The Influence of Digital Twin Technology on the Sustainable Development of World Cultural Heritage in Rural China

Juan guo and Manoon Tho-ard
Shinawatra University ,Thailand
Corresponding Author, Email: manoon.t@mru.ac.th

****

Abstract

The protection of digital cultural heritage in China from 2020 has also been issued by the Ministry of Culture and Tourism to promote the high-quality development of the digital cultural industry. There are many applications of digital twin technology, and in recent years, it has also played an important role in the sustainable development of World cultural heritage in rural China.This study aims to explore the sustainability factor of digital twin technology for rural cultural heritage in China. Quantitative research methods were used for validation in this study. Based on theoretical models of socio-technical systems, this study constructs a theoretical model of the influence of digital twin technology and China's rural cultural heritage. This model is used to explore the impact relationship between the six independent variables and the three sustainability-dependent variables. The study sample was selected from university students aged 18-28 in Chengdu, Kunming, and Nanchang provinces of China, and 1200 questionnaires were distributed. Data analysis and statistics were mainly carried out using the statistical analysis software SPSS. A confirmation factor analysis was performed on the model using the AMOS software. Assumptions and model validity are evaluated in the study.

The results show that: (1) It is found that the application of digital twin technology in China's rural world cultural heritage can be summarized into the following six indicators: digital culture and tourism, digital communication, digital archives, digital copyright, digital education, and digital management. (2) These six indicators have a positive impact on promoting the environmental, social, and economic sustainability of China's rural cultural heritage.

Keywords: Digital Twin Technology; Sustainable Development; World Cultural Heritage; Rural China

Introduction

The idea for the digital twin first emerged around 2003 in Professor Grieves's course on product lifecycle management at the University of Michigan. But at the time, the term "Digital Twin" had not yet been officially coined, Grieves called this idea a "Conceptual Ideal for PLM Product Lifecycle Management" (Grieves, M., and J. Vickers, 2017), as shown in Figure 1.1. In 2010, NASA's technical report officially proposed the term "DigitalTwin" and defined it as "a system or aircraft simulation process that integrates multiple physical quantities, multiple scales and multiple probabilities"; digitalTwin (DT) was proposed as an effective method, which was first used for spacecraft operation and maintenance (Glaessgen, E., and D. Stargel,2012) to generate a mirror image of the real world based on DigitalTwins technology. Based on blockchain technology, the economic system is constructed to realize the all-round integration of virtual and real world, so that every user can produce content and edit the world.

* Received: February 7 2024; Revised: February 20 2024; Accepted: February 22 2024

digital twinning is considered an important technical means to achieve the integration of virtual and real. (Wang Ruxi and Xiang Anling,2022)

This technique is applied to the protection of Cultural heritage in "Cultural heritage in context: the temples of Nubia, digital technologies and the future of conservation" mentioned that the biggest difficulty in cultural heritage protection lies in the protection of cultural background. The Nubian Temple project in this paper also uses digital twin technology, and uses GIS for mapping. (Rosa Tamborrino and Willeke Wendrich,2017) The Virtual Museum of Canada (vmc) system contains a list of more than 3,000 Canadian heritage institutions, a database of more than 600 virtual exhibits and more than 900,000 pictures. (David Ocon 2021)

However, it is worth noting that a significant number of World Cultural Heritage sites are located within Chinese villages. Consequently, the digital preservation and protection of rural cultural heritage in China emerge as indispensable research areas for ensuring the sustainable development of its cultural legacy.

This study aims to explore the influencing factors of digital twin technology on the sustainable development of rural cultural heritage in China and verify the concept of sustainable development based on the theoretical framework of a socio-technical system. Through qualitative research, six independent variables and three dependent variables will be used to verify the accuracy of the digital twin. The quantitative study will examine the impact of six indicators of China's digital twin technology on three sustainability indicators related to the environment, society, and economy of rural China.

Research Objectives

1. Digital twin technology has been applied in numerous fields and has also played an essential role in the sustainable development of China's rural world cultural heritage in recent years. In this paper, we study which technological factors play a role in the sustainable development of China's rural cultural heritage based on digital twin technology.

2. How digital twin technology affects the three main indicators of social sustainability, environmental sustainability and economic sustainability of China's rural World Heritage Sites.

