achieved subsequently by docking heritage data with modelling software such as 3Ds Max and SketchUp to support heritage space renovation design and renewal [40]. Achievements of the above-mentioned processes for heritage conservation and management rely on cross-technological collaborations and digital platform constructions. Researchers and professionals in China have recently undertaken a large number of conservation-relevant developments for heritage.

The possibility of extending BIM into heritage landscapes to achieve digital conservation is studied by [41]. Components of a BIM model should be comprised in the digital archive of a heritage landscape, and intangible elements, including traditional handicrafts, are crucial, as the primary information need of a heritage landscape focuses on oriented people rather than a virtual environment [41]. The proposal based on a heritage landscape outlines the importance of people or users and the necessity of valuing heritage in urban social, cultural, and economic promotions, even if a representative application related to platforms has not been reached.

Digital technologies, including 3D scanning, photogrammetry, and infrared thermal imaging, are adopted in the study of [42], in which the ground subsidence, deformations of walls, moisture distributions, etc., of the Beamless Hall at Linggu Temple in Nanjing are shown using different pseudo-colours. Digital drawings of heritage structures can include more information and be more intuitively readable thanks to graphical surveying and mapping data. The subsequent step of upgrading the application is to combine 2D information with 3D models to create a methodical and user-friendly data management approach for visual interactions of heritage managers, experts, and tourists [42].

A well-rounded scheme of preserving and using digital restoration of architectural heritage is provided by [43] while valuing knowledge visualisation. A digital platform has been developed for the architectural heritage management of Qinglian Temple in Shanxi, China, in which a detailed 3D model is available for users to conduct virtual touring based on permission. Digital utilisation on the platform serves as an innovative carrier of knowledge. This platform aims to promote local cultural heritage by enabling professionals, researchers, and even tourists to easily receive knowledge. On the other hand, it provides multiple dimensions of management, including data, systems, and users.

Current applications have covered everything from heritage digitalisation and visualisation to remote monitoring and touring. Considerations for heritage smartness beneficiaries range from heritage administrators, researchers, and conservation professionals to tourists, artists, etc. However, there is a lack of systematic guidance on which stage to consider what kind of group. The consideration for urban managers and development is still insufficient. More efforts for the improvement of heritage conservation awareness, such as the case conducted in the Netherlands [36], could be referred to in China's context. Following the outcomes of [38], platform developments rely on support from conservation-relevant charters and authorities.

In China, digital and smart interventions in urban architectural heritage in many places are still at the theoretical framework stage, but there are places with relatively good policy conditions, such as Guangdong Province [44] and Shanghai. Advances in digitalisation and increasing consciousness of sustainability have resulted in the growing demand for trustworthy information on each urban component [45]. They fill gaps left by traditionally unrecorded architectural heritage while collecting and integrating comprehensive data.

Based on the review, current practices relevant to heritage digitalisation and smartness seem isolated and not systematic. Meanwhile, pure digitalisation without integration and collaboration may be insufficient to maintain urban sustainability. Tentatively, the anticipated smart heritage method for conservation, management, and urban operation relies on positive policy contexts and consists of multiple stages, from digitalisation to integration and application with the involvement of a platform.

2.2. Case Study—The Management Platform of the Shanghai Federation of Literary and Art Circles (SFLAC), China

To find the way and meaning of smartness in urban architectural heritage conservation and management, needed supports, implemented initiatives, and features, this study takes the management platform of the Shanghai Federation of Literary and Art Circles (SLFAC) in China. The reason for this is that the development of this platform is a representative local pilot of innovatively preserving and managing urban architectural heritage from digitalisation to integration and application.

As an economically developed city, there are proposals and applications relevant to smartness in Shanghai. The selected case study represents penetrations of smart discourses into architectural heritage conservation. With China's smart ways becoming increasingly integrated, innovations in heritage and other urban components in Shanghai could provide insightful views on creative approaches towards conservation, management, and operation.

A great deal of original information about the historic building of SFLAC remains in the traditional archiving form, and some pieces of information were even missing. There were difficulties in identifying potential risks to the historical structure and communicating between conservation staff, heritage experts, and administrators of governmental heritage departments. And the inefficient disposal of conservation issues was anticipated to improve.

After completing the renovation work of SFLAC in 2021, the selected case study—a digital platform for conservation and management—was developed by technicians for scanning, monitoring, modelling, user interface design, architectural historians, etc., under the national and local regulations and guidance in urban digital transformation. Most functions (the interface architecture is shown in Figure 1) of the platform have been achieved in the past two years, while some work is still progressing. The interface consists of left, middle, and right parts. Each component is introduced in detail in the following paragraphs. The platform is now accessible to relevant authorities.

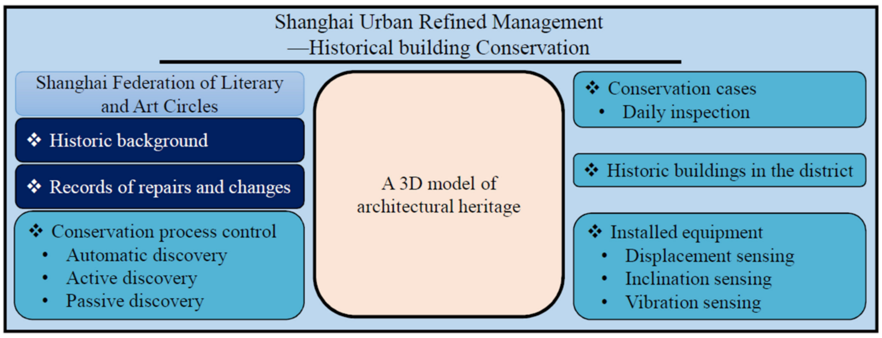

Figure 1. The overall interface architecture of SFLAC platform (by the authors).

