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THE SOCIO-TECHNICAL SYSTEM FRAMEWORK FOR MAINTAINING THE SMART HERITAGE OF CHENGDU'S HISTORICAL AND CULTURAL VILLAGES

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Abstract

As the development of smart cities continues to advance, Smart Heritage has become an essential component of cultural preservation and inheritance. The cultural Heritage of Chengdu's historical and cultural villages possess significant cultural and social value and currently faces complex challenges in terms of conservation. Based on the actual situation of Chengdu's historical and cultural villages, employs qualitative research methodology, including semi-structured interviews with experts, to construct a socio-technical system framework supporting the implementation of smart Heritage in Chengdu's historical and cultural villages, aiming at effective management and conservation of Smart Heritage. The study first identifies the expertise areas and the number of experts involved. It is divided into three main parts: the socio-technical system's social, technological, and environmental dimensions. Based on the findings of this study, it is evident that the Smart Heritage of Chengdu's historical and cultural villages require interdisciplinary cooperation and coordination across various sectors. Additionally, there is a need for continually updated and improved technological support systems to adapt to changes in the era and demands. This framework is believed to provide valuable references and guidance for managing and conserving Smart Heritage in Chengdu's historical and cultural villages.

Keywords: Smart Heritage, Socio-technical system, Chengdu's historical and cultural villages

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INTRODUCTION

In the face of rapid urbanisation and technological development, the protection of cultural heritage faces complex challenges, particularly in regions with rich historical backgrounds like Chengdu. Chengdu's historical and cultural villages are treasure troves of tangible architecture and important carriers for preserving traditional culture and enhancing ethnic cohesion, possessing significant cultural and social value. In recent years, smart heritage has emerged as a promising approach to scientific management and widespread dissemination of cultural heritage through digital and smart means. (Khalaf, 2019; Poulopoulos & Wallace, 2022) . However, applying such technologies often lacks a comprehensive strategy, focusing primarily on technological development without fully integrating social, cultural, and environmental aspects.

This paper proposes a socio-technical system framework as a comprehensive approach to maintaining the smart Heritage of Chengdu's historical and cultural villages. Rooted in socio-technical system theory, the framework advocates for designing and developing social and technical elements within organisations or systems as interdependent wholes to enhance efficiency, satisfaction, well-being, and sustainability (Majchrzak & Borys, 2001). It provides a perspective that can address the complexity of implementing smart heritage. By adopting this framework, the study aims to harmonise intelligent technologies with the social, cultural, and environmental contexts of Chengdu's heritage sites, fostering a sustainable conservation model that benefits from technological innovation while enhancing the villages' social, cultural, and economic value. In this process, the research contributes to the growing discourse on sustainable heritage conservation practices, gaining insights into the potential of socio-technical systems in addressing the multifaceted challenges faced by historical and cultural villages in Chengdu and other regions. A detailed examination of social, technological, and environmental factors formulates comprehensive strategies for protecting and enhancing Smart Heritage in the context of rapid urbanisation and technological change.

Smart Heritage of Chengdu's Historical and Cultural Villages

Chengdu, a renowned historical and cultural city in China and the birthplace of the ancient Shu civilisation, boasts a history of over 3,000 years. The "Chengdu Urban Master Plan (2016-2035)" emphasises the vigorous protection and development of cultural heritage. Chengdu has identified 13 historical and cultural villages and continues to expand this list (**Figure 1**). In October 2020, Chengdu proposed the "Smart City Construction Action Plan (2020-2022)" to develop smart infrastructure and cultural tourism services. In 2021, the Chengdu Municipal Government promulgated the "Regulations on the Protection of Historical and Cultural Famous Towns, Villages, and Traditional Villages of

Chengdu", advocating for smart protection through digital data collection, mapping, establishment of protection archives, integration into information management systems, and public disclosure. Moreover, it seeks to promote smart cultural tourism, including digitalising scenes and constructing internet-connected venues. Against the backdrop of China's digital rural development and Chengdu's smart city initiatives, historical and cultural villages are integral components of Chengdu's cultural heritage. Therefore, leveraging technology and intelligence to protect and develop the cultural Heritage of Chengdu's historical and cultural villages is crucial. Consequently, it is imperative to research the Smart Heritage of Chengdu's historical and cultural villages.

