Virtual-Physical Symbiosis: A Study on the Sustainable Path of Digital Transformation in the Exhibition Industry

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Abstract: The traditional model of China's exhibition industry faces challenges such as high resource consumption and severe environmental pollution. Digital transformation has become an inevitable direction for the industry's high-quality development. However, the current transition is constrained by the absence of "virtual-physical symbiosis" scenarios and the lack of real-time interaction between physical and digital exhibition booths. Centered on "virtual-physical symbiosis," this paper constructs a four-dimensional theoretical framework encompassing technology, management, experience, and sustainability. By integrating the linkage mechanism between the sustainable development goals (SDGs) and the digital transformation of the exhibition industry, it analyzes the China International Import Expo as a case study. The research clarifies the technological underpinnings and tool applications for exhibition digital transformation, proposes diverse pathways for SDG implementation, and ultimately provides theoretical foundations and practical guidance for government policy formulation and corporate digital practices. This contributes to achieving green, smart, and inclusive high-quality development in the exhibition industry.

Keywords: Digital transformation of the exhibition industry; Virtual-physical symbiosis; Sustainable development; Artificial intelligence (AI); China International Import Expo

1. Introduction

1.1. Research background

While China's exhibition industry has driven economic and trade exchanges, its traditional model faces pressing challenges such as high resource consumption and environmental pollution. Cai and Si incisively observed that the conclusion of an exhibition marks the birth of a landfill, profoundly highlighting the urgency of industry transformation [1]. Against this backdrop, national policies such as the"14th Five-Year Plan for the Development of the Digital Economy" explicitly advocate digitalization, intelligentization, and green transformation to empower

the high-quality development of the exhibition industry. In practice, flagship events like the China International Import Expo (CIIE) have pioneered the integration of online and offline experiences by establishing the "Digital CIIE" platform. However, despite dual drivers of policy and technology, the exhibition industry's digital transformation still faces critical research gaps. While existing studies have established preliminary analytical frameworks, deficiencies remain, namely, the absence of symbiotic virtual-physical scenarios and the lack of real-time linkage mechanisms between physical and digital booths. These shortcomings constrain the depth and sustainability of digital transformation.

1.2. Research questions and significance

Given these gaps, the exhibition industry must further explore how to achieve systematic and sustainable development during digital transformation. Specifically, how can real-time interaction mechanisms supporting "virtual-physical symbiosis" scenarios be established through technological empowerment? Addressing this question is crucial not only for the depth and breadth of the industry's digital transformation but also for achieving synergistic economic, social, and environmental benefits.

Grounded in national strategic priorities and industry realities, this study focuses on the core theme of "virtual-physical symbiosis" within the MICE sector's digital transformation. It aims to construct a systematic analytical framework at both theoretical and practical levels. The research outcomes are expected to provide theoretical foundations and practical guidance for government policy formulation and the digital advancement of exhibition enterprises. This work holds significant theoretical and practical implications for driving the digital transformation of the exhibition industry while contributing academic insights to promote China's exhibition sector toward green, smart, and inclusive high-quality development.

2. Theoretical basis and analytical framework

2.1. Theoretical basis

2.1.1. The connotation and path of exhibition digital transformation

Digital transformation is a paradigm shift triggered by digital technology. It reconstructs organizational operation and value creation through the deep integration of culture, labor and technology [2]. In the exhibition industry, the digital transformation is reflected in the trend of online and offline integration of exhibitions, technology-enabled operations, and digitization of service processes, which promotes the evolution of exhibitions from the traditional model to the collaborative system of "virtual and real symbiosis [3]."