The SFLAC platform is not open to the public yet. Due to the sensitivity of raw data and the original interface being displayed in Chinese, the images of the platform presented in this article are redesigned based on the original one, with translations from Chinese to English made by the authors. All contents and functions of the platform are not changed or omitted. Accuracy and rigour of demonstration and analysis are not affected.

This platform aims to first develop digital documentation and recordings for the historic building, then integrate heritage resources and support heritage conservation for users of the building, heritage-relevant staff, and governmental officials via different functions. The left side of the interface includes a historical overview and records relevant to the conservation of SFLAC (as shown in Figure 2). The part of conservation process control is under it.

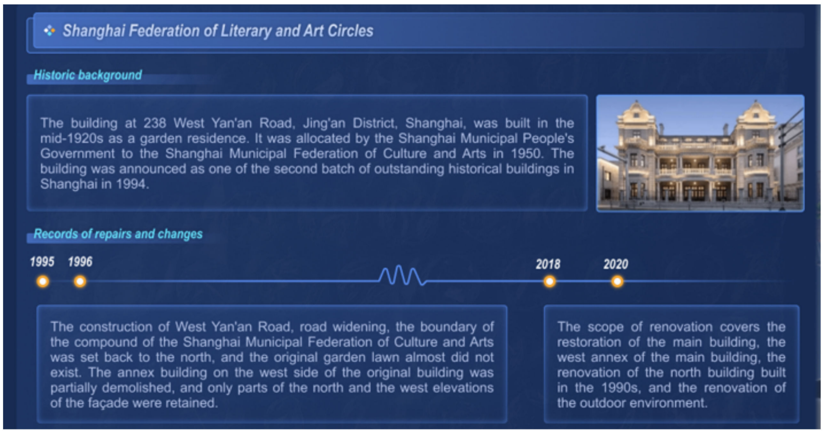

Figure 2. The general information and control section of the interface (by the authors).

This historic building is located at No. 238 West Yan'an Road, Jing'an District, Shanghai, which is the office of SFLAC. It was originally built in the mid-1920s as a garden residence with fine details and was listed in the second batch of excellent historic buildings in Shanghai (EHBS) in 1994 [46]. The overall building area is close to 3000 square metres, and the main building has three floors [46].

The historic building of SFLAC is a fine example of a modern garden house in Shanghai with high historical and artistic values [47]. Information about the historical overview of this historical structure is presented at the interface of the management platform, in which semantic information, including renovation records, maintained information, and current status, is also available.

EHBS represents historic buildings built for more than thirty years and meets one of the following criteria: (1) Historic or artistic features and research values exist in the architectural style and construction technique. (2) Local historical and cultural traits can be reflected. (3) Renowned architects' work. (4) Former workshops, shops, factories, and warehouses which witnessed the history of industrial development in China. (5) Other magnificent architectural heritage with historical and cultural values [48].

Renewal and conservation work for SFLAC was carried out in 2018 and lasted about 3 years. The scope of conservation covers repairing the main part of the heritage building, retrofitting the north building built in the 1990s, and renovating the outdoor environment. Renovation work implants modern equipment to enhance safety and comfort without destroying the historical appearance of the building, making the main part, i.e., the architectural heritage, an adaptable place for modern office functions [46].

In the control section (Figure 3), there are three types of case-finding mechanisms: automatic, active, and passive discoveries. Briefly, passive discovery refers to cases reported via the hotline of heritage conservation, which can be from surrounding residents, staff of SFLAC, and on-site heritage supervisors. Heritage administrators or interface supervisors would take measures to verify a reported case presented on the platform and even further propose solutions. This is generic to conservation cases with different discovering mechanisms.

Automatic discovery represents protection cases generated by warnings from placed sensors, while active discovery means cases found out via conservation-relevant staff. Physical conditions of the structure, including vibration, displacement, and inclination sensory data, are focused on for information collection and transmission to the management terminal via WSN. Accurate data and statistics would be complemented by the staff of the SFLAC platform.

The mechanism of automatic discovery is implemented. Further data on the ratio of placed sensors and cases generated by different types of them can be accessed on the platform, as shown at the bottom of the right section of the interface (Figure 4). Automatic discovered heritage conservation cases can also be accessed on the management platform by a supervisor or an administrator. For reactions to such cases, conservation staff need to compare the sensed value with codes or standards of vibration, displacement, or inclination. No action is required if the value is lower than standards, while further checks and solutions are necessary on the opposite.

Figure 3. The part of conservation process control (by the authors).

Figure 4. Historic building conservation information section of the interface (by the authors).

Other parts on the right comprise general information about architectural heritage conservation. The number of conservation cases and the rate of different causes are presented to the terminal for administrators. The conservation status of other historic buildings can be obtained on the SFLAC management platform. These benefit conservation staff by allowing them to count cases for SFLAC and obtain information on architectural heritage conservation states in the surroundings.

Numbers and locations of historic buildings in the district are replaced by asterisks. This article focuses on SFLAC, the component of monitoring other historic buildings demonstrates that the platform has this function for timely information acquisition. Detailed information such as addresses cannot be presented due to protection for raw data of other historic buildings. This would not affect analysis based on the SFLAC platform.