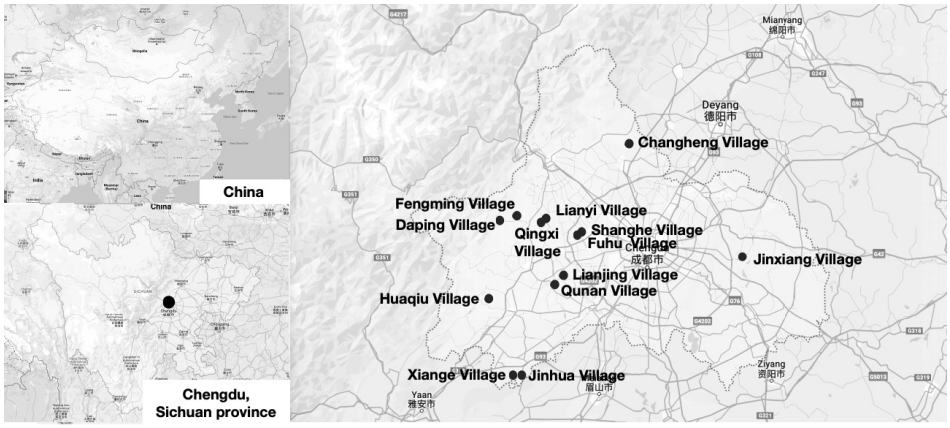

Figure 1: Chengdu's historical and cultural villages
Source: Google map

LITERATURE REVIEW

Smart Heritage

World Heritage refers to the invaluable and irreplaceable wealth recognised by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the World Heritage Committee (WHC), representing a universally recognised legacy of outstanding significance and universal value in natural and cultural landscapes. According to UNESCO, heritage is classified into three categories: natural heritage, cultural heritage (both tangible and intangible), and mixed heritage. Protection strategies have been formulated since 1972 and are continuously updated with social development. Smart heritage was initially proposed by the INTACH Heritage Academy (2007), aiming to address the challenges of cultural heritage protection in the era of smart cities by leveraging the advancements in Information and Communication Technology (ICT)(Adrian & Kurniawan, 2020). It is considered a relatively new system and management medium. Batchelor (2021) defined smart heritage as a complete ecosystem. Smart

heritage is the fusion of smart technology with the disciplines of smart cities and heritage, integrating smart technology's autonomy, automation, and innovation within the historical context and subjective interpretation(Batchelor et al., 2021). Smart heritage is a relatively new concept, intersecting smart city and heritage disciplines.

In 1992, UNESCO initiated the "Memory of the World" project, proposing digital technology for cultural heritage preservation. Since the 1990s, digital technology has rapidly developed and been utilised to protect and manage cultural heritage. Subsequently, the emerging field of cultural computing adopted methods such as reverse engineering and computer graphics to analyse, inspect, conserve, and visualise cultural heritage (Gonizzi Barsanti et al., 2015). After 2010, the field of cultural heritage preservation gradually shifted from digital recording to integrating and applying multiple technologies. It has evolved from simple information systems about cultural traditions to complex systems encompassing heterogeneous data sources (such as sensor networks and social networks), digital libraries, multimedia collections, and web-based data services. It includes geographic information technology, satellite positioning and measurement technology, remote sensing and high-definition imaging technology, information and communication technology, the Internet of Things (IoT), multimedia, network communication, cloud storage systems, and wireless sensor networks (WSN), facilitating digital preservation and dynamic monitoring of cultural heritage; sustainable utilisation and management of cultural heritage; as well as cultural heritage experience and services, promoting the dissemination of cultural Heritage (Borda & Bowen, 2017; Luo et al., 2024). Smart heritage integrates multiple disciplines, including archaeology, tourism, architecture, and those related to information technology and digital platforms(Batchelor & Schnabel, 2019). Furthermore, its application areas continue to expand, encompassing tangible and intangible cultural heritage.