Based on the theoretical framework, the digital transformation of exhibition can be regarded as a system of co-evolution of four dimensions: technology, management, experience and sustainability. Technology drives new productivity, management realizes intelligent operation, experience meets personalized needs, and sustainability integrates green concepts. Through the keyword-exhibition digital transformation, this paper retrieves about 393 Chinese literatures in CNKI, and uses CiteSpace to analyze the co-occurrence of topics related to the keyword 'exhibition digital transformation'. From the entire co-occurrence network map, it can be seen that the exhibition industry, digital economy, and digital exhibition are still current research hotspots (**Figure 1**). From the results of keyword emergence, it can be seen that the research heat of keywords such as 'exhibition industry' and 'AI' has increased significantly in recent years, reflecting that the digital transformation of exhibition has formed a clear research path and practical focus, which further verifies the realistic trend of multi-dimensional linkage of 'technology-management-experience-sustainability' (**Figure 2**).
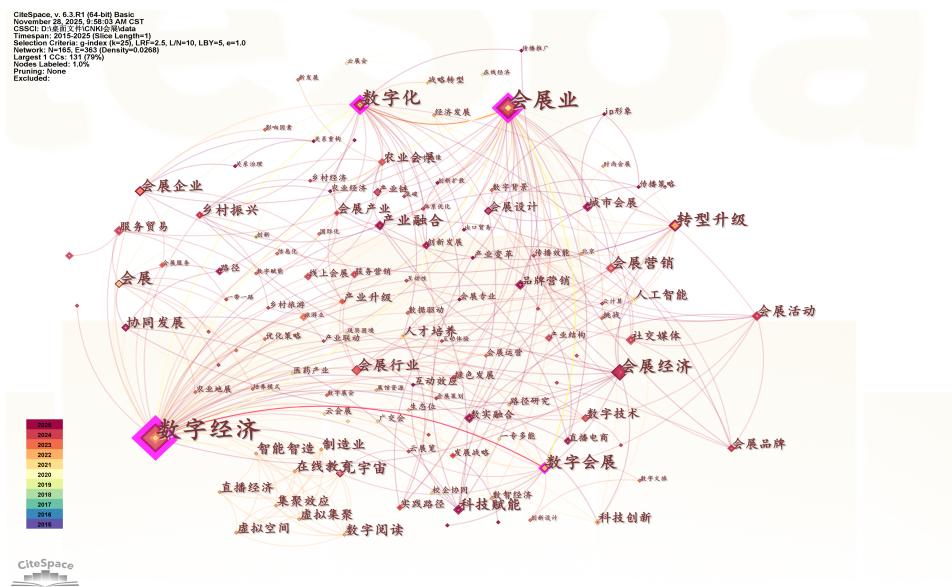
Figure 1. Keywords clustering view of digital transformation research of exhibition.

Top 7 Keywords with the Strongest Citation Bursts

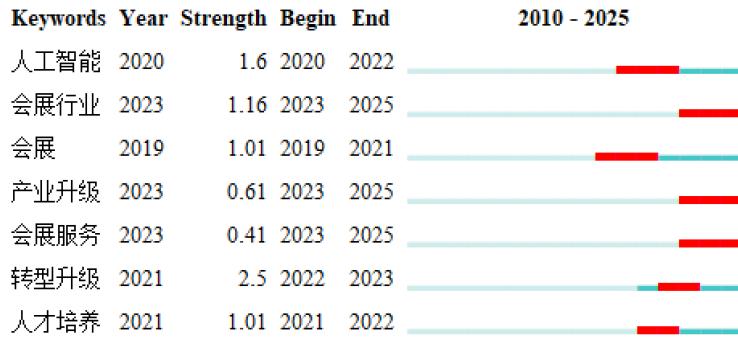| Keywords	Year	Strength	Begin	End	2010 - 2025
人工智能	2020	1.6	2020	2022	
会展行业	2023	1.16	2023	2025	
会展	2019	1.01	2019	2021	
产业升级	2023	0.61	2023	2025	
会展服务	2023	0.41	2023	2025	
转型升级	2021	2.5	2022	2023	
人才培养	2021	1.01	2021	2022	

Figure 2. Research keywords emergent results (2020–2025).

2.1.2. Sustainable development theory

The theory of sustainable development emphasizes that ' it not only meets the needs of contemporary people, but also does not constitute a harmful development to the ability of future generations to meet their needs [4]. In the field of exhibition, the theory extends to the comprehensive consideration of resource utilization, ecological protection and social responsibility. Taking Canton Fair as an example, Cai constructs an evaluation system of exhibition sustainable development covering six dimensions of economy, society, resources, environment, exhibition and community, and points out that economic sustainability and social sustainability are particularly important at this stage [5]. Liu further proposed that sports exhibitions should expand their sustainable development path through market-oriented operation, brand building and 'Internet +' integration [6]. From the perspective of 'cost-benefit', Pei *et al.* pointed out that the transformation of digital intelligence is conducive to the optimization of resource allocation and the improvement of operational efficiency of exhibition enterprises, so as to achieve the balance between economic benefits and environmental responsibilities [7]. It can be seen that the sustainable

development of the exhibition industry not only depends on policy support and technology empowerment, but also needs to systematically integrate multiple objectives at the strategic level to promote the industry to move towards green, efficient and inclusive high-quality development.