Literature Review

In the Web of Science, there are 3034 journals related to "Research on the sustainable development of rural cultural heritage digital twin", the number is still quite large, and the research focus is still concentrated in the research field of value research and environmental sustainable development. In "New realities: a systematic literature review on virtual reality and augmented reality in tourism research "A systematic literature review on virtual reality and augmented reality in tourism Research" (Ryan Yung & Catheryn Khoo-Lattimore, 2017) analyzed 46 literatures from the perspective of management research, and more objectively analyzed the promotion effect of using this technology on tourism. Digitalising endangered cultural heritage in Southeast Asian cities: preserving or replacing the digital cultural heritage focuses on the archiving of digital cultural heritage, which carries out the construction of digital archives to realize the sustainable development of architectural cultural heritage (David Ocon, 2021). However, this article focuses on the protection of urban cultural heritage. There is no research from a rural perspective. in addition, some articles start from the research Angle of rural ecological sustainable development and carry out related research. Cultural heritage in context: the temples of Nubia, digital technologies and the future of conservation, the temples

of Nubia, digital technologies and the future of conservation, introduced in detail the cultural heritage digital protection, data visit and sustainable development of Nubia temples in Egypt. It provides a good reference for the writing of this paper (Rosa Tamborrino & Willeke Wendrich, 2017).

Advancing socio-technical systems thinking: A call for bravery lays out the theoretical framework of socio-technical systems in detail, suggesting that socio-technical systems thinking can contribute to sustainable development by focusing on the interaction of organizations and technologies to provide more effective solutions that promote social, environmental, and economic sustainability. This paper argues that the original theory of socio-technical systems is too narrow, and carries out an expanded study, based on Lesvitt's original model of 1965. (Davis, M. C., et al. 2014)

The theoretical foundations of sociotechnical systems change for sustainability: In a systematic literature review, a systematic literature review is carried out on the theory of socio-technical system and sustainable development, the relationship between the two is analyzed in detail, and the theoretical definition is summarized. This paper lays a foundation for the theoretical framework of this paper. (Savaget, P., et al., 2018)

Dependent variable	Target	Literature Source
environmentally sustainable	Low-carbon, environmentally friendly and sustainable tourism and activities Sustainable development and resource protection of cultural heritage Promote behavioral changes among tourists toward environmentally friendly travel Enhance social and tourist awareness of environmental protection	Butler, R., & Boyd, S. (2014). Font, X., & Harris, P. (2004). Tapper, R. (2004).
Socially sustainable	Rural residents' participation in and sense of belonging to heritage Cultural inheritance and exchange activities within the countryside The younger generation's awareness and interest in traditional culture Balanced distribution of social resources and benefit sharing	Timothy, D. J., & Boyd, S. W. (2003). Timothy, D. J. (2002). Gursoy, D., Chi, C. G. Q., & Lu, L. (2013).

Economically sustainable	The quantity and quality of tourists attracted by cultural heritage Cultural heritage related employment opportunities Promote local participation in cultural heritage protection and development Diversity and sustainability of the cultural heritage industry	Ashworth, G., & Larkham, P. J. (2013) Hall, C. M., & Müller, D. K. (2004). Coccossis, H., & Mexa, A. (2004).

Research Hypothesis

The hypothesis is created based on the validity test of sociotechnical system theory, with 7 main hypotheses and 17 sub-hypotheses

H1 digital cultural tourism technology has a significant positive impact on the sustainable development of rural cultural heritage in China

H1a digital cultural tourism has a positive impact on the sustainable development of rural cultural heritage environment in China

H1b digital cultural tourism has a positive impact on the sustainable development of rural cultural heritage society in China

H1c digital cultural tourism has a positive impact on the sustainable development of rural cultural heritage economy in China

H2 The application of digital archive technology has a significant positive impact on the sustainable development of rural cultural heritage in China

H2a digital archives have a positive impact on the environmental sustainable development of rural cultural heritage in China

H2b digital archives have a positive impact on the sustainable development of rural cultural heritage society in China

H3 The application of digital education technology has a significant positive impact on the sustainable development of rural cultural heritage in China

H3a digital education has a positive impact on the environmental sustainable development of rural cultural heritage in China

H3b digital education has a positive impact on the sustainable development of rural cultural heritage society in China

H3c digital education has a positive impact on the sustainable development of rural cultural heritage economy in China

H4 The application of digital copyright technology has a significant positive impact on the sustainable development of rural cultural heritage in China

H4a digital copyright has a positive impact on the environmental sustainable development of rural cultural heritage in China

H4b digital copyright has a positive impact on the sustainable development of rural cultural heritage society in China

H4c digital copyright has a positive impact on the sustainable development of rural cultural heritage economy in China

H5 The application of digital communication technology has a significant positive impact on the sustainable development of rural cultural heritage in China

H5a digital transmission has a positive impact on the environmental sustainable development of rural cultural heritage in China

H5b digital transmission has a positive impact on the sustainable development of rural cultural heritage society in China

H5c digital transmission has a positive impact on the sustainable development of rural cultural heritage economy in China

H6 The application of digital management technology has a significant positive impact on the sustainable development of rural cultural heritage in China

H6a digital management has a positive impact on the environmental sustainable development of rural cultural heritage in China

H6b digital management has a positive impact on the sustainable development of rural cultural heritage society in China

H6c digital management has a positive impact on the sustainable development of rural cultural heritage economy in China

H7 digital twin technology has a significant positive impact on the environmental sustainable development of rural cultural heritage in China

H8 digital twin technology has a significant positive impact on the sustainable development of rural cultural heritage society in China

H9 digital twin technology has a significant positive impact on the environmental sustainable development of rural cultural heritage in China

Research Methodology

1. Research area

The research of cultural heritage in this paper is limited to rural China. Samples are selected from the nine provinces where rural world cultural heritage is distributed in China. These nine projects are respectively in Sichuan, Guangdong, Jiangxi, Yunnan and Shanxi.

