

Transforming Brick-and-Mortar Institutions: An Analysis of Digital Engagement in Small-City Museums and the Impact of Digital Transformation

Xinyao Wang^{1*a}, Shyhnan Liou^{1b} and Chia-Han Yang^{1c}

¹*Institute of Creative Industries Design, National Cheng Kung University, Taiwan*

**Corresponding author: Xinyao Wang, PA8073010@ncku.edu.tw*

Abstract

This paper explores the digital transformation journey of Liaoyang Museum, a national-level museum located in a small city with limited resources and audiences. An analysis of the museum's WeChat public account and official website reveals a dynamic interplay between digital strategies, cultural heritage preservation, audience engagement, and sustainable development. The study highlights the museum's proactive response to the COVID-19 pandemic by embracing online platforms and investing in physical infrastructure and technology. Challenges identified include resource optimization, talent gaps, and the need for a more holistic approach to digitalization. The paper concludes by emphasizing the importance of integrating digital technologies with traditional practices to foster community engagement, promote cultural awareness, and achieve sustainable museum development.

Keywords: Digital Transformation, Sustainable Development, Small-City Museums, COVID-19 Pandemic

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Introduction

Museums play an increasingly important role in promoting sustainable development, contributing to cultural heritage preservation, community engagement, education, and societal awareness. Although research on digital transformation in museums is expanding, the specific needs and challenges faced by smaller, national-level museums in small cities remain underexplored. This paper examines how these museums can leverage digital transformation to overcome limitations, enhance cultural influence, and foster sustainability.

The research explores the interplay between museum digitalization, sustainable development, and the unique challenges faced by smaller museums. By analyzing the case of the Liaoyang Museum, the paper provides insights into:

Effective Digitalization Strategies: Strategies for navigating digital landscapes are explored, with a focus on optimizing resources and maximizing impact within the small-city context.

Cultural Heritage Preservation: The study investigates how digital technologies can meaningfully and accessibly preserve cultural heritage for future generations.

Audience Engagement: The paper examines how digital tools can attract larger, particularly younger, audiences and create a more engaging museum experience. Building Sustainable Practices: The research explores how museums can use digital transformation to promote community involvement, enhance cultural awareness, and develop sustainable practices.

The research aims to offer valuable insights and practical recommendations for small-city museums navigating digital landscapes, contributing to museum studies, and providing concrete steps for sustainable museum development in a rapidly changing world.

Literature review

Museums, Digital Transformation, and Sustainable Development

The relationship between museums and sustainable development has gained recognition, highlighting museums' potential contributions. Before the COVID-19 pandemic, research emphasized organizational changes needed to enhance sustainability in museums. Jung (2016) examines how these changes affect workplace culture, emphasizing leadership and communication's role in aligning museum operations with sustainable development goals. Kornelaki et al. (2018) studied educational programs in archaeological museums to improve science education for young students, aligning with UNESCO's sustainable development objectives. Málaga et al. (2019) discussed museums as tools for sustainable community development, focusing on their role in fostering sustainable practices within local communities.

Digital technology began emerging as a promising avenue for sustainability. Museums recognized digital tools' potential to enhance visitor engagement and broaden access to collections, marking the beginning of a transformative journey. Krämer-Weidenhaupt (2020) noted that the gradual adoption of digital practices supports sustained development, laying the groundwork for a more integrated approach to cultural heritage management. Literature on museum digital transformation and sustainability is still evolving. For example, Hadi et al. (2021) examined sustainable business performance determinants in Malaysia's upstream petroleum industry, and Qin et al. (2022) discussed digital technology-driven sustainable transformation in agriculture. Stroumpoulis et al. (2022) explored the relationship between sustainable supply chain management and digital transformation, focusing on technologies like blockchain and big data analytics. Feng et al. (2022) provided an empirical analysis of the impact of enterprise digital transformation on green innovation, showcasing the positive effects on environmental initiatives.

The COVID-19 pandemic catalyzed a critical shift in museums, accelerating digital transformation and sustainability discussions. As in-person visits became impractical, museums adopted innovative digital initiatives to engage audiences. The federal government recognized the need to address the digital divide in

museums and libraries during COVID-19 (Federal Government, 2020). This period underscored digital technology as crucial for maintaining educational outreach and cultural engagement during crises. Consequently, digital transformations in museums have become essential for survival in a rapidly evolving cultural landscape.

Despite challenges, digital transformation in museums is seen as inevitable, with the pandemic accelerating technology adoption (Roque et al., 2024). The connection between digitalization and sustainability in museums has become increasingly apparent (Richardson, 2021). Grants supporting digital initiatives have helped museums navigate challenges (Lutman, 2021). As museums adapt their digital strategies, recognizing digital transformation to promote sustainability has led to increased scholarly discourse.

With funding and grants bolstering digital initiatives, museums are well-positioned to adapt and innovate, enhancing their role in sustainable cultural heritage practices. Literature indicates that digital transformation has led to new approaches to engaging audiences, preserving cultural heritage, and enhancing educational experiences (Cosmin & George, 2021). From crowdsourcing to virtual museums, digital technologies are becoming integral to museum operations (Reynolds, 2017). This trend supports current sustainability strategies and indicates a fundamental shift in how museums contribute to sustainable development.

Digital Transformation in Museums

The digital transformation of museums has become crucial over the past few years, driven by the need to enhance visitor experiences and preserve cultural heritage. Early discussions on digitalization emphasized integrating technology into museum practice to address contemporary needs. For example, Park (2012) highlights the digital restoration of Seokguram Grotto and the development of Virtual Museums, showcasing how advanced technologies can preserve cultural legacies. Din et al. (2014) underscore the importance of comprehensive digital strategies, noting that effective policymaking and business models are pivotal for successful integration into museum operations.