2.2. The definition of the concept of "virtual and real symbiosis"

In the field of exhibition, "virtual and real symbiosis" refers to the "real" of physical venues, physical exhibits and real people's participation, and the "virtual" of digital twin pavilions, virtual exhibitors and data assets. Through AI, digital twin and other technologies, the two can achieve a closed loop of "real-time mutual reflection (spatial structure with virtual reality and virtual reality)-flow mutual promotion (offline passenger flow and online flow mutual diversion)-experience mutual integration (the audience can obtain seamless experience in the continuous experience of virtual and real)", which provides a " theory + technology" integration path for the development of exhibition industry [8,9].

2.3. Construct theoretical framework

Taking "virtual and real symbiosis" as a meta-concept, the digital transformation of exhibition is regarded as an adaptive system that combines four dimensions of "technology-management-experience-sustainability" and co-evolves online and offline.

2.3.1. Technological dimension

New technology is the core engine of "new quality productivity". New productivity emphasizes technological innovation and digital transformation, which promotes the exhibition industry to accelerate the introduction of AI, digital twin and other technologies, realize new forms such as intelligent exhibition and virtual exhibition, and improve the efficiency of the industry [10].

2.3.2. Management dimension

Technology empowers and reshapes the operation and management model. Li points out that digital technology is a key means of supply-side reform, which is conducive to promoting the overall transformation of the industrial chain, transforming management in the direction of intelligence, reshaping organizational management capabilities, and improving the innovation ability of the exhibition industry. Mining potential creativity plays a significant role in promoting [11].

2.3.3. Experience dimension

The experience economy emphasizes the relationship between the three elements of "audience-space-exhibition" to promote the integration of modern exhibition design and technology culture. The experience economy provides a path to meet the personalized and diversified consumer demand for the exhibition, enhances the audience's sense of participation and satisfaction, and thus enhances the exhibition effect [12].

2.3.4. Sustainability dimension

Professor He Jun puts forward three ways to promote green exhibition design. In the whole society, we should establish green value concept, cover system norms and management system guarantee system, take "3R" principle and human care as the core level, enrich the innovative ways of green exhibition design, and help the exhibition industry to achieve sustainable development [13].

2.4. Basic technical support

2.4.1. Virtual reality: Creating immersive exhibition experiences

A digital technology applicable to the convention and exhibition field, which can provide participants with a brand-new online digital experience and enable exhibitors and audiences to obtain an immersive experience.

2.4.2. Augmented reality: Overlaying digital information on the real environment

A digital technology that can overlay digital information on the real environment, applicable to scenarios such as exhibition navigation and exhibit display, providing precise services and immersive experiences for exhibitors.

2.4.3. Artificial intelligence: Intelligent recommendation, customer service, and data analysis

Based on machine learning algorithms, it analyzes the data of exhibitors and professional audiences to conduct precise matching, greatly improving trade efficiency and reflecting the core logic of digital economy empowering the value creation of the convention and exhibition industry [14]. Chatbots and virtual assistants using natural language processing technology can answer common questions at any time, freeing up human resources to focus on high-value services. Furthermore, AI can conduct in-depth mining of massive data generated during exhibitions, such as pedestrian flow and stay time, providing a scientific basis for organizers to evaluate exhibition effects, optimize venue layout, and predict future trends.

2.5. Classification and practice of application tools

Table 1 summarizes the major categories of digital tools applied in the convention and exhibition industry, including exhibition and display tools, intelligent management systems, business matching tools, data analysis tools, and safety management tools. For each category, the table outlines representative application cases, target user groups, and core functions. Overall, these tools demonstrate how digital technologies enhance immersive exhibition experiences, optimize operational management, improve business matching efficiency, support data-driven decision-making, and strengthen on-site safety management across the entire exhibition lifecycle.

Table 1. Digital tools and application scenarios in the convention and exhibition industry

Tool type	Specific applications	Target users	Main functions
Exhibition and display tools	1. Taobao Creation Festival disseminates through short videos and other media [15]; 2. Louvre Museum in France builds a digital exhibition platform using high-definition image collection technology to realize immersive online display of cultural relics [16]; 3. Mio Exhibition's "Net Exhibition & Trade MAX" platform realizes 3D online display of exhibits through digital modeling [17].	Exhibitors, audiences	Provide immersive experience of exhibits or cultural content; break time and space limitations to display exhibition content; enhance exhibition participation experience
Intelligent management systems	1. Cloud Native Conference realizes online ticket purchase, DingTalk face-scan authentication, and paperless meetings, building a digital conference management system [18]; 2. Mio Exhibition launches OA, CRM, ERP and other systems, decomposing the exhibition process into modular assembly lines to realize informatization of operation and business management; 3. Xiamen International Convention and Exhibition Center builds an intelligent energy management system, dynamically adjusting energy consumption such as venue air conditioning and lighting through AI.	Exhibition organizers, venue operators	Process automation, data integration, intelligent energy consumption regulation; improve the operational efficiency of conventions and exhibitions