2. Method of sampling

The sample for this study is a group of college students aged 18-28, including undergraduate, master's, and doctoral students as the primary sample. In addition, the sample was selected according to the nine provinces where rural world cultural heritage is distributed in the interview sample catalog of Chinese world cultural heritage. The nine projects are located in Sichuan, Guangdong, Jiangxi, Yunnan, and Shanxi provinces. The quantitative research approach of the questionnaire is to validate the research objectives from the perspective of urban college students to ensure the objectivity of the results.

In this paper, we use stratified random sampling to collect a quantitative study sample. The units are randomly sampled according to the group The study sample was divided into three regions: Chengdu, Kunming, and Nanchang for distribution. The sample was made up of college students aged 18-28 years old who had an understanding of local cultural heritage and digital twin technology. Based on statistical data on the number of college students in each province, we were able to obtain the number of questionnaires distributed in Chengdu, Kunming, and Nanchang, the three cities selected for the sample.

The sample size of quantitative research is calculated using Taro Yamane's formula.

$$n= N / (1 + Ne^2)$$

n= sample size

N= population size

e= deviation (0.05)

Table 1 Questionnaire sample selection and distribution quantity list for China's rural world cultural heritage

Province	Number of rural world cultural heritage sites	Number of college（Unit ten thousand）students on	Number of questionnaires distributed (number of copies)
Chengdu	2	116.4	400
Kunming	2	74.99	400
Nanchang	2	81.47	400

Source: https://www.163.com/dy/article/IA38PAI10546MZWC.html

3.Questionnaire design

Questionnaire design concept The design of the question items in this study was based on a discussion of the relationship between latent variables in the main model and was created under the premise of the study assumptions. In the first part of the questionnaire, respondents were asked about their gender, age, education level, knowledge of digital twin technology, and selected cities to determine the demographic characteristics of the sample.

Researchers collected study data from the sample using a constructed questionnaire. The questionnaires were distributed in Chengdu, Kunming, and Nanchang.

The questionnaire was divided into two sections as follows:

3.1 User Information: Personal profile. The questionnaire for college students aged 18-28 includes gender, age, city of study, university, education level, and basic information about the digital experience of cultural heritage. Eight information points are listed.

3.2 The five-point Likert scale is used in the second part of 3.2. The variables designed for this study include six independent variables for digital archives, digital culture and tourism, digital communication, digital education, digital copyright, and digital management, and three dependent variables for society, environment, and economy. A total of 66 questions were included.

Through 66 indicators, we can understand which indicators play a decisive role in the sustainable development of China's rural cultural heritage through digital twin technology, and whether there are synergies between these indicators. This concludes a review of the impact of digital twin technology on factors related to the sustainable development of China's rural cultural heritage.

Results

1. Frequency analysis

The completed survey results were loaded into the statistical program SPSS 26.0. The first step is to perform a descriptive analysis of the data. The descriptive analysis of this study includes the descriptive part of the statistical results of the demographic characteristics of the respondents and the questionnaire variables: the selection frequency, percentage, and cumulative percentage of the demographic characteristics are described, and the results of the whole sample are visually reflected numerically to understand the basic background information of the respondents. Questionnaire items were assessed using a five-point Likert scale, the size of which represented the level of agreement: 5 being "heavily agree", 4 being "partially agree", 3 being "neutral", 2 being "partially disagree", and one being "heavily disagree". If the questionnaire item has a higher degree of approval, the item has a higher value, indicating that the item is closer to the subjective approach of the respondent. If the questionnaire item has a lower approval rating, the item has a lower value, contrary to the subjective approach of the respondents.