However, significant challenges remain in digitalization efforts. Pan et al. (2012) identify difficulties in connecting stakeholders like archaeologists and museums, while Wang (2014) describes Japan's collaborative approach to overcoming financial and technical barriers through government and large enterprise partnerships. Zhang (2014) discusses incorporating new media and Web3D technology to enhance digital museum platforms. Li et al. (2017) demonstrate how virtual reality can enrich visitor experiences, as evidenced by the Shihsanhang Museum. To address digital transformation challenges, Bernardi et al. (2019) emphasize the need for robust digital strategies, as echoed by Shi et al. (2020) and Podzharaya et al. (2020), who explore smart tourism's impact on museum digitalization in Montenegro.

Technological advancements have significantly influenced how museums navigate digital landscapes. Mobile applications have become key tools for enhancing museum experiences, as Šobánková (2016) examines their typology and purpose concerning visitor interaction. Yi (2018) analyzes the impact of the "Internet plus" concept on cultural tourism, using the "digital palace museum" as an example of content innovation. Cultural content drives digital transformation, as Arrigoni et al. (2019) highlight the intersection of digital technologies and heritage. In the realm of digital cultural relics, Li et al. (2020) presents a visual system combining cultural knowledge with visualization techniques, enriching the narrative of exhibitions.

Collectively, this body of literature underscores technology's critical role, management practices, and cultural heritage in the digital transformation of museums. As institutions navigate this complex landscape, integrating innovative strategies will be crucial for enhancing visitor engagement, preserving cultural resources, and ensuring museums remain relevant in the digital age.

Methodology

This study focuses on the themes of digital transformation and sustainable development within the context of museums. It specifically examines how museums can use technology and management strategies to innovate cultural content, with a focus on the unique pathways and characteristics of digital transformation in small-city museums. The theoretical frameworks of sustainable development and digital transformation are central to this exploration. Sustainable development emphasizes the balance of social, economic, and environmental factors, while digital transformation highlights how digital technologies can reshape organizational operations and value delivery. The research process is depicted in Figure 1, detailing the stages and tasks involved.

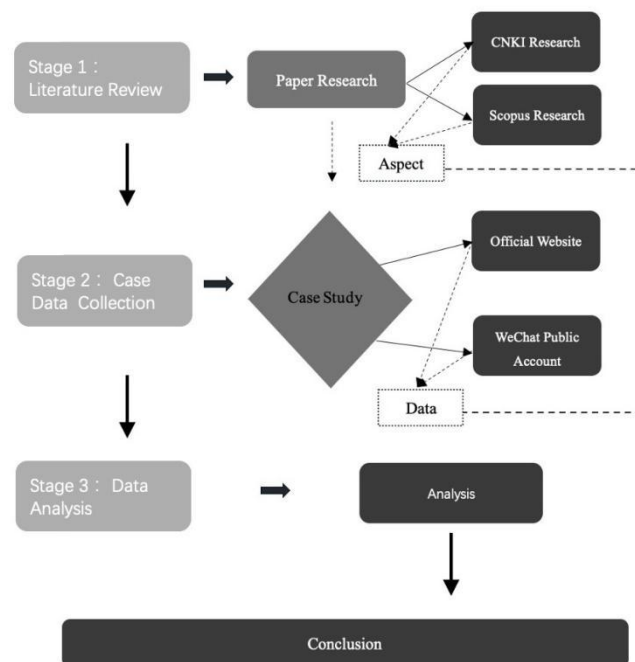


Fig. 1 Research Process

To achieve this, a comprehensive literature review was conducted using two major academic databases (Table 1): CNKI (China National Knowledge Infrastructure) and Scopus. The selected literature spans from 2020 to 2024, capturing recent developments in museum digitalization, especially in response to the COVID-19 pandemic, which has accelerated the adoption of digital technologies. This period also marks significant technological advancements, increased policy support for digital initiatives, and a growing body of research that provides valuable insights for analysis.

The study places a particular emphasis on analyzing the official website and WeChat public account of the Liaoyang Museum as primary sources for data collection and organization. By examining the content and themes of various activities promoted through these digital platforms, the research aims to explore how the museum's digitalization efforts contribute to cultural innovation and the sustainable transmission of heritage. This methodology not only allows for an integrated analysis of how small-city museums navigate digital transformation while emphasizing sustainable practices, but it also highlights contemporary developments, challenges, and best practices in digitalization. The insights derived from this examination underscore technological advancements in small-city museums and elucidate management approaches that facilitate meaningful cultural transformation in the digital age.