A detailed 3D model of the historic building is developed with the involvement of BIM technology. A BIM execution plan (BEP) is developed to guide 3D restoration. The plan outlines the overall requirement of digital restoration while detailing positions of conducting photogrammetry and UAV scanning. Meanwhile, it guides engineers to model specific structural components based on different sources of information (e.g., CAD drawings and on-site captured images).

The 3D visualisation of SFLAC is available on the platform (Figure 5). Light-weight versions can be used on various websites or social media. With a pop-up window, panoramic views of crucially protected areas are accessible. For instance, there are particular features of material, decoration, and patterns of different components in an SFLAC room, as shown in Figure 6. Viewers can take panoramic tours through different terminals, such as personal laptops and mobile phones. The visit can be switched to different places via the map on the top-right corner of the interface.

Figure 5. Three-dimensional visualisation of the historic building (by the authors).

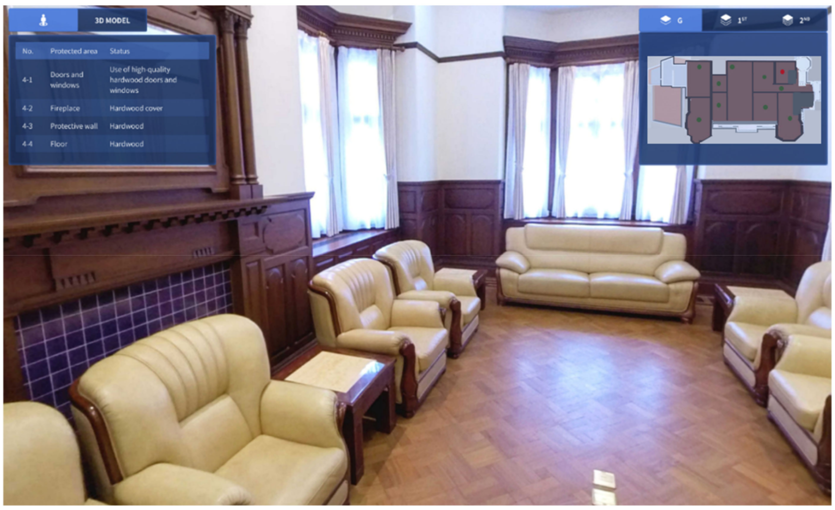

Figure 6. A panoramic view in the interface (by the authors).

2.3. Methodology

Following the integrated review for identifying the gap in knowledge and proposing a synthesis, documentation of the case study is presented with descriptions in the previous section. This research seeks to discover how to develop smartness in urban architectural heritage conservation, management, and operation and why it occurs while investigating supports and characteristics. Depending on technologies and personnel involvements, smart heritage is a complicated discourse. Qualitative research methods are more appropriate to this study as they help to provide a solid knowledge base through a deeper understanding of an issue [49].

2.3.1. Data Collection

Qualitative data, including texts, images, 3D images, etc., for the case study, national and local regulations, policies, and plans, as well as strategic documents and reports on heritage conservation, digital transformation, and smart development, are collected. Meanwhile, open-ended interviews were conducted after the site visit to the platform centre for data collection. Open-ended interviews aim to learn more details and experience about the platform development and practice to support the smart heritage discourse.

Interviews were conducted right after the on-site visit via forms of online meetings due to COVID restrictions in Shanghai at that time. Each interview lasted about thirty to forty minutes. Three direct participants in developing the SFLAC platform and two administrators from local authorities relevant to the project were selected as interviewees. Based on these, more interviewees in engineering digitalisation and heritage conservation are recommended. They have experience in relevant fields, including design of architectural heritage conservation and adaptive reuse, heritage digital data collection, 3D modelling of historic buildings, and smart transformation consultancy in the architecture, engineering, and construction (AEC) industry.

Interview questions include but are not limited to what vocabularies come into your minds when talking about smart heritage, what terminologies are tied with smartness in the AEC industry, what supports are needed for smartness, what the meaning of smartness for architectural heritage is, how the platform is developed, when the platform is developed, what the procedure of digitalising architectural heritage is, what should be considered in digitalisation and platform development, how should the consideration be taken, what and how technologies are used, what has been achieved so far, what are problems/obstacles/challenges in platform development, what should be carried out in the future, etc.; after each question, there might be follow-up questions to find more reasons or concerns behind the proposed points.

There are twelve interviews coded based on the roles in smart heritage relevant areas. Detailed information of each interviewee is listed in Table 1. To avoid complexity, interviewees who provide consulting opinions towards platform developments and smartness in architectural heritage conservation are coded as C1. . .S, in which S represents the case study—the platform of SFLAC. Those whose roles and perspectives are highly associated with monitoring and management are coded as M1. . .S.

Table 1. Interview codes.

No.	Code	Roles in Relevant Areas	Work Experience
1	C1.S	BIM engineer	10+ years
2	C2.S	Consultant (participated to develop the platform)	10+ years
3	C3.S	Engineer (participated to develop the platform)	10+ years
4	C4.S	Consultant (participated to develop the platform)	5+ years
5	C5.S	Architect	5+ years
6	C6.S	Consultant in digital transformation	5+ years
7	C7.S	Engineer in architectural heritage conservation	10+ years
8	C8.S	Consultant in smart building	2+ years
9	C9.S	Consultant in smart building	10+ years
10	M1.S	Director in data management (participated to develop the platform)	10+ years
11	M2.S	Director in smart building	10+ years
12	M3.S	Director in heritage conservation (participated to develop the platform)	10+ years

2.3.2. Data Analysis

The primary data, including texts, policies, and interview transcriptions in Chinese, were translated into English by the authors with the assistance of DeepL translator to ensure language accuracy. Only relevant content is transcribed. All qualitative data are analysed via the thematic analysis. Starting from a topic, smart heritage without definite theories and frameworks, structures, and themes are anticipated to be enriched via the analysis.