Table 1 (Continued)

Tool type	Specific applications	Target users	Main functions
Business matching tools	1. Mio Exhibition's "Net Exhibition & Trade MAX" establishes an O2O shared database, integrating customs bill of lading data from 154 countries around the world to realize two-way information sharing and precise matching between buyers and sellers; 2. Mio Exhibition's "Net Exhibition & Trade Meta" adopts an online-offline dual exhibition mode, collecting the list of intended buyers from exhibitors before the exhibition and inviting precise buyers to attend.	Exhibitors, professional audiences	Precise business matching; pre-match supply and demand information; improve trade docking efficiency; reduce exhibitors' customer acquisition costs
Data analysis tools	1. The Data Command Center of Cloud Native Conference displays real-time data such as the number of participants, crowd characteristics, and venue environment through LED screens, predicting the peak of visits and exits; 2. The convention and exhibition audience flow prediction model based on big data integrates historical exhibition, social media, and macroeconomic data, predicting audience flow through algorithms such as linear regression and random forests [19].	All roles	Data collection, trend analysis, decision support
Safety management tools	1. Convention and exhibition centers deploy infrared sensors, video surveillance, and AI intelligent security systems to monitor crowd density in real time, identify abnormal behaviors such as fighting and gathering, and issue early warnings; 2. The convention and exhibition audience flow early warning mechanism based on big data adopts green/yellow/orange/red graded early warning and initiates corresponding diversion and flow restriction measures.	Risk and safety management managers	Risk early warning, emergency response; ensure on-site safety of conv

3. The correlation mechanism between SDGs and the digital transformation of the exhibition industry

3.1. The corresponding relationship between SDGs and digital transformation

Digital transformation drives the innovation and upgrading of exhibition marketing models, with the help of digital technologies such as VR/AR virtual display and big data analysis, we can build online promotion systems and virtual exhibition platforms. These platforms break geographical restrictions to expand the scope of communication, and realize targeted promotion through accurate user profiles. Driven by technological innovation, this model reform not only optimizes the promotion ecosystem, but also promotes the in-depth integration of the exhibition industry and the digital industry .

The digital transformation of the exhibition industry is deeply linked to the construction of smart cities. Functions like intelligent traffic scheduling and online community interaction can be better integrated into urban development. At the same time, online exhibition platforms also provide more convenient channels for community residents. In the marketing and promotion stage, online publicity can replace traditional paper materials such as posters and brochures, and cloud exhibition halls and online live broadcasts can be used to reduce the consumption of promotion materials. This digital green marketing model not only conforms to the sustainable development concept of SDG 12, but also reduces the operation costs of exhibition marketing .

3.2. The implementation paths of SDGs in the digitalization of the exhibition industry

To put SDGs into practice, the government should formulate incentive policies and improve relevant laws and

regulations; industry associations should play a linking role and build communication platforms; exhibition enterprises should integrate the concept of SDGs into their digital strategies; and the public's awareness and acceptance of SDGs need to be raised at the social level. Technological innovation is the key point for the implementation of SDGs. We should speed up the construction of digital infrastructure, provide technical support for the achievement of SDG goals, and form a synergistic effect between green technology and digital technology. The exhibition industry needs to build a broader and more efficient service system. We should optimize online platforms by adding barrier-free functions to protect the right of special groups to participate in exhibitions; provide training and low-cost solutions for small and medium-sized enterprises to narrow the gap between different market players. Upstream and downstream industries should work together to build a sustainable development ecosystem of the industrial chain through digital transformation. We can use digital platforms to promote information sharing and resource coordination, and popularize the circular economy model.