Table 1. Influential Museum Digital Aspect Articles

<i>Authors</i>	<i>Talent</i>	<i>Technology</i>	<i>Collaboration</i>	<i>Cultural Content</i>	<i>Media Platforms</i>
<i>Cassidy, K. A. et al. (2020)</i>	Emphasizes enhancing staff understanding and application of digital technology.	Uses disruptive technology to connect museums with community digital technology.	/	Emphasizes the integration of cultural content between community and museums.	/
<i>Dibitonto et al. (2020)</i>	Museum directors must understand the needs and support the professional talent required for digital transformation.	Technological innovation should be combined with human resource development to drive organizational transformation.	Employees need to be flexible to adapt to changes, update their skills, and collaborate with various professionals.	Emphasizes cross-disciplinary cooperation to promote cultural management through technology and innovation.	/
<i>Kamariotou et al. (2021)</i>	Emerging positions must support digital transformation and enhance the team's technical capabilities and adaptability.	Combines digital archives with artworks, allowing users to browse freely between art and archives.	The distinction between organizational roles becomes blurred in the digital space, emphasizing the need for more collaborative practices to engage visitor experiences.	Plans for digitized exhibits and collections, as well as enhancing user experience.	Updates information and establishes interaction with the audience through social media platforms.
<i>Zou Dehan (2022)</i>	Cultivating professional knowledge of immersive technologies for display design.	Introduces cloud services, digital multimedia, and virtual reality technologies to change traditional display methods.	Promotes social participation in cultural relic digitization, emphasizing technology and sharing efforts.	Emphasizes the application of digital technologies in multi-dimensional displays of archaeological museums.	/
<i>Leite et al. (2022)</i>	During the pandemic, the team needs to reshape itself to respond to changes.	Online guide services and digital content enhance the dissemination of museum exhibition information.	Maintains contact with public health authorities and relevant partners to share information and experiences.	During the pandemic, museums need to enhance their attractiveness and accessibility.	Produces a large amount of video content to promote virtual visits and permanent exhibitions.
<i>Muškar et al. (2022)</i>	Emphasizes the importance of trained staff in enhancing visitor engagement.	Utilizes digital technologies for information collection, organization, and digital display to promote interactive experiences.	Museums collaborate with other organizations to enhance digital services and infrastructure.	Explores the role of digital technologies in the protection and dissemination of cultural heritage.	Uses social media to enhance museum visibility and invites visitors to participate in promotional activities.
<i>Agostino, D. & Costantini, C. (2022)</i>	Emphasizes the digital skills and capabilities of museum personnel, pointing out the lack of emphasis on digital talent.	Proposes a framework for assessing the degree of digitalization in museums, exploring the use of digital tools.	Improves the digitalization of internal processes in museums, particularly in customer interactions.	Provides comprehensive indicators for digital transformation to assist museum managers in decision-making.	/
<i>Raimo et al. (2022)</i>	Highlights the need for museums to possess professional talent and skills to meet digital transformation.	Focus on website development, social media, and online ticketing systems to enhance visibility and visitor experience.	Emphasizes teamwork to improve museum management efficiency and customer interaction.	Discusses the impact of digital transformation on attracting visitors and protecting cultural heritage.	Mentions the concentration of digital museums in showcasing historical building information and images.
<i>Dou Wenlong (2023)</i>	/	Builds a mobile crowdsourcing platform to encourage broad public participation in cultural relic digitization.	Promotes the development and sharing of cultural data resources to expand cultural dissemination channels and consumption scenarios.	/	/
<i>Zhang Yuqin (2023)</i>	/	Utilizes virtual restoration technology to enhance visitor satisfaction and engagement	/	Enhances tourists' understanding and engagement with exhibits through virtual restoration.	/
<i>Sebastián Lozano et al. (2023)</i>	Emphasizes multidisciplinary cooperation for integrating silk cultural heritage information and data.	Utilizes machine learning and data standardization to enhance the digital management and dissemination of silk heritage.	Promotes open cooperation with different institutions and experts.	Discusses the significance of protecting silk heritage and the importance of digital documentation.	Mentions using digital museums and online platforms to disseminate silk cultural heritage.
<i>Liu Bingbing (2024)</i>	Enhances employees' understanding in the field of digital technology and encourages participation in external seminars.	Utilizes 3D technology for relic scanning to support data preservation.	Emphasizes the importance of project management and collaboration from various parties to support fundraising.	Showcases the depth and diversity	/
<i>Wang Meng & Wang Jinlan (2024)</i>	Need for technical personnel to train in VR and AR technologies; requires high-level specialized knowledge.	Applies AR and VR technologies to provide immersive historical experiences.	Collaborates closely with historians and education experts to ensure rich exhibition content.	Promotes the dissemination and education of cultural heritage through immersive experiences.	/
<i>Wang Wei & Ma Min (2024)</i>	Interaction designers need to understand visitor needs and expectations.	Museum displays transform to increase interaction with the audience, using technology to enhance visitor understanding.	The British Museum establishes collaboration with the public through lectures and discussions.	Emphasizes the in-depth understanding and experience of visitors regarding the historical and cultural	Maintains good interaction with the public through social media.

<i>You Xinyue et al.</i> (2024)	Enhances the capabilities of technical staff, emphasizing necessary technical support.	Introduces three-dimensional panoramic technology for exhibition navigation, enhancing immersion and participation.	Balances resource sharing and information security, emphasizing multi-party collaboration.	context of exhibits. Highlights user participation in the design of digital museums, promoting a user-centered two-way communication model.	/
<i>Al-Hashim, A. & Bankari, N.</i> (2024)	Multidisciplinary experts collaboratively participate in HBIM construction, requiring cooperation among architects, engineers, and others.	Combines drone photogrammetry technology with HBIM to provide 3D models and methods for acquiring building information.	Encourages open collaboration, using open-source software and cooperating with experts.	Emphasizes the importance of preserving vernacular architecture while exploring the digital documentation of cultural heritage.	/

The digital transformation of museums involves several key aspects (Table 2), each with unique characteristics. First, talent is crucial, requiring professionals with expertise in technology and digital tools. Interdisciplinary collaboration, involving historians, designers, and technical experts, is also vital. Continuous learning and development are necessary, with staff regularly attending training sessions to keep pace with technological advancements. Second, the introduction of technology is foundational for digital transformation. Museums should adopt cutting-edge technologies such as cloud computing, 3D scanning, and drone photogrammetry and use various digital tools to enhance management efficiency and audience interaction. The integration of multiple technological approaches can create a multi-dimensional display experience.