Table 2 provides the design for this research. According to the integrated literature review in this study, a promising policy environment with a specific institution for pushing smartness in architectural heritage conservation and management is important. A platform serving from the perspective of managers with various functions is expected in multi-stage smart heritage development.

Table 2. Research design: phases and outputs.

Phase	Output
Literature review	1. Policy context 2. Specific institution 3. A platform that is beneficial to heritage conservation, monitoring, urban administration, operation, etc. 4. Multi-stage development
Analysis	1. Evaluation 2. Findings 3. Outcomes

To be more specific, the method of inductive thematic analysis is adopted in this study. In terms of policy document analysis, a top–down order is followed to see how smart initiatives and developments rise in the heritage discourse and what themes support the development of smart heritage. Data from interviews are analysed to validate and enrich different themes with the case study.

3. Results

3.1. Smart Heritage Development Based on Implmentation of Initiatives

A grid-based management form is increasingly discussed in urban administration and operation in China. The so-called grid management can be understood as relying on information on urban fine details and a digital platform that intelligently connects all data, dividing each area into a single grid that specifically addresses its needs and challenges [50]. The focus and refinement of smart city development in China extend considerations of sustainability and smartness in architectural heritage. Urban heritage, as a significant part of cities, can also be seen as an area requiring specific grid-based management.

Although China attaches great importance to the development of smart cities, texts relevant to smart cities have been mentioned less in documents in the last half-decade, especially in local urban policies. This might be due to urban dimensions for smart development being divided downwards into neighbourhoods, streets, and buildings, including both old and new. Novel, relevant smart concepts are proposed to amplify a single smart space (C1.S).

Smart cities may form their brand effect as the trade market becomes increasingly competitive, which makes many international companies (e.g., IBM, GE, Bosch, etc.) tap into this profitable environment [14]. If there is an excessive focus on branding and no emphasis on implantation, the term is likely to be an isolated concept. Investments in technologies and applications may be wasted if so-called smartness in urban components has not been successfully practised (M1.S).

The successful development of smart cities relies on effective practice in each detail. Chinese President Xi Jinping visited the Hangzhou City Brain Operation Command Centre in March 2020 and stated that using big data, cloud computing, blockchain, artificial intelligence (AI), and other cutting-edge technologies to foster innovation in urban administration is a reliable way to achieve modernisation [51].

The idea of grid-based management is to divide each part of a city into grids, and each grid is connected by technologies such as IoT to achieve comprehensive urban management and operation. As the indelible past, urban architectural heritage can be considered as a particular grid. Such a grid to support intelligent urban management is highly reliant on digitalisation and visualisation.

The construction of this SFLAC platform can be regarded as the epitome of urban grid-based management in architectural heritage conservation, which practices smart initiatives from the national level. Currently, China is breaking down smartness into various sectors, including carbon neutrality for sustainability and liveability, and heritage should not be left behind (C9.S).

Functional modules of the SFLAC platform, including conservation process control, conservation cases, and historic buildings in the district, are planned to be docked with the urban architectural heritage conservation scenario under the grid-based management (C3.S). This aims to help urban authorities such as housing administration strengthen the mastery and management of dynamics of historic building conservation or renovation projects. Managers can efficiently receive information about project establishment and scheme and then dispose of validations or approvals (M1.S).

The experience of implementing platforms such as the one in SFLAC should be shared to prevent the terminology of smart heritage from becoming a catchphrase for competition between various corporations or cities (C8.S). The positive policy background stimulates smart construction, such as the SFLAC platform. Meanwhile, the implementation of initiatives in every urban detail reversely promotes overall urban smartness (C6.S).

3.2. Smart Heritage Development Based on Integration of Digital Mechanisms

Digital urban transformation may be the start of smart developments. Shanghai is entering a new stage of development that promotes digital transformation in the economy, infrastructure, and governance [52]. Urban digitalisation builds a new form of well-rounded operation. In the architectural, engineering, and construction (AEC) industry, the digital twin city and real-time interaction become the basis of attaining smartness and enhancing liveability with the faster deployment of technologies such as GIS, BIM, and CIM (City Information Model) (M2.S).

To visualise the life cycle and to safely manage the AEC industry, BIM technology is increasingly proposed to be used more deeply in urban infrastructure and administration. Considering the worth and significance of urban architectural heritage, comprehensive inspection, management, and conservation may require the implementation of BIM to provide digital visualisation. Digitalisation might create the groundwork for proposing the smart heritage discourse in historic buildings.

In recent years, Shanghai has been actively improving urban digital transformation in architectural heritage (C2.S). Following initiatives relevant to urban unified management from the national level, which highlights the combination of digital technologies and urban governance via an integrated platform for promoting efficiency and coordination [53], local authorities relevant to architectural heritage proposed two significant initiatives towards digital and smart development in heritage conservation (M3.S).

The first one is called one building, one archive (OBOA), which refers to digitally archiving all EHBS. OBOA aims to consolidate the documentation foundation of architectural heritage conservation, in which accurate representation of the number of blocks and floor areas of each EHBS should be recorded, and 2D drawings should be included. As a pilot project, the case study upgrades information to 3D visualisation. A site survey is required in the process of digital archiving [54].