Since 2013, with the revitalisation of rural areas in China in 2018, the application of Smart Heritage in the research of historical and cultural villages has gradually emerged. When the Smart Village Strategy was proposed in 2019, relevant studies surged, and research directions began diversifying. The core content and information of cultural heritage in historical and cultural villages are objectively and comprehensively recorded, preserved, and structured into data resources, which can be retrieved, learned, and disseminated through data platforms, 3D technology, human-computer interaction, virtual reality (VR), augmented reality (AR), and other technologies (Hongji & Yong, 2017; Jin & Haopeng, 2021; Rahmat et al., 2023; Ali et al., 2018). This initiative provides a solid data foundation and decision support for protecting, restoring, and disseminating cultural Heritage in Chinese historical and cultural villages. These technologies offer new possibilities for recording, participating, and interpreting

cultural heritage, but their implementation often lacks frameworks that fully consider the social and cultural dimensions.

Socio-technical system

The Socio-Technical System (STS) is a system involving complex interactions among human (social components), machine (technical components), and social-environmental components. It aims to design a system with characteristics of an open system, providing a robust analytical framework for complex systems and organisations to address better complexity, dynamism, new technologies, and competitive environments(Trist, 1980). Leavitt (1965) provided a research framework for socio-technical system theory. The framework shifted the discovery of entire organisations and focused on the relationships among people, tasks, structures, and technologies. Bostrom and Heinen (1977) advocated for the interrelatedness of these system components and the necessity of considering them together (**Figure 2**), proposing a socio-technical system framework. The social subsystem comprises structures and people, while the technical subsystem comprises technology and tasks. The environmental dimension refers to external dimensions that affect the system. On the one hand, there are complex political, economic, social, technological, environmental, and legal factors. On the other hand, architectural environments, physical environments, geographical locations, and natural disasters also constitute complex environmental factors.

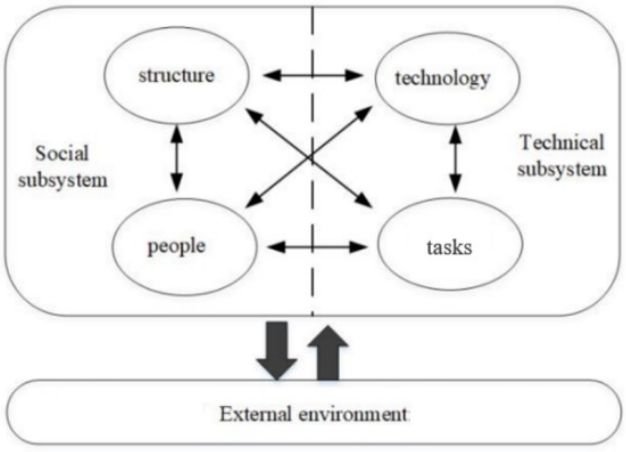

Figure 2: The Socio-Technical System Framework
Source: Bostrom & Heinen,1977

The Socio-Technical System (STS) was introduced by Emery and Trist in the 1950s in the British coal mining industry when mechanical technology was

introduced. It enhanced organisational efficiency and job satisfaction(Trist, 1980), emphasising the interaction between social systems and technological infrastructure. It has been developed and applied for over 60 years, successfully applied in many critical areas, especially in the design of new technologies and redesign of job roles (Geels, 2004; Li et al., 2018). It provides a comprehensive perspective on cultural heritage preservation, particularly in addressing the complexity of smart heritage's technological, social, and environmental interactions. Yakel (2007) discussed the application of STS in digital management, emphasising the importance of technological and social factors in implementing digital projects. Parry (2010) demonstrated the alignment of STS theory through case studies of digital transformation in museums and cultural institutions. Srinivasan (2012) explored how to promote diversity and inclusiveness in cultural heritage by integrating technology and social learning. This aligns with the core principles of socio-technical system theory, which considers social factors in technology design and implementation. Elisa Giaccardi (2012) focused on the role of social media as a technological tool in facilitating community engagement and dynamic preservation of cultural heritage, demonstrating the potential application of STS theory in Smart Heritage preservation.