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Digital transformation also requires multi-party cooperation, involving cultural institutions, technology companies, universities, and experts. Encouraging community participation helps museums engage the public in the protection and dissemination of cultural heritage. Cross-disciplinary collaboration consolidates broader knowledge and resources, driving innovation. In terms of cultural content, digital transformation should enhance content richness and rethink the presentation of cultural narratives by incorporating interactive elements and storytelling. Digitalization also offers new possibilities for the protection and dissemination of cultural assets, ensuring better preservation and sharing of cultural heritage. Visitor experience is crucial, and museums should strive to enable visitors to gain a deeper understanding of cultural and historical contexts. Finally, media platforms play a significant role. Digital media, such as social media and digital museums, facilitates widespread cultural dissemination and two-way communication between the audience and the museum. Leveraging media power can enhance the museum's brand image, attracting more visitors and sponsorship.

In summary, the digital transformation of museums is a comprehensive project encompassing talent development, technology application, collaboration models, cultural content presentation, and media dissemination. By effectively integrating these factors, museums can enhance exhibition quality, visitor experience, and cultural protection and dissemination.

Table 2. The Key Aspect and Characteristics in Museum Digital Transformation Influential

<i>Aspect</i>	<i>Characteristics</i>
Talent	Requires professionals with expertise in technology and digital tools.
	Cross-disciplinary collaboration, including historians, designers, and technical experts.
	Continuous learning and development, with staff attending regular training and seminars.
Technology	Adoption of cutting-edge technologies (e.g., cloud computing, 3D scanning, drone photogrammetry).
	Use of digital tools to enhance management efficiency and audience interaction.
	Integration of various technological means to create a multi-dimensional display experience.
Collaboration	Multi-party collaboration, including cultural institutions, tech companies, universities, and experts.
	Encourage and facilitate community participation, allowing the public to be involved in cultural heritage protection and dissemination.
	Cross-disciplinary collaboration to consolidate broader knowledge and resources.
Cultural Content	Richness in content, rethinking the presentation of cultural content by incorporating interactive elements and storytelling.
	Protection and dissemination, utilizing digitalization for preserving and sharing cultural assets.
	Emphasizing visitor experience by enabling deeper understanding of cultural and historical contexts.
Media Platforms	Information dissemination through digital media (social media, digital museums) for broad cultural heritage outreach.
	Interactivity, promoting two-way communication between the audience and the museum.
	Brand building, enhancing the museum's image through media engagement to attract more visitors and sponsorship.

Liaoyang Museum, located at 2 Zhongxin Road, Dongsi Road, Liaoyang City, Liaoning Province, China, originates from the "Peng Mansion," a building established during the Republic of China era in 1921. It covers an area of 11,552 square meters, with nearly 3,000 square meters of construction space. The museum officially opened to the public in 1985 and was designated a provincial-level cultural relic protection unit in 1988. Today, it is recognized as a national AAAA-level tourist attraction. The museum houses over 6,000 artifacts, including more than 1,000 items classified as national third-tier relics or above, showcasing significant historical, artistic, and regional value.

The Liaoyang Museum plays a practical role in society by organizing exhibitions and educational activities to meet the public's demand for spiritual and cultural enrichment and fostering community participation and awareness of local history. In response to modern demands, the museum promotes digital transformation, incorporating technologies such as augmented reality (AR) and 3D scanning to enrich exhibition formats and provide an immersive visitor experience. By using digital platforms, the museum enhances interactivity and encourages visitor participation while showcasing rich historical narratives.

The museum also emphasizes sustainable development by integrating environmental protection principles into its operations,

supporting the preservation and transmission of cultural heritage. In summary, the museum's efforts in historical research, cultural protection, and digital transformation underscore its role in contemporary society. Director and Party Secretary leads the Liaoyang Museum, overseeing its operations. The museum has adopted modern technologies, offering Wi-Fi, a WeChat public account, and digital touch screens to enhance the visitor experience. Additionally, the three-dimensional guided exhibition hall and digital guidebooks provide engaging, interactive experiences, while the digital cinema enriches exhibition content. These applications not only enhance modernity but also deepen visitors' understanding of cultural content.

From 2017 to 2019, the museum organized traditional activities emphasizing the sustainable development of culture (Table 3). It collaborated with entities such as the Liaoyang Municipal Bureau of Culture, Tourism, and Radio and Television, and the Liaoyang

Public Cultural and Sports Service Center, to host events promoting intangible cultural heritage. Activities like the volunteer interpretation competition, involving local arts groups, reflected the commitment to cultural preservation. Since 2023, the museum has continued traditional activities while gradually integrating digital functions like digital touch screens and social media promotion, enhancing interactivity and dissemination effectiveness.

However, these activities predominantly maintain traditional forms, sustaining principles of cultural exchange and community participation. For instance, the museum has hosted calligraphy donation ceremonies and performances of local intangible cultural heritage, indicating that while digital advancements are welcomed, the importance of traditional modes in cultural transmission and development remains central. Data for these activities is sourced from the museum's official website, ensuring credibility and relevance.