Table3 Frequency statistics (n=1201)

Name	Option	Frequency □	Percentage %
Your gender	A.male	631	52.54
2您的性别	B.female	570	47.46
Your level of education	B.Undergraduate course	656	54.621
4您的受教育程度	A.Junior college	264	21.982
4您的受教育程度	C.postgraduate	198	16.486
4您的受教育程度	D.Doctoral candidate	83	6.911
Your city	B.Chengdu	401	33.389
5您所在的城市	A.Kunming	401	33.389
5您所在的城市	C.Nanchang	399	33.222
Do you think the current digital technology of cultural heritage should first protect the cultural heritage of the city or the rural cultural heritage	B.city	952	79.267
6您认为目前文化遗产数字技术应该先保护城市的文化遗产还是乡村的文化遗产	A.village	249	20.733

Source: Author interview data collection

Frequency analysis is used to study the distribution of a certain type of data, and frequency and percentage are chosen separately. As can be seen from the table above, the results of the gender frequency analysis are as follows: A. Male frequency 631, 52.54%; B. The number of female frequencies is 570, which is 47.46 percent. Among them, A. male (52.54%) was the highest and B. female (47.46%) was the lowest. The results of the analysis of the frequency of education level are as follows: B. The frequency of undergraduates is 656, or 54.621; a. The frequency of junior colleges is 264, or 21.982%; c. The frequency of graduate students was 198, or 16.486%; the frequency of Ph.D. students was 83, or 6.911 percent. among them, B. undergraduate students (54.621%) were the highest, and D. doctoral students (6.911%) were the lowest. The frequency analysis results for your city are: B. Chengdu has a frequency of 401, which is 33.389 percent; a. Kunming has a frequency of 401, accounting for 33.389%; c. The frequency in Nanchang is 399, which is 33.22 percent. among them, B. Chengdu (33.389%) was the highest, and C. Nanchang (33.222%) was the lowest. Do you think the current digital technology for cultural heritage should first protect urban cultural heritage or rural cultural heritage? The results of the frequency analysis are as follows: B. urban frequency 952, 79.267%; A. The rural frequency is 249, which is 20.733 percent. among them, B. urban (79.267%) was the highest, and A. rural (20.733%) was the lowest.

2.Multiple response analysis

Multiple responses are used in multiple-choice analysis to analyze the proportion of multiple choices. There are two terms involved, namely, response rate and popularity rate. The response rate is used to compare the relative selection ratio of each option, and the popularity rate is used to select the popularity of a particular option. The difference between the two is that dividends are not the same. For example, if there are 100 samples and each sample selects three items on average, there are a total of 300 items selected by 100 samples. Moreover, if there are 60 sample choices for an option, then the response rate is =60/300 =20%; penetration rate =60/100=60%). First, the response rate, that is, the proportion of multiple-choice options, is analyzed, focusing on items that describe higher proportions. (The sum of the response rate must be 100%) Second: analyze the popularity rate, that is, on the whole, the proportion of multiple choice options in all choices, focusing on the analysis of the higher proportion of choices; (The combined penetration rate is commonly higher than 100%)

Table4 Response and Penetration Summary Table (n=1201)

name	Options	Respond		Penetration
		n	Response rate %	rate %
8. What do you know about the World Cultural Heritage in rural China	Yungang Grottoes	1077	20.800	89.675
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Dazu stone carving	949	18.328	79.017
8你对中国乡村世界文化遗产哪项有所	Mount Emei, Leshan Giant Buddha Scenic Spot Mount Emei Scenic Spot	840	16.222	69.942

了解 【多选题】				
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Sanqingshan National Park	779	15.044	64.863
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Pingyao Ancient city	541	10.448	45.046
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Chengjiang fossil site	279	5.388	23.231
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Kaiping watchtower and village	276	5.330	22.981
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Jiuzhaigou Scenic spot	251	4.847	20.899
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Honghe Hani terraces human landscape	186	3.592	15.487
8你对中国乡村世界文化遗产哪项有所了解 【多选题】	Collect	5178	100.00	431.141

Source: Author interview data collection

Specifically compare differences by response rate or penetration rate. Specifically, in 8 of China's rural World cultural heritage which you have some understanding of Yungang Grottoes, Dazu stone carvers, Mount Emei, Leshan Giant Buddha Scenic area of Mount Emei Scenic Area, a total of 3 items response rate and popularity rate is significantly higher.

3.Reliability analysis

In this study, the Cronbach's α coefficient of each scale was calculated through the reliability analysis of SPSS25.0, so as to test the reliability of the scales of digital literature travel, digital archives, digital education, digital copyright, digital communication, digital management, environmental sustainability, social sustainability, and economic sustainability. Cronbach's α coefficient ranges from 0 to one, and the closer it is to one, the higher the reliability of the scale. In this study, Cronbach's α coefficient is greater than 0.7 as the acceptance criterion. The results of the reliability tests are given in Table. It can be seen from the table that, digital cultural tourism, digital archives, digital education, digital copyright, digital communication, digital management, environmental sustainability, social sustainability, and Sustainable economic scale Cronbach's alpha coefficients were 0.901, 0.824, 0.941, 0.907, 0.898, 0.889, 0.825, 0.86, 0.88, were greater than 0.7, and delete any item after each

scale Cronbach's alpha coefficients will not improve, This indicates that 9 scales passed the reliability test, and each scale has a high internal consistency.