Challenges facing the historical and cultural villages in Chengdu include pressure from urbanisation and the risk of losing tangible cultural heritage. Smart heritage has the potential to strengthen heritage conservation in this context. However, the approach we need should not only adopt smart technology but also consider how technological solutions can adapt to the socio-cultural environment of cultural heritage and engage local communities and stakeholders in meaningful ways. (Ab Dulhamid et al., 2023). Jointly protecting and developing cultural heritage can promote rural tourism (Dulhamid et al., 2023; Ismail Isa et al., 2022). Integrating Socio-Technical Systems into heritage conservation represents a paradigm shift, emphasising the importance of understanding and addressing social and technological dimensions in conservation work. For villages in Chengdu, this may mean developing conservation strategies with technological innovations that optimise technological, social, and environmental systems, leading to more comprehensive and sustainable heritage conservation approaches.

RESEARCH METHODOLOGY

This study will conduct qualitative research through semi-structured interviews with experts. Experts were selected from research domains, including the tangible cultural heritage of historical villages in Chengdu (4), Smart Heritage (2), and Socio-technical Systems (2). Purposeful sampling and snowball strategies were employed to select participants, and each interviewee was assigned a code (E1 to

E8). Information about the interviewees is presented in **Table 1**. Before collecting data, semi-structured interview questionnaires were prepared based on research questions, objectives, relevant literature, and theoretical frameworks. Detailed question lists were designed for the interviewees. These questions were open-ended, allowing interviewees to construct their answers, and they also had to be sufficiently engaging to prompt detailed discussions on specific topics for both researchers and interviewees. (Qu & Dumay, 2011).

Table 6: Interviewees' Information

Interviewees	Interviewees' Position / Agencies
E1	Associate Professor / Sichuan Agricultural University
E2	Professor / Southwest Jiaotong University
E3	Associate Professor / Southwest Jiaotong University
E4	Associate Professor / China West Normal University
E5	Project Director / Lifang Digital Technology Group Co., Ltd
E6	Associate Professor / Southwest University of Science and Technology
E7	Associate Professor / Sichuan University of Science and Engineering
E8	Associate Professor / Sichuan Agricultural University

The questionnaire framework was divided into three (3) sections. Part A included three questions about the technological dimension in the socio-technical system framework; Part B included three questions about the social dimension; Part C contained four questions about the environment. Efforts were made to communicate with and interview the eight experts through telephone calls, and interview locations were determined to be varied, including their workplaces and private offices. All interviews were conducted between July and September 2023 and were documented through written notes and audio recordings.

Study scope

The scope of this study focuses on the tangible cultural heritage of historical villages in Chengdu, which encompasses historical relics, historical buildings, and cultural sites. Chengdu's historical and cultural villages possess favourable natural conditions. Due to cultural history and geographical structure differences, a tangible cultural heritage has emerged, characterised by family settlements, religious culture, and traditional craft culture. Overall, the tangible cultural heritage of historical villages mainly consists of two forms: historical buildings, and cultural relic protection units (**Table 2**).

Table 2: The Tangible Cultural Heritage of Historical Villages in Chengdu.