Table 3. Cooperation Characteristics Notification from Official Website

COOPERATION	CONTENT FROM OFFICIAL WEBSITE
2017-2019	<p>Liaoyang Museum successfully held an intangible cultural heritage promotion activity: Liaoyang Municipal Bureau of Culture, Tourism, and Radio and Television; Liaoyang Public Cultural and Sports Service Center; Municipal Public Cultural and Sports Service Center. 20190610</p> <p>Liaoyang Painting Academy: A special performance of Pan-Chuan School Guqin Art will be held at the Folk Museum. 20190605</p> <p>Local arts groups: Liaoning News reported on the Liaoyang Museum Little Volunteer Interpreter Competition 20190520 ; "Telling the Story of Liaoyang and Passing on Historical Culture—Liaoyang Little Volunteer Interpreter Competition" came to a close. 20190517</p> <p>Media organizations: Collaborated with local news media for promotion and reporting during the "5.18 International Museum Day" event. 20190515</p> <p>Liaoyang Folk Museum: The "Intangible Cultural Heritage" project display activity will be held at the Folk Museum during the May Day holiday. 20190430</p> <p>Local cultural research institution: The exhibition of novel manuscripts and samples by renowned author Mr. Li Yunde opens today at our museum. 20181109</p> <p>Local cultural research institution: Resumption notice for the series of lectures on Cao Xueqin's "Dream of the Red Chamber." 20180911</p> <p>Taitung Calligraphy and Painting Association: The "Cultural Exchange in Liaoning" exhibition by the Taitung Calligraphy and Painting Association opened at our museum. 20180813</p> <p>School: Collaborated with Liao Hua No. 3 Primary School in volunteer activities. 20180323</p>
2023-2024	<p>Liaoyang Painting Academy: The exhibition of the report of study sketches from the Ink Wash Figure Painting Workshop of Wang Mi, held at the Liaoyang Painting Academy. 20230901</p> <p>Local cultural and arts groups: The donation ceremony of calligraphy works by Wang Wenjie, themed "Sentiment for Hometown," was held at Liaoyang Museum. 20230923</p> <p>Intangible cultural heritage related organizations: Amazing! The performance event of the representative project "Tang Dynasty Costume Hand-Painting" of Liaoyang's intangible cultural heritage was spectacular. 20230821</p> <p>Cultural Relics Protection Center: The Liaoyang Cultural Relics Protection Center celebrated the 2023 Cultural and Natural Heritage Day with various colorful activities.</p> <p>Community or grassroots organizations: Liaoyang Museum conducts a mobile museum outreach program — Exhibition of renowned collection artifacts images (Part II); Liaoyang Museum conducts a mobile museum outreach program — Exhibition of renowned collection artifacts images (Part I). 20230727</p> <p>Cultural Bureau or related government agencies: On International Museum Day, there were 'little volunteer interpreters'; artistic performances by national first-class actor Wang Peng and local theatrical groups; and the representative project of Liaoyang's intangible cultural heritage "Tang Dynasty Costume Hand-Painting." 20230518</p>

Several activities at the museum highlight the role of digital technology in cultural dissemination and audience interaction (Table 4). For example, during "5.18 International Museum Day," digital tools enhanced public awareness and participation, promoting digital culture. The "Liaoyang Museum Little Volunteer Interpreter Competition" used digital strategies to engage presentations, which fostered cultural literacy and responsibility

among young volunteers. The online lectures on Cao Xueqin's "Dream of the Red Chamber" facilitated the transmission of classical literature and cultural understanding. Additionally, the "Journey into the Wilderness: Chinese Painting Exhibition" used digital displays to enhance visitor interactivity. These digital approaches increased the appeal and reach of exhibitions and expanded the museum's influence on local history and culture.

Table 4. Meaning of Digitalization from Liaoyang Museum (Official Website)

<i>Activity</i>	<i>Date</i>	<i>Theme</i>	<i>Meaning of Digitalization</i>
<i>5.18 International Museum Day</i>	2019-05-15	Cultural Promotion and Educational Activities	Enhance public awareness and participation in museums, promoting the dissemination of digital culture.
<i>Liaoyang Museum Little Volunteer Interpreter Competition</i>	2019-05-20	Volunteer and Community Culture	Cultivate cultural literacy and sense of responsibility among young people while enhancing the fun of presentations through digital means.
<i>Cao Xueqin's "Dream of the Red Chamber" Lecture Series</i>	2018-09-11	Traditional Literature Education	Spread classical literature through online lectures, facilitating cultural understanding and interaction.
<i>Journey into the Wilderness: Chinese Painting Exhibition</i>	2018-09-10	Chinese Traditional Art Exhibition	Increase audience interaction experience by digitally showcasing and disseminating traditional art.
<i>Completion of the Little Volunteer Summer Camp Activity</i>	2018-08-27	Volunteer Service and Cultural Heritage Preservation	Combine digital platforms to enhance students' awareness and participation in culture.
<i>Liaoyang Museum's Participation in the "Exhibition of the Five Capitals of Daliao" in Beijing</i>	2018-09-07	Volunteer Service and Cultural Heritage Preservation	Utilize digital means to demonstrate the history and culture of Liaoyang, expanding its influence.
<i>"Lighthouse Rural Commercial Bank Cup" Calligraphy Competition Exhibition</i>	2018-08-21	Calligraphy Art	Attract young audiences by showcasing calligraphy works through digital methods.

Several museum projects also exemplify sustainable development (Table 5). For example, the mobile museum outreach program — "Exhibition of Renowned Collection Artifacts Images," promotes cultural heritage preservation and community cultural participation. The "Intangible Cultural Heritage" project emphasizes the protection and transmission of local intangible heritage, contributing positively to sustainable development. The "Spring Festival Art Exhibition" promotes cultural practices,

helping the community maintain vibrancy. Moreover, the lecture series on "Dream of the Red Chamber" raises public awareness about protecting cultural heritage. The "Lighthouse Rural Commercial Bank Cup" Calligraphy Exhibition promotes traditional calligraphy culture, driving the revival of local cultural arts. These activities demonstrate the museum's dedication to enriching cultural life and sustainable development

Table 5. Meaning of Sustainability from Liaoyang Museum (Official Website)

<i>Activity</i>	<i>Date</i>	<i>Theme</i>	<i>Meaning of Sustainability</i>
<i>Mobile Museum Outreach — Exhibition of Renowned Collection Artifacts Images (Part I)</i>	/	Cultural Exhibition	Promote the protection and dissemination of cultural heritage, facilitating community cultural participation.
<i>Liaoyang "Intangible Cultural Heritage" Project Display Activity</i>	2019-04-30	Intangible Heritage	Emphasize the protection and transmission of local intangible culture, contributing to sustainable development.
<i>Spring Festival Art Exhibition</i>	2019-01-25	Spring Festival Exhibition	Promote local culture through art exhibitions, aiding in the sustainable transmission of culture.
<i>Cao Xueqin's "Dream of the Red Chamber" Lecture Series</i>	2018-09-11	Traditional Literature Education	Disseminate traditional culture, enhancing public cultural identity and awareness of heritage protection.
<i>"Lighthouse Rural Commercial Bank Cup" Calligraphy Exhibition</i>	2018-08-21	Calligraphy Art	Promote the protection and development of traditional calligraphy culture.