OBOA aims to record and preserve the full lifecycle digital assets of EHBS. The functional module 3D visualisation, historical background, records of repairs and change, and key component demonstration are all manifestations of OBOA practice by developing the

SFLAC platform. These enable conservation personnel, designers of retrofitting, structural engineers, etc., to obtain historical information in real time.

According to the requirements of OBOA, as one of the significant information in architectural heritage conservation, engineering drawings of major buildings should be digitally archived based on historical as-built drawings. If there is no original information on the drawings, on-site mapping should be involved [54]. The integrity, history, and name changes of a historic building should be included, and a summary of repairs and contents over the years needs to be provided [54].

On the other hand, an early warning and disposal mechanism named three-action discoveries (TAD) for EHBS conservation is proposed and practised (C2.S). TAD means three types of mechanisms for detecting potential risks in architectural heritage, including active discovery, automatic discovery, and passive discovery. Modules of these are included in the platform (Figure 3). Active discovery refers to conservation staff identifying potential problems during daily or routine inspections of historic buildings.

Automatic discovery involves the use of WSN, which represents finding out risks via beforehand placed sensors in various positions of architectural heritage. In response to different issues that need to be identified, vibration sensors are widely applied to pilot cases of architectural heritage conservation, following which crack sensors, settlement detection equipment, inclination sensors, and termite monitoring sensors are proposed.

An architectural heritage conservation hotline has been set up for citizens to call to report potential hazards to the safety, stability, and integrity of historic buildings. This process is summarised as the passive discovery. The proposal of TAD is based on the concept of grid-based management. The conservation process control module of its practice on the SFLAC platform is the primary part of developing connections with district and urban operations. TAD targets enhancing the ease, speed, and efficiency of risk identifications and solutions for the protected built heritage, following the initiative on efficient disposal and system integration (C2.S).

The platform supervisor will receive notifications when a potential risk is detected by any mechanism. In the automatic mechanism, a verification by comparing with sensor standard or with variation allowable range is conducted to decide whether subsequent disposals are needed. For the passive mechanism, the supervisor might designate an on-site inspector to figure out what happened exactly. Inspectors would communicate in detail with the platform supervisor to determine whether more interventions are needed in the case of active discovery.

Every detected conservation issue is recorded in the platform. Problems from the active discovery are reported and verified at the sub-district level, but those from the automatic and passive discovery are verified at the district level. This is due to the arrangement of personnel based on sub-district scope providing more detailed coverage of historic building inspections, while TAD data collection focuses on districts (C2.S). The head of a platform disposes of reported cases accordingly. For instance, sensor detections that are in the permitted scope are only assembled to statistics rather than further investigations.

If a solution needs upper approval or collaboration from urban authorities such as urban management and law enforcement, platform supervisors and district heads of heritage conservation can report this via the platform (C4.S). Upper administrators can receive information in time via data interfaces and look into details of the issue via the platform, after which relevant authorities can collaborate efficiently while coordinating disposal personnel through the platform (M3.S).

Traditionally, the disposal of a conservation case or the solution for damage needs to be reported by different people travelling between the heritage site and different departments, during which much paperwork needs to be prepared and completed. Approval is then obtained for taking measures. The conservation process control module plus 3D visualisation, etc., on the SFLAC platform allows staff to communicate and view real-time information through different terminals. They streamline the disposal approval process and improve efficiency.

As a pilot project, the SFLAC platform follows the guidance and requirements of OBOA and TAD to achieve digital and smart management of architectural heritage. The practice procedure is summarised in Figure 7, which provides a novel scenario of architectural heritage conservation by integrating digital mechanisms. The intervention of systems such as the SFLAC platform combines the safety and health perception data obtained from sensing equipment and on-site inspections with digital archives of architectural heritage, transforming inherent salvage heritage preservation into a planned, systematic, and preventive mode (M1.S).

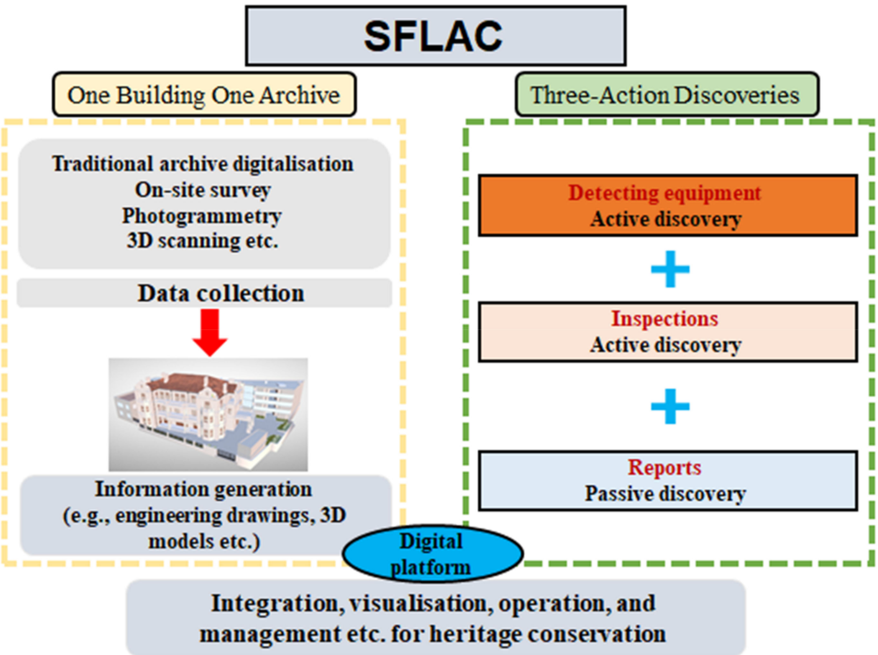

Figure 7. Collaboration of OBOA and TDA in for conservation of SFLAC (by the authors).