No.	History building	No.	Cultural relic protection units
1.	Li's courtyard	1.	The Imperial Tea Garden
2.	Xu's courtyard	2.	Daming temple
3.	Chongjiang Bridge	3.	Feixian Ge
4.	Yin Changheng's Residence	4.	Chongyang 1886 Ancient Cellar Pool
5.	He Lin's Residence	5.	
6.	Zhengjia courtyard	6.	
7.	Yu Jiapian residence	7.	
8.	Banmu Pond Cultural Courtyard		

Source: Author

ANALYSIS AND DISCUSSION

Figure 3 illustrates the survey results regarding the socio-technical system framework for maintaining the Smart Heritage of historical villages in Chengdu. It depicts three internal dimensions: social, technical, and environmental; each also outlines the requirements for sustaining the Smart Heritage of historical villages in Chengdu.

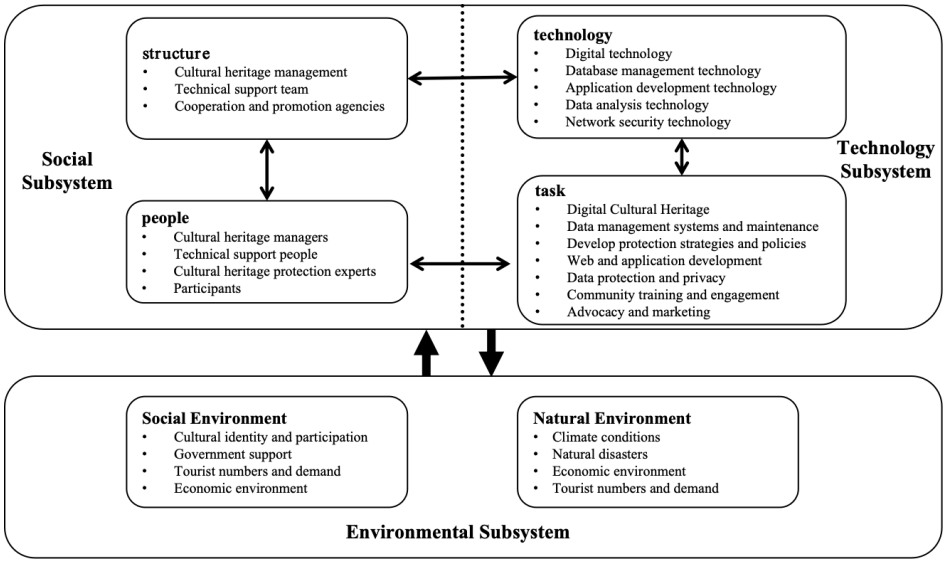

Figure 3: The socio-technical system framework of the Smart Heritage of historical villages in Chengdu.
Source: Author

Technology Subsystem

Tasks

Several experts emphasised the collaborative nature of multiple tasks required to maintain Smart Heritage, with application and development tasks paramount in promoting cultural heritage dissemination. The descriptions are as follows:

"Development of Smart Heritage applications, including guides, virtual exhibitions, and social media interactive features. A user-friendly interface and interactivity are required to provide a rich user experience". (E1).
"Development of websites and mobile applications to provide information and interactive experiences". (E2).
"Provision of a user-friendly interface and interactivity to create a profound and enriching user experience. This includes designing interactive maps, virtual exhibitions, narration features, etc., to help users explore and understand cultural heritage more deeply". (E5).
"Development of online platforms for Smart Heritage, including websites and mobile applications, to provide a user-friendly interface and interactivity. These platforms may include virtual tours, historical background information, interactive maps, and multilingual support to enrich users' cultural experiences". (E6).
"Creation of educational resources, including online courses, educational games, and teaching materials". (E7).

Furthermore, the experts emphasised the importance of comprehensive cultural heritage digitalisation, including digitising cultural heritage, establishing regular data management systems, maintenance updates, and extensive data protection and privacy measures. It is essential to develop appropriate smart heritage protection strategies and policies. Equally important is encouraging community training and participation, conducting publicity and marketing campaigns, promoting knowledge and application of cultural heritage, and increasing visibility to attract more tourists and researchers. By fulfilling these tasks, we can only better support the realisation of smart heritage.