4.Confirmatory factor analysis

In this study, AMOS 24.0 software will use confirmatory factor analysis to evaluate the validity of the sample. Confirmatory factor analysis was used to confirm convergence validity and discriminant validity. hair(2010) believes that the absolute value of the factor load estimate should be at least 0.5, and the best index value should be 0.7 or heavy high: the extracted mean variance (AVE) index value should be at least 0.5 and the construction reliability index value should be greater than 0.7 to determine the convergence validity of this paper. Using the method described by Eome and Larcke1981, differential validity is determined by comparing the square root of AVE with the correlation coefficient of the structure of the two components. In this study, the maximum likelihood method was used to estimate the model and the following metrics were used to verify the fit of the model.

In this study, AMOS24.0 software was used to conduct confirmatory factor analysis on the scales of digital literature travel, digital archives, digital education, digital copyright, digital communication, digital management, environmental sustainability, social sustainability and economic sustainability involved in this paper. Standardized factor loading, combination reliability (CR) and mean variance extraction (AVE) were used to determine the convergence validity and discrimination validity of each variable dimension.

Table5 Results of model fit

Fit parameter	**CMIN**	**DF**	**CMIN /DF**	**GFI**	**AGFI**	**NFI**	**RFI**	**IFI**	**TLI**	**RMSEA**
result	1612.0	1559	1.034	0.95	0.95	0.958	0.955	0.999	0.998	0.005
Standard			<3	>0.9	>0.9	>0.9	>0.9	>0.9	>0.9	<0.08

Source: Author interview data collection

Table 6 discriminative validity test

	Digital travel	**Digital archives**	**Digital education**	**Digital copyright**	**Digital communication**	**Digital management**	**Environmental sustainability**	**Social sustainability**	**Economic sustainability**
Digital travel	0.730								
Digital archives	0.355**	0.736							
Digital education	0.301**	0.383**	0.770						
Digital copyright	0.323**	0.378**	0.257**	0.742					
Digital communication	0.301**	0.38**	0.315**	0.391**	0.724				
Digital management	0.291**	0.312**	0.35**	0.289**	0.329**	0.732			
Environmental sustainability	0.48**	0.531**	0.496**	0.505**	0.547**	0.507**	0.736		
Social sustainability	0.358**	0.333**	0.292**	0.317**	0.324**	0.279**	0.497**	0.779	
Economic sustainability	0.323**	0.344**	0.365**	0.297**	0.321**	0.314**	0.491**	0.325**	0.805

Note: *** indicates $p < 0.001$, and the diagonal is the AVE value of the variable.
Source: Author interview data collection

The above table is a discriminative validity test table. It can be seen from the table that the correlation coefficients among variables range from 0.291 to 0.547, all of which are smaller than the AVE square root of the variable. Therefore, it can be considered that the digital cultural tourism, digital archives, digital education, digital copyright, digital communication, digital management, environmental sustainability and social sustainability designed by this research can be considered as the main factors. The economic sustainability scale has good discriminative validity.

5.Correlation analysis

Pearson correlation analysis is used to investigate the significance and direction of the linear correlation degree between variables. In Pearson correlation analysis, we generally use correlation coefficient r to describe the linear correlation degree between variables. If the correlation coefficient r<0, it indicates that the correlation between two variables is negative; if the correlation coefficient r>0, it indicates that the correlation degree between two variables is negative. The correlation between the two variables is positive, and if the correlation coefficient r=0, there is no correlation between the two variables.

Table 7 Pearson correlation analysis

		Environmental sustainability	Digital archives	Digital education	Digital copyright	Digital communication	Digital management	Digital travel	Social sustainability	Economic sustainability
Environmental sustainability	Pearson correlation	1								
	Sig.（Two tails）									
Digital archives	Pearson correlation	0.436**	1							
	Sig.（Two tails）	0								
Digital education	Pearson correlation	0.436**	0.336**	1						
	Sig.（Two tails）	0	0							
Digital copyright	Pearson correlation	0.437**	0.326**	0.236**	1					
	Sig.（Two tails）	0	0	0						
Digital communication	Pearson correlation	0.470**	0.326**	0.288**	0.354**	1				
	Sig.（Two tails）	0	0	0	0					
Digital management	Pearson correlation	0.430**	0.263**	0.320**	0.259**	0.292**	1			
	Sig.（Two tails）	0	0	0	0	0				
Digital travel	Pearson correlation	0.412**	0.304**	0.276**	0.292**	0.269**	0.257**	1		
	Sig.（Two tails）	0	0	0	0	0	0			
Social sustainability	Pearson correlation	0.421**	0.280**	0.261**	0.280**	0.287**	0.244**	0.314**	1	

	Sig. (Two tails)	0	0	0	0	0	0	0		
Economic sustainability	Pearson correlation	0.417**	0.293**	0.332**	0.266**	0.285**	0.278**	0.287**	0.282**	1
	Sig. (Two tails)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	