The museum's activities reflect the gradual integration of digital technology with sustainable cultural development (Table 6). For example, the mobile museum outreach program used digital means to showcase artifacts, enhancing audience engagement and promoting cultural preservation. Online lectures on "Dream of the Red Chamber" improved cultural awareness, demonstrating digital

tools' application in education. The "Intangible Cultural Heritage" project digitally recorded and presented heritage items, fostering cultural preservation. During "5.18 International Museum Day," digital promotion heightened public awareness of cultural heritage protection. These initiatives highlight digital technology's growing role in cultural sustainability.

Table 6. Meaning of digitalization and Sustainability from Liaoyang Museum (Official Website)

<i>Activity</i>	<i>Date</i>	<i>Theme</i>	<i>Meaning of digitalization + Sustainability</i>
<i>Mobile Museum Outreach — Exhibition of Renowned Collection Artifacts Images (Part I)</i>	/	Cultural Exhibition	Utilize digital means to showcase cultural relics, promoting community participation and cultural preservation.
<i>Cao Xueqin's "Dream of the Red Chamber" Lecture Series</i>	2018-09-11	Traditional Literature Education	Enhance public cultural awareness through online lectures, while facilitating the sustainable dissemination of traditional culture.
<i>Intangible Cultural Heritage Project Display Activity</i>	2019-04-30	Intangible Cultural Heritage	Use digital methods to record and display intangible cultural heritage projects, promoting the protection and transmission of culture.
<i>"5.18 International Museum Day" Event</i>	2019-05-15	Cultural Promotion and Educational Activities	Strengthen public awareness of cultural heritage protection through digital promotion and active participation in events.

The museum's WeChat public account activities from 2015 to 2024 are categorized into two themes (Table 7). Theme 1 covers

fixed daily topics, including notable figures, historical anecdotes, and cultural appreciation. Theme 2 includes main content areas

related to activities like exhibitions, educational programs, and community engagement. The rise of "Online Exhibition" during 2020-2021 reflects the museum's adaptation to the COVID-19 pandemic and commitment to cultural accessibility and engagement. The data was collected by classifying and counting

each activity by theme and nature, ensuring accurate and comprehensive information for analysis. In total, 241 activity themes and 486 directional statistics were compiled, providing a basis for further research on the museum's digital transformation and contributions to sustainable development.

Table 7. Data of Paper and Notification from Liaoyang Museum (WeChat Public Account)

Year	AQ	Theme 1	Q	Theme 2	Q
2015	142	【Notable Figures】	4	Cultural Relics Exhibition	15
		【Historical Anecdotes】	5	Traditional Culture and Educational Activities	10
		【Cultural Relics Knowledge】	3	Art Exhibition	8
		【Antique Appreciation】	1	Volunteer Activities	4
		【Traditional Culture】	4	Cultural Exchange and Cooperation	4
		【Cultural Treasures】	2	Intangible Cultural Heritage Display	3
		【Collection Highlights】	1	Community Participation	2
		【Etiquette and Culture】	3	Cultural Promotion	5
		【Seasonal Sentiments】	1	Festival Activities	3
		【Reference Materials】	1	Calligraphy Exhibition	4
		【Excavation Reports】	1	Thematic Exhibition	4
		【Art Culture】	1	Photography Exhibition	5
		【Fun History】	1	Other Artistic Activities	3
		【Liaoyang Poetry Selection】	1		
		【Qing Dynasty Liaoyang Poetry】	1		
		【Historical Facts of the Ancient City】	1		
			4		
		Subtotal	4	Subtotal	70
			4		
2016	70	【Historical Facts of the Ancient City】	8	Cultural Relics Exhibition	12
		【Collection Highlights】	5	Traditional Culture and Educational Activities	9
		【Exhibition Preview】	6	Art Exhibition	9
		【New Exhibition Preview】	4	Volunteer Activities	4
		【Notable Figures】	4	Cultural Exchange and Cooperation	5
		【Historical Anecdotes】	3	Intangible Cultural Heritage Display	3
		【Cultural Relics Knowledge】	2	Community Participation	3
		【Antique Appreciation】	2	Cultural Promotion	4
		【Traditional Culture】	1	Festival Activities	4
		【Etiquette and Culture】	1	Calligraphy Activities	5
		【Reference Materials】	1	Thematic Exhibition	5
		【Excavation Reports】	1		
		【Art Culture】	1		
		Subtotal	4	Subtotal	63
			3		
2017	71	【Historical Facts of the Ancient City】	9	Cultural Relics Exhibition	13
		【Collection Highlights】	8	Traditional Culture and Educational Activities	11
		【New Exhibition Preview】	3	Art Exhibition	7
		【Exhibition Preview】		Volunteer Activities	4
				Cultural Exchange and Cooperation	4
				Intangible Cultural Heritage Display	3
				Community Participation	3
				Cultural Promotion	3
				Photography Exhibition	3
				Calligraphy Exhibition	3
2018	70	【Historical Facts of the Ancient City】	5	Commemorative Activities	3
		【Collection Highlights】	7	Festival Activities	3
		【New Exhibition Preview】	9		
		【Exhibition Preview】	4	Cultural Relics Exhibition	12
		【Activity Preview】	1	Art Exhibition	10
		【Public Welfare Activities】	1	Educational and Cultural Activities	7
				Volunteer Activities	3
				Cultural Exchange and Cooperation	5
				Intangible Cultural Heritage Display	2
				Community Participation	3
2019	43	【Historical Facts of the Ancient City】	2	Festival Activities	3
		【Collection Highlights】	7	Calligraphy Activities	4
		【Exhibition Preview】	5	Thematic Exhibition	5
		【New Exhibition Preview】	7	Photography Exhibition	3
		【Performance Preview】	1		
		【Lecture Preview】	1		
			3		
			2		