Technology

Several experts mentioned the need for diverse technological collaborations to support task implementation, with technology support for application and development tasks being the most important in maintaining the protection and development of smart heritage. The descriptions are as follows:

"Virtual and augmented reality technologies are used to create virtual tours and educational experiences". (E2).
"Digital display technologies are used to produce multimedia content". (E8).
"Network and Internet technologies: support online access and interaction". (E7).
"Mobile application development technologies are used to create user-friendly mobile applications, providing guides, virtual exhibitions, and interactive experiences". (E5).
"Cloud computing and storage technologies are used to store and manage large amounts of data and content, including cultural heritage information. They allow for remote storage and access, providing highly scalable storage solutions for easy storage capacity expansion when needed. This contributes to the effective preservation and management of cultural heritage data". (E6).
"Geographic Information Systems: used for geolocation and map navigation functions". (E5).

Furthermore, experts pointed out that supporting task implementation requires digital technology for collecting, storing, and managing information related to historical and cultural villages, photos, documents, etc. Database management technology is essential for storing and managing large amounts of data and content. In contrast, data analysis techniques, artificial intelligence (AI), and machine learning are used for data analysis, task automation, and personalised content recommendations. Network security technology, including firewalls, data encryption, access control, malware detection, and vulnerability management, is equally important to ensure data security and user privacy. It is through the collaboration of these technologies that smart heritage can be realised. **Figure 4** illustrates three-level coding to analyse the expert interview data for the Technology Subsystem.

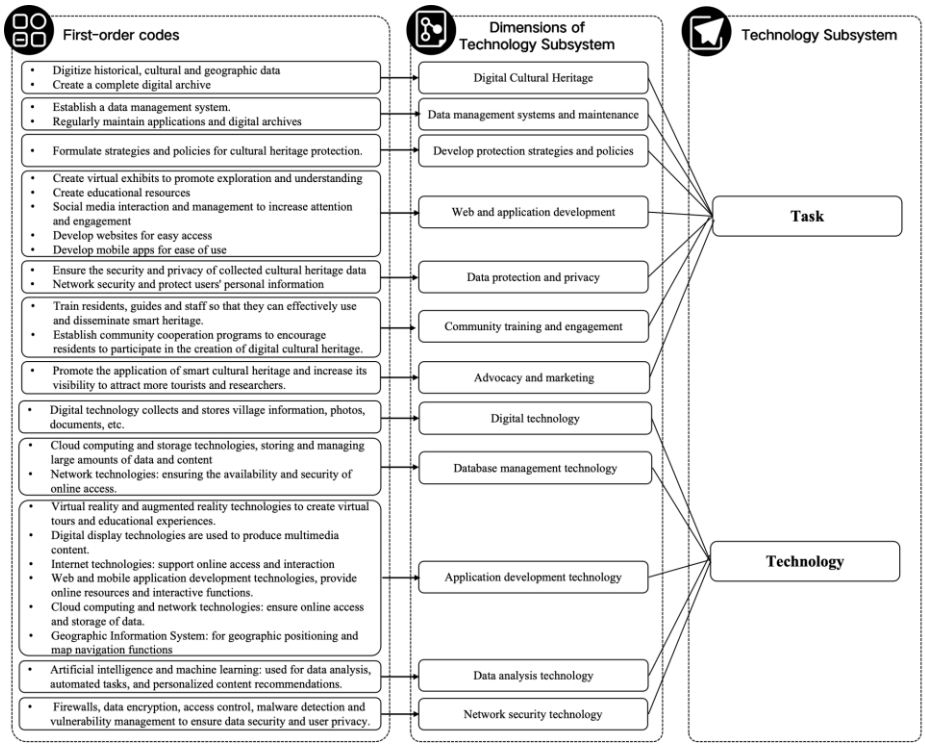

Figure 4: The Coding Scheme of the Technology Subsystem
Source: Author

Social Subsystem

Structure

Several experts emphasised the importance of organisational structure, with the technology support team being crucial in protecting smart heritage. Descriptions are as follows:

"Data Management Team: Responsible for collecting, storing, and maintaining cultural heritage data". (E3).
"Technology Team: This team is responsible for application development, database management, network maintenance, and security". (E6)
"Technology vendors: Provide digitalisation and application development technologies, assisting in system development and maintenance". (E4).