** The correlation was significant at level 0.01 (two-tailed).
* The correlation was significant at level 0.05 (two-tailed).
Source: Author interview data collection

Correlation analysis was used to study the correlation between environmental sustainability, digital archives, digital education, digital copyright, digital communication, digital management, digital cultural tourism, social sustainability, and economic sustainability, and Pearson correlation coefficients were used to express the strength of the correlation. A detailed analysis shows that:

The correlation value between environmental sustainability and digital archives was 0.436, showing a significant level of 0.01, indicating a significant positive correlation between environmental sustainability and digital archives. The correlation value between environmental sustainability and digital education was 0.436, indicating a significant level of 0.01, indicating a significant positive correlation between environmental sustainability and digital education. The correlation value between environmental sustainability and digital copyright is 0.437, showing a significant level of 0.01, indicating a significant positive correlation between environmental sustainability and digital copyright. The correlation value between environmental sustainability and digital communication is 0.470, showing a significant level of 0.01, indicating a significant positive correlation between environmental sustainability and digital communication. The correlation value between environmental sustainability and digital management is 0.430, showing a significant level of 0.01, indicating a significant positive correlation between environmental sustainability and digital management. The correlation value between environmental sustainability and digital cultural tourism was 0.412, showing a significant level of 0.01, indicating a significant positive correlation between environmental sustainability and digital cultural tourism. The correlation value between environmental and social sustainability is 0.421, indicating a significant level of 0.01, indicating a significant positive correlation between environmental and social sustainability. The correlation value between environmental and economic sustainability is 0.417, indicating a significant level of 0.01, indicating a significant positive correlation between environmental and economic sustainability. The correlation value between social sustainability and digital archives is 0.280, showing a significant level of 0.01, indicating a significant positive correlation between social sustainability and digital archives. The correlation value between social sustainability and digital education was 0.261, indicating a significant level of 0.01, indicating a significant positive correlation between social sustainability and digital education. The correlation value between social sustainability and digital copyright is 0.280, showing a significant level of 0.01, indicating a significant positive correlation between social sustainability and digital copyright. The correlation value between social sustainability and digital communication is 0.287, showing a significant level of 0.01, indicating a significant positive correlation between social sustainability and digital communication. The correlation value between social sustainability and digital management

is 0.244, indicating a significant level of 0.01, indicating a significant positive correlation between social sustainability and digital management. The correlation value between social sustainability and digital cultural travel was 0.314, showing a significant level of 0.01, indicating a significant positive correlation between social sustainability and digital cultural travel. The correlation value between economic sustainability and digital education was 0.332, showing a significant level of 0.01, indicating a significant positive correlation between economic sustainability and digital education. The correlation value between economic sustainability and digital copyright is 0.266, showing a significant level of 0.01, indicating a significant positive correlation between economic sustainability and digital copyright. The correlation value between economic sustainability and digital communication is 0.285, showing a significant level of 0.01, indicating a significant positive correlation between economic sustainability and digital communication. The correlation value between economic sustainability and digital management is 0.278, showing a significant level of 0.01, indicating a significant positive correlation between economic sustainability and digital management. The correlation value between economic sustainability and digital cultural travel is 0.287, indicating a significant level of 0.01, indicating a significant positive correlation between economic sustainability and digital cultural travel. The correlation value between economic and social sustainability was 0.282, indicating a significant level of 0.01, indicating a significant positive correlation between economic sustainability and digital cultural trave.

Conclusions

Correlation analysis results

There is a significant positive correlation between environmental sustainability and digital archives, digital education, digital copyright, digital communication, digital management, and digital cultural tourism.

There is a significant positive correlation between social sustainability and digital archives, digital education, digital copyright, digital communication, digital management, and digital cultural tourism.

There is a significant positive correlation between economic sustainability and digital education, digital copyright, digital communication, digital management, and digital cultural tourism.