		【Activity Preview】	1	Festival Activities	3
		【Notifications】	1	Photography Exhibition	3
		【Activity Reports】	3		
		【Volunteer Corner】	1		
		【Safety Production Public Welfare Advertisement】	1		
		【Public Welfare Advertisement】			
		【Emergency Management Public Welfare Advertisement】			
		Subtotal	3	Subtotal	38
			0		
2020	45	【Historical Facts of the Ancient City】	1	Cultural Relics Exhibition	10
		【Collection Highlights】	3	Traditional Culture and Educational Activities	7
		【Exhibition Preview】	5	Art Exhibition	5
		【New Exhibition Preview】	4	Volunteer Activities	3
		【Online Exhibition】	8	Cultural Exchange and Cooperation	4
		【Announcements】	3	Intangible Cultural Heritage Display	2
		【Activity Preview】	1	Community Participation	3
				Cultural Promotion	4
				Festival Activities	2
				Calligraphy Activities	3
				Thematic Exhibition	2
				Photography Exhibition	3
		Subtotal	2	Subtotal	48
			5		
2021	48	【Historical Facts of the Ancient City】	1	Cultural Relics Exhibition	11
		【Collection Highlights】	2	Traditional Culture and Educational Activities	7
		【Exhibition Preview】	5	Art Exhibition	5
		【New Exhibition Preview】	6	Volunteer Activities	2
		【Online Exhibition】	8	Cultural Exchange and Cooperation	5
		【Announcements】	2	Intangible Cultural Heritage Display	2
		【Activity Preview】	1	Community Participation	3
		【Safety Production Public Welfare Advertisement】		Cultural Promotion	4
				Festival Activities	3
				Calligraphy Activities	1
				Thematic Exhibition	5
				Photography Exhibition	4
			2	Subtotal	52
			5		
2022	16	/	/	Volunteer Recruitment	2
				Cultural Activities	10
				Education and Training	3
				Research Activities	1
				Cultural Relics Donation	1
				Art and Calligraphy Exhibitions	2
				Photography Competition	2
				Epidemic Prevention and Control	1
		Subtotal	/	Subtotal	22
2023	27	【New Exhibition Preview】	1	Cultural Activities	12
		【Announcements】	1	Volunteer Recruitment	3
				Education and Training	2
				Art Exhibitions	4
				Community Participation	3
				Intangible Cultural Heritage Display	2
				Mobile Museum	3
				Cultural and Natural Heritage Day Activities	2
				Other Activities	3
		Subtotal	2	Subtotal	34
2024	62	【New Exhibition Preview】	6	Cultural Relics Exhibition	8
		【Activity Recruitment】	4	Traditional Culture and Educational Activities	7
		【Exhibition Preview】	5	Art Exhibition	6
		【Lecture Preview】	1	Volunteer Activities	4
		【Activity Preview】	1	Cultural Exchange and Cooperation	3
				Intangible Cultural Heritage Display	3
				Community Participation	3
				Cultural Promotion	3
				Festival Activities	3
				Photography Exhibition	2
		Subtotal	1	Subtotal	42
			7		
		Total	2	Total	486
			4		
			1		

Analysis and discussion

Analysis of the Liaoyang Museum's WeChat public account reveals a dynamic relationship between museum activities and external factors. Article publications peaked in 2015 and 2016, decreased until 2022, then slightly increased. A significant drop occurred in 2020-2021 due to the COVID-19 pandemic, highlighting the museum's shift to "Online Exhibition" to maintain cultural engagement. While both themes show a similar declining trend, Theme 2 demonstrates greater stability. The recent rise in Theme 1 articles after 2022 suggests a potential shift towards greater emphasis on digitalization and its practical application (Figure 2).

While this shift towards online content shows a willingness to embrace the digital landscape, the museum faces challenges in fully leveraging its potential. The content often relies on traditional images and text, suggesting the need for more interactive digital experiences. Additionally, the museum requires talent development in content creation and technical skills. Addressing these challenges requires further investment in digital resources and infrastructure.

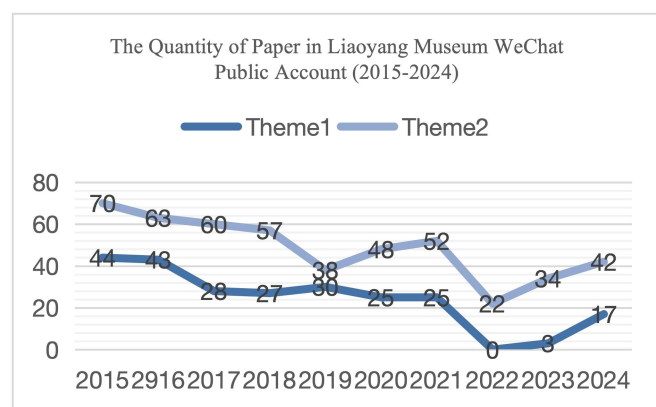


Fig. 2. The Quantity of Paper in Liaoyang Museum WeChat Public Account (2015-2024)

Cooperation activities from 2017 to 2018 and 2020 to 2022 displayed stability, with an average of 4-5 collaborations per year (Figure 3). However, a decline in 2019 indicates a possible shift in strategies or resource allocation. In 2023, a dramatic increase to 6 collaborations highlights a renewed focus on expanding social influence post-pandemic, underscoring the role of partnerships in museum development. The post-pandemic emphasis on collaboration suggests a strategic focus on leveraging partnerships for broader reach and impact.