Experts also pointed out that establishing cultural heritage management, collaboration with multiple teams, and promotion are essential to better realising smart heritage.

People

Figure 5 illustrates three-level coding to analyse the expert interview data for the Social Subsystem. Several experts mentioned the need for collaboration among various professionals to sustain the operation of Smart Heritage in historical cultural villages. Descriptions are as follows:

"Technical developers are responsible for creating and maintaining digital systems; traditional village conservation and cultural heritage experts provide professional guidance on protection and display; data analysts process and interpret relevant data; government officials provide policy support and regulation". (E8).
"Suppliers provide equipment and technical support; representatives of residents communicate residents' needs and feedback". (E4).
"Tourists can collaborate to facilitate better execution". (E3).
"Investors provide financial support". (E5).

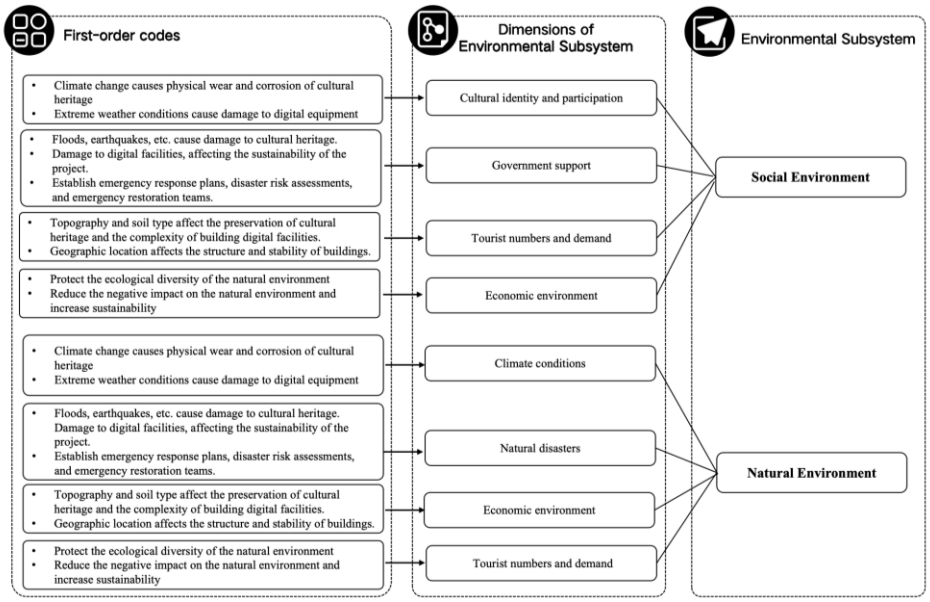

Figure 5: The Coding Scheme of the Social Subsystem.
Source: Author

Environmental Subsystem

Social Environment

Several experts emphasised the importance of government support, including government policies, funding support, and regulation, which significantly

influence the implementation and sustainability of Smart Heritage in historical cultural villages. Descriptions are as follows:

"National and local government cultural policies play a crucial role in protecting and inheriting cultural heritage". (E4).
"Government funding support can drive project development". (E3).
"Government regulation has a significant impact on project implementation and sustainability". (E7).

Experts also pointed out that community cultural identity and residents' active participation are crucial for project success. Active participation can enhance the preservation and dissemination of cultural heritage. The number and behaviour of tourists can affect the protection and sustainability of cultural heritage. Tourists' interests and needs can influence project content and experience design. Equally important is the economic environment, which affects sustainability.