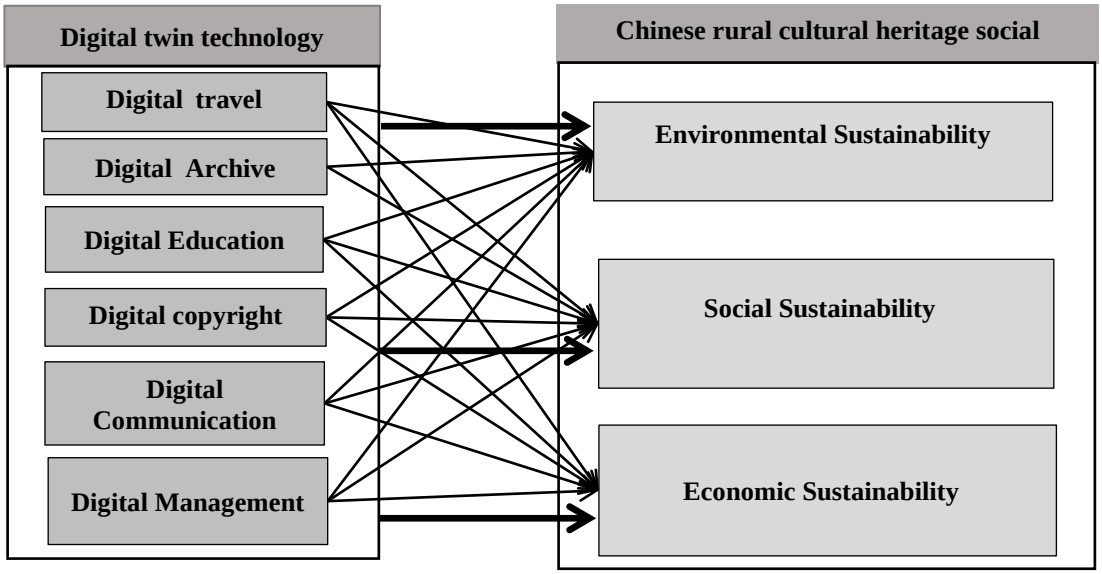

Figure 1 Conclusion frame diagram

Discussion

1. Discussion of Research Objective 1:

Digital twin technology plays an important role in the sustainable development of World cultural heritage in rural China through six technical factors: digital communication, digital management, digital copyright, digital archives, digital education, and digital cultural travel. It can be seen from the previous data verification that these six indicators play an important role in the environment, economy, and society of the sustainable development of the World cultural heritage in rural China. Through the joint application of various technical factors such as digital communication, digital management, digital copyright, digital archives, digital education, and digital cultural travel, It can promote the inheritance, protection, and development of the world cultural heritage in rural China, and inject new vitality into the sustainable prosperity of rural areas. Digital communication has narrowed the distance between urban and rural areas, domestic and foreign countries, and provided strong technical support for the sustainable development of rural cultural heritage in China. In terms of digital management, digital twin technology can comprehensively manage rural cultural heritage. From the perspective of technical application of digital copyright, digital twin technology provides strong technical support, and realizes copyright protection of rural cultural heritage-related content through technical means such as blockchain. Establishing digital archives provides the basis of information and data for the sustainable development of rural cultural heritage. Digital education provides a new way to cultivate rural cultural heritage talents in China, improves the willingness of Chinese talents to return to the countryside, and trains local digital technical talents for the countryside. The development of digital cultural tourism has driven the prosperity of the rural economy and created a new economic growth point for the sustainable development of rural areas.

2. Discussion of Research Objective2:

In terms of environmental sustainability, digital twin technology can promote the development of low-carbon, environmentally friendly, and sustainable tourism activities of World cultural heritage in rural China, promote the sustainable development and resource protection of rural cultural heritage in China, and promote the change of tourists' environmentally friendly tourism behaviors. Digital twin technology can improve the awareness of society and tourists on environmental protection in China's rural areas, which has been verified by the positive impact.

In terms of social sustainability, digital twin technology can promote the participation and sense of belonging of Chinese rural residents to cultural heritage, promote cultural inheritance and exchange activities in rural areas, enhance the younger generation's awareness and interest in traditional culture, and promote the balanced distribution of social resources and benefit sharing. The positive effect was verified.

In terms of economic and social sustainability, digital twin technology can promote the improvement of the number and quality of tourists, the application of digital twin technology can provide more employment opportunities for rural cultural heritage in China, digital twin technology can improve the participation of indigenous people in the protection and development of cultural heritage, and digital twin technology can promote the diversity and sustainable development of rural cultural heritage industry in China. The positive effect was verified.

Research contribution

Based on the digital twin system, the theoretical system of sustainable development of World cultural heritage in rural China is sorted out, and a basic research work is formed. In the past, studies on the sustainability of World cultural heritage in China's rural areas were all single studies, with more partial literature studies and case studies. In the existing literature research, it is found that the disciplines of digital research on World cultural heritage in China are relatively single, focusing on the fields of tourism, museums, archival research, and architectural science and engineering. In particular, less attention has been paid to the application of digital twin technology to World cultural heritage sites in remote villages in China. This study verifies the influence of six technical indicators of digital twin technology in the field of sustainable development of World cultural heritage in rural China and makes a theoretical review of the application indicators of digital twin technology through sociological research theories, which provides some research basis for the in-depth study of individual indicators in subsequent relevant research. These six indicators have been verified and studied on the impact ranking of the three important sustainability-dependent variables of environment, society, and economy, providing a theoretical basis for the subsequent protection and development of World cultural heritage in rural China with digital twin technology.