3.3. Smart Heritage Development Based on Digital Applications

Smartness cannot be successfully implemented for architectural heritage conservation if only relying on technologies. It can be seen as a system integrating human, material, and financial resources. Digitalisation and visualisation are fundamental and must-stops on the path of smart heritage. Smartness is the application capabilities embodiment of high digitalisation. In other words, how to use the developed digital archive of architectural heritage represents the effect.

Based on the standards and detailed guidance from smart urban constructions, factors which are supportive of smart heritage development are summarised in Table 3. From the overall perspective, new terminologies are encouraged to be generated. Smart heritage can be seen as one of them. This article specifically looks at architectural heritage smartness. Technologies including ICT, IoT, and BIM which support digitalisation, are also significant for achieving smartness within the construction of a platform. Management and service requirements may highlight more potential applications.

Table 3. Factors from initiatives relevant to smart heritage (by the authors).

Factors from Initiatives Relevant to Smart Heritage		
Overall	Techniques	Management & Service
Terminology: i.e., smart heritage	ICT, IoT, BIM, etc., and platform	Digitalisation, inspection, and supervision

According to the BEP and the preliminary site survey with communication, the digital modelling for the main building facade and interior structures is based on 2D CAD drawings of SFLAC and the results from 3D scanning and indoor image acquisition refer to digital restoration of details such as each room, staircases, window frames, floors, handrails, etc. (C3.S).

Through the 3D modelling of characteristic elements, a standard family of components of EHBS can be formed in the future, supporting digital archive improvement (M1.S). This extension corresponds to the concept of HBIM [24]. The complete refined model with output format of .3DS or .Max is archived to the platform and the converted light-weight version is in .Gltf format for the adaptation of terminal equipment can be further docked to different platforms (C2.S). Following this idea, beneficiaries of smart heritage can reach tourists and students.

Docking the 3D model to various environments benefits to the enhancement of existing urban architectural heritage databases. A VR panoramic display based on it can be further accessible to the public to enable more people to know the cultural and historical characteristics of the heritage building (M1.S). Such application rely on well-rounded data collection and it may manifest the role of smart heritage in cultural inheritance. The investigation of historical overviews of the chosen architectural heritage including allusions, stories, and what it has been through, etc., should be seen as a compulsory part of the early stage of conservation work (C4.S).

Digitalised documents from different historical periods might form a scenario for designers or engineers to simulate schemes of future conservation and update (C7.S). But many historic buildings have no recording or archive of their basic structural information and deterioration, which hinders the work of retrofitting (C3.S). Historical information (from structural forms, materials, and damages to structural components, etc.) is recorded and stored in the SFLAC platform, which can be referenced during decision-making (C5.S).

The platform of SFLAC also includes a supervision section about information on nearby EHBS. The purpose is to know information about other nearby historic buildings from this platform in real time. By monitoring other architectural heritage and opening the interface of sensing detection, 3D visualisation, and case statistics with the urban grid management system, efforts under smartness towards architectural heritage management aim to achieve unified maintenance and operation for EHBS in a district or even the whole city via one scenario in the future (C3.S and M3.S).

Functional modules of statistics for conservation cases and installed equipment in the SFLAC platform can support analysis when those data are then completed, which is crucial for optimisation on both the technological and application sides (C2.S). Based on statistics, risks that frequently affect the safety and stability of historical structures can be derived by conservation staff. Then, such applications help to summarise the aspects from which efforts should be made to achieve preventive preservation.

The SFLAC platform integrates the practice of guidelines such as grid-based management, OBOA, and TAD. Successful implementation of smartness in urban architectural heritage also relies on the integration of technologies and people. The idea of platforms provides a chance for technicians to adopt different technologies and assemble collected information into one scenario.

3.4. Smart Heritage Development Based on Potential Optimisations

There are still some challenges in developing such a platform and achieving smartness for urban heritage, which may involve potential optimisations for smart heritage development in the future. Particular standards or guidelines for the systematisation of smartness in architectural heritage conservation are still lacking, especially for what basic functional modules each platform should possess and how different platforms can be docked (C7.S). Although there are initiatives such as OBOA and TAD in Shanghai, specific data fusion and cross-system interaction need to be unified by frameworks and guidelines.

Integrating online and offline management requires an awareness of and commitment to removing the discrepancies that exist between online presentations and on-site situations for historic building conservation. Achieving this is complicated. Solutions to some on-site situations require collaboration with different departments; there are no set rules about who (platform supervisors or on-site inspectors) should be responsible for coordinating other authorities to solve those problems (C4.S). Further research and pilots are required to determine how to practice (M1.S).

The whole process of smart development involves a great deal of communication; hence, more professional and technical talents are required in the industry. The SFLAC platform is accessible to conservation professionals and urban authorities at the current stage. The full realisation of smartness needs to enable everyone with different requirements to access some functional modules of the platforms. But how to consider the accessibility and to what extent is still challenging (C2.S).

As significant sources of spatial cultural meanings, urban planning and architecture may connect technology and culture by generating common symbolic meaning and remaking the public space in the new metropolitan setting [55]. Architectural heritage represents significant urban spaces. Technological adoptions in heritage conservation seem to narrow such a gap between technology and history. The multi-dimensional integration of community supported by applications may be important for constructing advanced urban systems such as smart cities.