Natural Environment

Several experts emphasised the impact of the natural environment on the feasibility and sustainability of Smart Heritage projects, where natural disasters can damage cultural Heritage, historical villages, and digital facilities, affecting the protection and maintenance of cultural heritage. Emergency response plans, disaster risk assessments, and emergency repair teams should be established. Descriptions are as follows:

"Natural disasters such as floods, earthquakes, and fires may threaten the physical preservation of cultural heritage, requiring measures to protect digital cultural heritage data and items". (E2).
"Extreme weather and natural disasters (such as floods, earthquakes) may damage historical villages and digital facilities, affecting project sustainability". (E1).
"Natural disasters such as earthquakes, floods, and fires may cause severe damage to cultural heritage. Emergency response plans, disaster risk assessments, and emergency repair teams are needed". (E5).

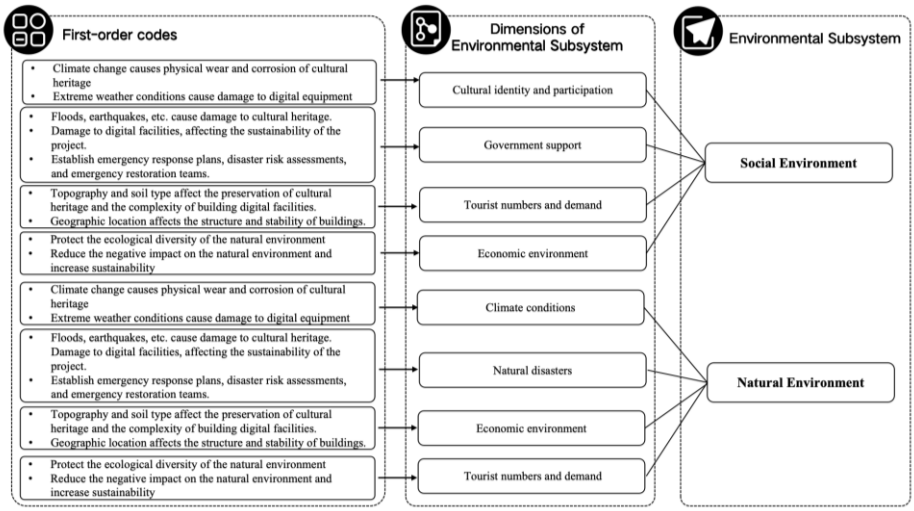

Figure 6: The Coding Scheme of the Environmental Subsystem
Source: Author

Figure 6 illustrates the process of using three-level coding to analyse the expert interview data for the Environmental Subsystem. Experts also pointed out that climate change and geographical conditions may affect the preservation of cultural heritage and the complexity of building digital facilities. Environmental protection is equally important to reduce negative impacts on the natural environment and increase the sustainability of smart heritage protection. These social and environmental factors are intertwined and collectively influence the success and sustainability of Smart Heritage projects.

CONCLUSION

This study conducted interviews with eight experts. Based on the research findings, a socio-technical system framework for the Smart Heritage of historical villages in Chengdu was constructed to promote sustainable development and protection. This framework integrates social, technical, and environmental factors organically, providing comprehensive and systematic guidance for the maintenance and management of Smart Heritage. Firstly, in the technical dimension, specific tasks and relevant technologies supporting their implementation must be clearly defined for the Smart Heritage of historical villages in Chengdu to achieve comprehensive protection and utilisation of Smart Heritage. Secondly, in the social dimension, a diversified organisational structure needs to be established, requiring collaboration among various professionals, including cultural heritage conservation experts, smart technology specialists, and government administrators, to ensure the better operation of the Smart

Heritage of historical villages in Chengdu. Lastly, significant natural and social environmental factors that impact the implementation and sustainability of smart heritage in historical villages in Chengdu need to be identified in the environmental dimension. The Smart Heritage of historical villages in Chengdu requires interdisciplinary and interdepartmental cooperation and coordination to integrate resources, optimise management, and continuously improve the technical support system to adapt to changing times and demands. Through continuous improvement and optimisation, this framework contributes significantly to protecting and developing the Smart Heritage of historical villages in Chengdu, leaving behind a rich and valuable cultural legacy for future generations.

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