Recommendation

1. Promote support policies for 6 indicators: Develop comprehensive policy support measures to encourage and guide the application of digital twin technology in rural cultural heritage protection and sustainable development. The government may set up special funds to support projects in digital communication, digital management, digital copyright, digital archives, digital education, and digital cultural tourism to promote the wide application of technology in the sustainable protection and development of rural cultural heritage.

2.Promote the training of rural digital twin technical personnel: We will strengthen support for digital education and promote the popularization of digital education related to world cultural heritage in rural China. Rural artisans are encouraged to create digital education accounts, develop digital education development plans for the inheritance of the world's cultural heritage, and provide digital training resources for local rural digital twin technology-related talents to improve cultural literacy and environmental awareness among rural residents.

3.Strengthening the infrastructure of digital equipment in rural China: Concerns about the construction of rural networks and digital equipment in China were reflected in interviews with experts, and the construction of digital tourism infrastructure was strengthened to ensure improvements in rural communications, networks, data storage, and other infrastructure. Governments can provide digital infrastructure support through investment or collaboration to ensure the effective operation and development of digital twin technology indicators.

4. Formulate digital tourism standards for World Cultural Heritage in rural China: Standardize the application of digital technology in cultural and tourism industry. Strengthen the supervision of digital cultural tourism with digital management technology, ensure the deep organic combination of digital technology and cultural heritage, and promote the balance between digital tourism development and cultural protection.

5. The synergy of digital twin technology improves the sustainable development of rural employment: Through the application of digital twin technology, young people are encouraged to improve the dissemination of rural cultural heritage, and through the synergistic effect of digital archives, digital copyright, digital management, and other indicators, current economic growth points of China's rural world cultural heritage are realized, rural employment opportunities are enhanced, and population return is realized.

References

Ashworth, G., & Larkham, P. J. (2013). Building a New Heritage Tourism Destination: The Case of Margate. *Tourism Geographies,* 15 (1), 70-89.

Butler, R., & Boyd, S. (2014). *Tourism and heritage site sustainability. In Tourism and National Parks:* International Perspectives on Development, Histories, and Change (pp. 255-272). Routledge.

Coccossis, H., & Mexa, A. (2004). The contribution of ecotourism to the sustainable development of mountain regions: The case of Mount Pelion, Greece. *Sustainable development,* 12 (3), 158-17

David Ocón. (2021). Digitalising endangered cultural heritage in Southeast Asian cities: preserving or replacing? *International Journal of Heritage Studies*.（27）, 975–990

Davis, M. C., Challenger, R., Jayewardene, D. N. W., & Clegg, C. W. (2014). Advancing socio-technical systems thinking: A call for bravery. *Applied Ergonomics*, 45, 171-180.DOI：10.2514/6.2012-1818

Edward H. Glaessgen, D. S. Stargel. (2012). *The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles.* 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference
20th AIAA/ASME/AHS Adaptive Structures Conference
14th AIAA 2012

Font, X., & Harris, P. (2004). *Sustainable tourism: Social and environmental impacts*. Channel View Publications.

Grieves M, Vickers J. (2017). *Digital Twin: Mitigating unpredictable, undesir able emergent behavior in complex systems*. In Transdisciplinary Perspectives on Complex Systems (Issue August). Springer International Publishing; p. 85–113

Gursoy, D., Chi, C. G. Q., & Lu, L. (2013). Antecedents and outcomes of museum visitors' satisfaction: The case of the Hermitage Museum. *Tourism Management,* 37, 52-63.

Hall, C. M., & Müller, D. K. (2004). *Tourism, mobility, and second homes: Between elite landscape and common ground.* Channel View Publications.

Rosa Tamborrino & Willeke Wendrich. (2017). Cultural heritage in context: the temples of Nubia, digital technologies and the future of conservation. *Journal of the Institue of Conservation*. (4), 168-182

Ryan Yung & Catheryn Khoo-Lattimore.（2017）.*New realities: a systematic literature review on virtual reality and augmented reality in tourism research*. (22), 2057-2081 .doi.org/10.1080/13683500.2017.1417359

Savaget, P., Geissdoerfer, M., Kharrazi, A., & Evans, S. (2018). *The theoretical foundations of sociotechnical systems change for sustainability: A systematic literature review*. Journal of Cleaner Production. Advance online publication. doi:10.1016/j.jclepro.2018.09.208

Tapper, R. (2004). *Tourism and development in the developing world*. Routledge.

Timothy, D. J. (2002). *Cultural heritage and tourism: An introduction*. Channel View Publications.

Timothy, D. J., & Boyd, S. W. (2003). Heritage tourism in the 21st century: Valued traditions and new perspectives. *Journal of Heritage Tourism*, 1 (1), 1-16.

Wang, R. & Xiang, A. (2021). Report on Metaverse Development in 2020-2021. *Online.* Retrieved November 1, 2022, from: https://www.toutiao.com/article/7009255639734059528/?group_id=7009255639734059528&wid=1667291802865.