4. Discussion: Characteristics Based on the SFLAC Platform for Smart Heritage

The SFLAC platform highlights heritage digitalisation, integration, and applications. Its functional modules, including 3D visualisation, conservation status, and installed equipment, enable a supervisor to monitor and pinpoint actions taken for heritage conservation and renovation. Similar to [32], the compatibility of the SFLAC platform is required in its development as it will subsequently make it connect with urban heritage applications.

The development of this platform starts from the perspective of managers both at urban and district levels, which is different from previous practices that focus on society and conservation experts [38]. Digital documentation of the SFLAC historic building enables heritage authorities to efficiently obtain information while updating traditional archives. It also solves problems in heritage conservation, such as lack of original information and scattered applications [6], by integrating and demonstrating heritage data in various modules (i.e., historical background and record of repair and changes).

By docking the SFLAC platform to upper heritage management scenarios under urban refinement operation, a bridge for communication between different departments is constructed with the TAD mechanism plus 3D visualisation to solve problems of insufficient coordination [6] and simplify the report, review, and approval process (C4.S). Increasing modelling of significant structural components accelerates the establishment of the EHBS family library, matching the HBIM concept.

Compared to a previous platform based on HBIM [39], which focuses on data integration, processes, and techniques for renovation and updates, the SFLAC platform highlights integration and working processes for heritage conservation and urban operation while valuing digital modelling. The integration phase first proves that regulations and guidelines of smartness in urban architectural heritage are practised. The development of a platform or system is an important process to integrate conservation staff to adopt all technical resources beneficial to conservation.

The platform can be seen as a transfer point in the whole process of developing smart heritage, and further applications are necessary to achieve so-called smartness. The proposal of smart heritage first values conservation for urban architectural heritage. In the case of the SFLAC platform, technologies are no longer obstacles to heritage smartness; the creation of novel applications is crucial (C8.S).

Smart heritage affects cultural and historical inheritance. Three-dimensional visualisation can be further applied to teaching or touring scenarios with a highlight on interaction and user experience [35]. Relevant applications based on the SFLAC platform need further practice. More people will contribute to architectural heritage promotion via functions such as uploading personal experiences or thoughts [33].

> *Smartness in the heritage discourse should have the ability to evolve, namely smart heritage should be able to perceive, optimise and innovate.* (Interviews with the author in 2022.)

Each architectural heritage has its unique features and values. A unified platform for aggregating all heritage information does not eliminate their characteristics or omit their importance in urban regeneration. It aims to provide equal attention to problems existing in historic building conservation and the potential for cultural creativity. The heritage conservation platform of SFLAC meets the various needs of records, management, building inspection, panoramic touring, and future optimisation.

Hence, one of the most significant features in smart heritage should be multi-stage with evolvement, as shown in Figure 8. Digitalisation, integration, and application consist of its first three key factors. Furthermore, the simultaneous conduction of architectural heritage conservation and innovation is a crucial path to implementing smartness, in which the conservation effect requires analysis in real time and strategies needed to drive developments in relevant industries (M3.S).

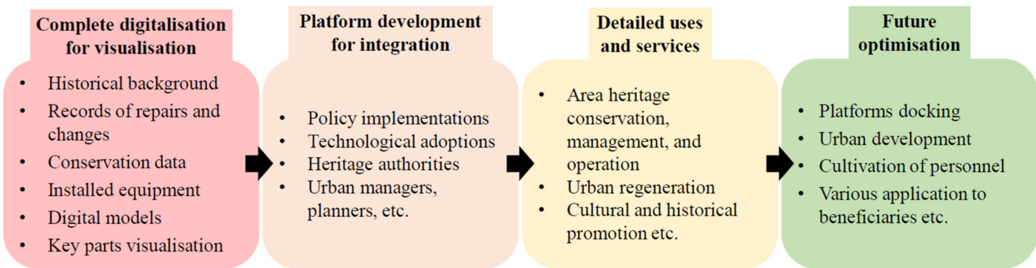

Figure 8. Evolvement in smart heritage (by the authors).

The case study in this article took place in Shanghai and has research strengths in culture, history, economy, science, and technology, laying a foundation for a blueprint of regional heritage smart conservation. An effective policy orientation to smart heritage development accelerates its practice. Optimisations based on the current practice should start with testifying more applications such as personnel coordination and scenario docking.

Smartness in enterprises or cities emphasises continuous decision-making simulation and configuration selection based on core technologies such as big data and AI, in which model analysis is used for core resources, such as people and finance, to achieve efficient and optimal selections and outputs [56]. The evolution of smart heritage may not require such interventions.

More guidelines and regulations about integrating data, developing functional modules, and combining systems, staffing, and scheduling would consolidate policy support for smart heritage methods. The cultivation of professional personnel is another entry point for the following upgrade. Considerations for the final destination should be based on what cultural and historical features the architectural heritage has.

The method towards smartness in urban heritage preservation and management proposed in this study targets providing particular services for people in different stages. The SFLAC platform begins with solving problems in architectural heritage archiving and the inefficiency in conservation case detection and disposal. Further connections and optimisations come after the previous stage.

Hence, it might be unrealistic to rank the developing sequence of the platform or smartness because each case has its uniqueness (interviews with the author in 2022).

To be more specific (Table 4), considering the evolvement and stakeholders, urgent problems and requirements of architectural heritage should be solved within a short term in the whole approach of smart heritage. In the medium term, applications involving convenience, efficiency, and integrity in management and operation should be developed and used in a heritage area rather than a single building. Long-term considerations and optimisations should cover the correspondence with urban development while considering the continuation of culture and history.