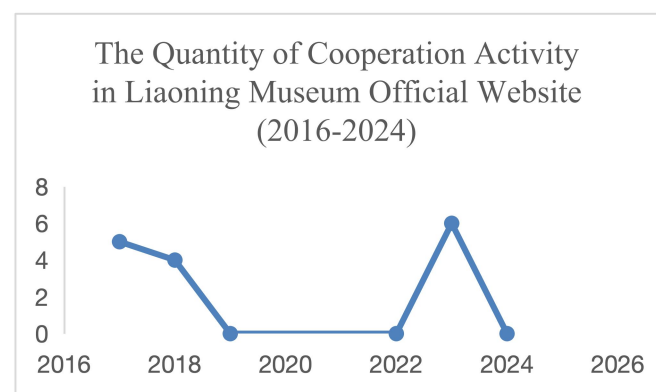


Fig. 3. The Quantity of Cooperation Activity in Liaoning Museum Official Website (2016-2024)

An analysis of publications on the museum's official website reveals a shift in priorities towards digitalization and sustainable

development (Figure 4). In 2018, the focus was on traditional culture preservation and social responsibility. However, 2019 saw a significant increase in digitalization-related articles, indicating a strategic shift towards digital growth. This suggests an active effort to integrate digital transformation with sustainable development for a positive impact.



Fig. 4. The Quantity of Digitalization and Sustainability in Liaoyang Museum Official Website (2018-2019)

The study's data reveals an ongoing digital transformation at the Liaoyang Museum. Articles related to digital initiatives surged, especially in 2019 and post-pandemic, showing a commitment to digital technology. The rise of "Online Exhibition" reflects the museum's proactive response to the pandemic and efforts to maintain cultural accessibility (Qin et al., 2022). These findings align with a broader museum trend of leveraging digital platforms to expand reach and engagement (Reynolds, 2017). Complementing online content, the museum has also enhanced the physical experience by implementing digital infrastructure like Wi-Fi, digital screens, 3D exhibition guides, and digital guidebooks. These initiatives aim to provide an engaging visitor experience and improve collection accessibility.

However, challenges remain the decline in article publications during 2020-2021 suggests obstacles, likely due to the pandemic (McKeown, 2020). Despite efforts to boost digital content, the museum must evolve towards more dynamic, interactive digital experiences. This shift requires investment in digital resources and skilled personnel to maximize the potential of digital platforms (Lutman, 2021).

The Liaoyang Museum's trajectory illustrates that digital transformation in museums requires a holistic approach, incorporating technology, management strategies, and collaboration. The museum's partnerships with cultural organizations showcase its commitment to collaboration and community engagement, enhancing its ability to achieve objectives and reach wider audiences. While data indicates progress, future research should explore management strategies for small-city museums, focusing on data-driven practices to ensure smooth digital transformation and sustainability.

Digital Transformation and Sustainability on Culture

The use of digitalization has significantly enhanced the sustainable development of museums, particularly during the challenges of the COVID-19 pandemic. As restrictions limited physical access to cultural institutions, museums adapted by leveraging digital platforms to ensure the continuity of cultural engagement. The implementation of "online exhibitions" allowed museums to transition traditional displays into virtual formats, offering unprecedented access to collections. This approach removed barriers to access, attracting a broader audience, including

those unable to visit in person. By engaging a diverse demographic, museums fulfilled their roles in cultural education and appreciation.

Additionally, interactive digital experiences have increased visitor engagement. Many institutions have introduced virtual tours, workshops, and live events that create immersive experiences beyond traditional formats. This engagement fosters a deeper connection between museums and the public, cultivating a sense of community essential for cultural appreciation. Digitalization has also bolstered collaboration among cultural organizations. By forming partnerships, many museums have launched joint online initiatives and shared resources, enhanced cultural exchange and promoting community involvement. Looking ahead, it's crucial for museums to refine their digital strategies to ensure visitor engagement and operational sustainability. This includes enhancing online content and incorporating technologies like augmented reality (AR) to create more dynamic exhibitions.

Ultimately, the pandemic has highlighted digital transformation as vital for ensuring cultural sustainability. Embracing digital tools not only enhances efficiency but also enables museums to thrive in a rapidly changing environment, preserving and evolving cultural heritage. Ongoing investment in digital resources and skilled personnel will help museums successfully navigate this digital landscape while fulfilling their commitment to cultural education and community engagement.

Conclusion

This study explores digital transformation in small-city museums, focusing on Liaoyang Museum as a case study. Analysis of the museum's WeChat public account and website reveals a dynamic interplay between digital strategies, cultural heritage preservation, audience engagement, and sustainable development. The museum's proactive response to the COVID-19 pandemic through online platforms and investments in physical infrastructure and technology is notable. However, challenges such as limited resources, talent, and the need for a holistic approach to digitalization remain. The study emphasizes integrating digital technologies with traditional practices, fostering community engagement, and promoting cultural awareness as key drivers for sustainable development within the museum sector.

This study's limitations include a sole focus on one museum, which may limit generalizability, and reliance on official website data, which may not fully represent all aspects of digital transformation. Further research should explore a broader range of museums to better understand the scope of digitalization's impact on cultural heritage preservation and audience engagement.

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About the Authors

Xinyao Wang

Institute of Creative Industries Design, National Cheng Kung University, Taiwan

Shyhnian Liou

Institute of Creative Industries Design, National Cheng Kung University, Taiwan

Chia-Han Yang

Institute of Creative Industries Design, National Cheng Kung University, Taiwan

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