3.3. Theoretical framework of "Master Teacher Studio"

Theoretical framework is the basis and purpose of all research. Thus, researchers are trying to find an appropriate theoretical perspective to analyze the construction process of Master Teacher Studios. According to relevant literature and monographs, the commonly used theoretical analysis perspectives in existing studies include Professional Learning Community, Learning Organization Theory, Cooperative Learning Theory, situational learning theory, Group Dynamics Theory, etc., or some researchers adopt Professional Capital Theory, Social Constructivist Theory, Distributed Leadership Theory, Action Learning Theory, Plan-Do-Check-Act Theory, etc. From the further review of relevant literature, it can be seen that most researchers tend to position the theoretical basis of Master Teacher Studio in the community model, that is, the Master Teacher Studios are essentially a kind of professional learning community, which is the localization practice in China.

4. Case analysis: China International Import Expo

4.1. Case background

Hosted by the Ministry of Commerce of the People's Republic of China and the Shanghai Municipal People's Government, the first China International Import Expo (CIIE), personally planned, proposed, deployed and promoted by President Xi Jinping, was successfully held in Shanghai, China from November 5 to 11, 2018 . China's entry into the Expo is a major decision made by China to promote high-level opening-up in the new era. A new round of scientific and technological revolution and industrial change are advancing by leaps and bounds. New technologies such as artificial intelligence and green low-carbon are developing at an unprecedented speed and scale. They have become an important force in cultivating new quality productivity, promoting quality change, efficiency change and dynamic change, and promoting industrial transformation and upgrading, economic growth, social progress and sustainable development .

4.2. Case analysis

The digital transformation of the CIIE revolves around the concept of "virtual and real coexistence", systematically advancing from four dimensions: technology, management, experience, and sustainability. It has constructed a new exhibition ecosystem that is seamlessly integrated between online and offline, data-driven, and efficiently collaborative.

4.2.1. Technical dimension

Relying on cutting-edge technologies such as cloud computing, big data, AI, and 5G, the CIIE has built a powerful "Digital CIIE" online platform. Cloud display and cloud publishing functions break the constraints of physical space, while big data precision matching enhances the effectiveness of exhibitions. Cloud live streaming and cloud negotiation enhance interactivity. With full coverage of 5G networks, 84 base stations provide a peak rate of 10 Gbps, and AI intelligent scheduling ensures zero congestion. The unified network management platform achieves intelligent scheduling, providing a solid guarantee for the efficient operation of the exhibition.

4.2.2. Management dimension

Digital transformation has profoundly changed the operation and management model of exhibitions, enabling refined management throughout the entire process. Exhibitor registration, review, booth allocation, and other aspects have been moved online, reducing labor costs. The construction of a data platform has made data a core asset, and AI has deeply mined audience behavior data to provide market insights for organizers and optimize the layout of exhibitions.

4.2.3. Experience dimension

Digital transformation has created a new immersive, personalized, and real-time interactive participation model for all exhibitors. Exhibitors achieve "dual-channel exposure" by combining online new product launches with offline physical exhibitions. Online live streaming attracts traffic and enhances brand awareness. VR/AR technology provides a new interactive experience, and digital virtual technology expands real-life scenes. Technology products such as hearing-aid glasses allow audiences to experience the charm of technology, significantly enhancing their sense of participation and satisfaction, making the CIIE a feast of technology and culture.

4.2.4. Sustainability dimension

Promoting the zero-plastic standard, leveraging digital means to achieve paperless operations and low-carbon travel, thereby reducing the use of paper materials and carbon emissions from travel. The venues fully adopt green electricity, with 10 million kWh of green electricity reducing carbon emissions by approximately 4,200 tons. Online platforms enable more enterprises from developing countries and least developed countries to participate in global trade, promoting the construction of an open world economy.

5. Conclusion

This research takes the digital transformation of the convention and exhibition industry as the core of the research, and takes the concept of "virtual and real symbiosis" in the field of convention and exhibition as the core. That is, through AI and other technologies, the "real" elements such as exhibition physical venues and exhibits are integrated with "virtual" elements such as virtual exhibitors and data assets to form an interactive closed-loop system, and based on this, build a four-dimensional theoretical framework of "technology-management-experience-sustainability". Taking the CIIE as a case, it relies on cloud technology, AI, etc. to realize digital transformation, build an online platform in technology, realize the refined management and operation of the whole process, create an immersive experience model, and practice the sustainable green and low-carbon concept. At the same time, the application of digital tools such as VR/AR, AI systems, etc. in all aspects of the conference and exhibition has promoted the efficiency improvement and resource optimization of the convention and exhibition

industry. And the digitalization of the convention and exhibition industry. Transformation is deeply related to SDGs, and it is also necessary to promote its implementation through policies, technologies, service systems and other paths.

Disclosure statement

The authors declare no conflict of interest.

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