Table 4. Practice considerations (by the authors).

Smart Heritage Practice Considerations	
Short term	To address urgent problems and requirements of architectural heritage
Medium term	To develop services benefiting the convenience, efficiency, and integrity of heritage conservation and management and use in historical and cultural areas
Long term	Considerations and optimisations corresponding to urban smartness, as well as continuation of culture and history

5. Conclusions

From theory to practice, smart heritage for better heritage conservation in the background of urban sustainable development depends on numerous efforts. The belief in grid management in the national context fundamentally opens up the fine-grained digital management of urban architectural heritage. The SFLAC platform raises the novel mechanism of architectural heritage maintenance and management from digitalisation to application, which seeks to switch the traditional preservation process into one that is organised, methodical, and preventative.

The practice of smart heritage for historic buildings should comprise five stages, as shown in Figure 9. It is anticipated that more practices will follow the procedure proposed in this study to better preserve and maintain urban architectural heritage while valuing urban development. The engagement of the expert committee is not a stage. It is a vital involvement to supervise and check on progress as well as outcomes, which should be in at least two stages. Its formation can be further designated by a specific institution of architectural heritage smart conservation and management. The stages are listed as the following:

(1) The development of policies, such as OBOA and TAD, standards, and guidelines for heritage digitalisation and smartness and establishment of particular platform standards with pilot projects for practice. A positive policy context is crucial to achieve smartness. On the contrary, the practice of smart heritage implements national and local strategies, resulting in effective urban smart updates;
(2) Digitalisation for starting the practice of pilot projects: well-rounded information collection, including traditional archives digitalisation and on-site surveying, digital modelling, sensor placement, etc., should all be included;
(3) The development of a smart platform for heritage data storage and demonstration, integrating conservation personnel (e.g., technicians, professionals, etc.) and supportive technologies to satisfy different requirements;
(4) Further applications of digital archives and the platform, including heritage conservation, safety and stability monitoring, conservation staff (e.g., on-site inspectors, platform supervisors, etc.) management, and coordination of different heritage conservation authorities;
(5) Future optimisations are required in the proposal of heritage smartness. It can start with technologies and platform connections and carry on to personnel cultivation.

Smart heritage characteristics based on the SFLAC platform include multi-stage development with evolvement, people-oriented approaches, and promotion of culture and history. The digitalisation of heritage archives enables heritage inspectors and administrators to intuitively view the architectural heritage status. The proposal for developing the SFLAC platform integrates conservation technicians and professionals to develop applications based on their contributions. And the platform assembles all digital outcomes.

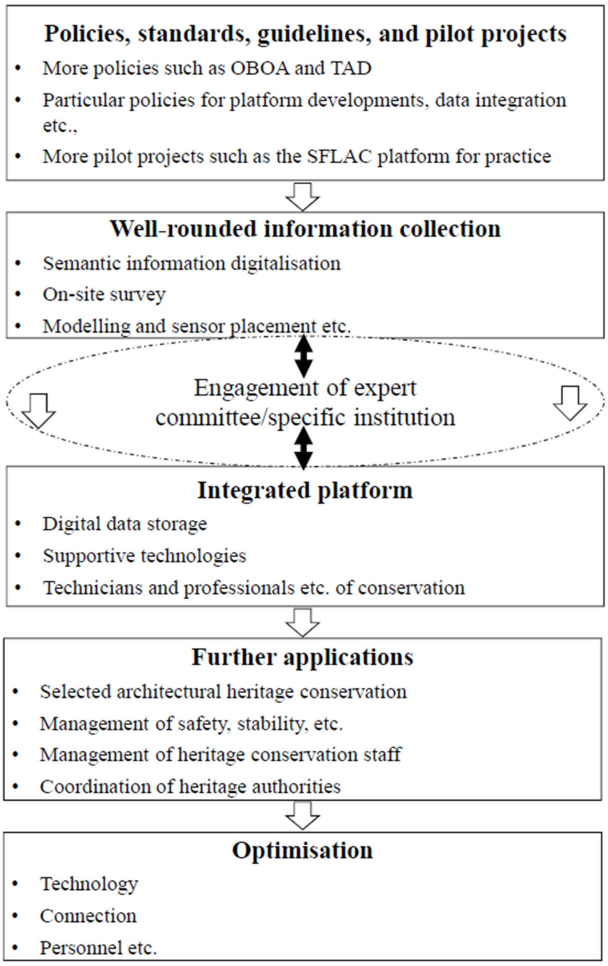

Figure 9. Stages for smart heritage practice in architectural heritage conservation (by the authors).

With the involvement of a platform, the smart heritage discourse creates a community for conservation staff, designers, planners, and managers to communicate, coordinate, and collaborate. Considerations in smart heritage development should be taken in terms of time with specific requirements rather than according to a ranking. It cannot be ensured that relevant implementation, such as the SFLAC platform, can be stimulated by a particular conservation institution, but an expert committee for supervision and guidance is indispensable in practice.

However, there are some limitations in this study. Analysis and discussions about platform docking, optimisation, etc., are based on the subjective views and experiences of the interviewees. New challenges may arise in actual implementation. This study only provides an example of smartness practice in architectural heritage against the background of urban development in Shanghai, China. Other domains in heritage have not been studied, and the practicality of this in other urban and national backgrounds needs to be further analysed. Specific implementation and optimisation routes, such as what particular personnel should be cultivated and how platforms in different disciplines and levels can be docked, have not been validated yet. Thus, future efforts can be made in these parts.

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