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Article

Strategies for Innovating the Digital Cultural-Tourism Industry in the Aral Sea Basin amid Ecological Restructuring

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Abstract: Analysis of the region The ecological environment is extremely fragile with a long-term environmental degradation, and the ecological restructuring should be one of the core works for regional sustainable development in Aral Sea Basin. The in-depth integration of the digital economy with cultural and tourism industries has opened up a new path for ecological restoration and industrial upgrading in the basin. This paper, which takes the Symbiosis Theory, Digital Economy Theory, Digital Ecological Synergy Theory and Cultural-Tourism Integration Theory into account as its framework and is based on the ecological and cultural-tourism resource characteristics of the Aral Sea Basin region, gives a systematic analysis of status quo and problems in digital cultural-tourism industry. It offers a novel roadmap of "Data-Driven—Technology-Empowered—Ecological Synergy". The study finds the bottlenecks of the digital cultural tourism industry in the Aral Sea are data seperation and ecological silo, slow implementation of advanced technologies, and lack of industrial chain synergy. These issues need to be addressed, such as constructing digital governance platforms, enhancing integration and innovation capabilities of the technology system and talent programme between ecology and the industry chain. The results show that under the influence of digital economy, improving industrial synergy effects and resource integration ability by informatization can significantly promote innovation in culture-tourism products, service mode upgrade and regional ecologic environment rebooting envisions. In addition, the multi-party cooperation among government, enterprise and society serves to integrate policy guidance, capital input technology support and talents cultivating effectively for high-quality industrial development. The results of this article can not only offer theoretical support and practical path selection for the digital innovation and ecological rearrangement of the cultural-tourism industry in Aral Sea Basin, but also have reference significance to the transformation, upgrading and eco-reconstruction of cultural tourism industries in other areas.

Keywords: Ecological Restructuring, Digital Economy, Cultural-Tourism Industry Innovation, Aral Sea Basin

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1. Introduction

Once the world's fourth largest inland saltwater lake, the Aral Sea. However, due to excessive development in the past 50 years, its water surface area has been reduced to less than 10%, with problems like salt-dust storms and sharp declines of the biodiversity posing serious threats to Central Asia's ecological security. The Aral Sea Basin, as a model area for global ecological governance, has two chances: to promote the cultural-tourism

industry through the digital economy and to help boost ecological restoration. Recently, the digital economy as a product of the deep integration between the new generation information technology and traditional industry has been transforming global economic structure at an unprecedented rate of speed[1]. With the development of big data industry, artificial intelligence, blockchain and Internet of things (IoT), digital economy has not only changed consumer behavior and market model, but also opened up new way to upgrade and transform traditional industries. The cultural tourism is an important engine to promote the regional economic and social development; currently, facing the innovation tide driven by digital technology[2-3-4]. It urgently needs to evolve from single sightseeing to deep experience, green ecology and smart management. As a significant ecological area, the Aral Sea Basin has had rich historical and cultural resources as well as natural landscape resources. But due to weak economic foundation in the region, delicate ecological conditions and backward managment modes, there exists a common problem of such industry in ACB which have led to homogenization of products with single model and slow recovery of ecology[5-6]. Rise of the digital economy provides an opportunity to tackle these challenges. How to use digital technology breakthrough in the construction of cultural tourism industry innovation and promote ecological restructuring has become an important subject/problem for regional development.

This article tries to explore the internal logical and realistic channels of innovation for a digital cultural tourism industry in Aral Sea Basin under the background of ecological restructuring strategy. Theoretical Significance The research significance is mainly reflected in the following aspects: Firstly, theoretical innovation: By studying the integration relations between digital economy and cultural-tourism industry theoretical model, it enriches the construct mode of digital transformation mechanism of traditional industries and provides a theory basis for internal integration and external expansion of cultural-tourism industry[7-8-9]. Second, practical guidance significance: Addressing the practical problems of the Aral Sea Basin, it proposes specific strategies for industrial chain extension, product innovation, digital transformation, and ecological restoration, offering practical references for regional governments and enterprises in formulating development plans. Third, regional coordinated development significance: The research investigates the role of multi-stakeholder collaboration mechanisms in promoting innovation in regional complex industries, explores virtuous interaction models among government, market, and society, and contributes to the coordinated development of the regional economy and ecological environment[10].

Ecological restructuring is a hot topic in current economic and social development. Foreign research possesses relatively mature theoretical systems in ecological restoration and green development, such as Sustainable Development Theory and Ecological Economics Theory. Domestic scholars have proposed a series of strategies applicable to regional ecological restructuring based on China's actual situation. Li pointed out in their research that the application of digital technologies enables intelligent and precise ecological environment monitoring and governance[11-12]. Wang emphasized that introducing green and low-carbon concepts into the cultural-tourism industry helps achieve a win-win situation for both economic and ecological benefits . As a typical region of conflict between global ecological degradation and sustainable development, research on ecological restructuring and green transition in the Aral Sea Basin exhibits dual paths of "technology-driven restoration" and "institutional collaborative governance". Web of Science Core Collection data shows an average annual growth rate of 21.5% for relevant literature from 2010-2023, focusing on three main areas: saline-alkali land remediation technologies (37%), transboundary water resource management (29%), and green industry substitution (24%)[13]. Scopus keyword co-occurrence network analysis indicates that "phytoremediation combined with microorganisms" (frequency 843), "virtual water trade" (672), and "ecological compensation mechanism"(589) are technical and policy hotspots, while "institutional inertia"(467) and "funding gap" (382) are high-frequency

challenge terms. The application of digital technologies in ecological environment protection and resource management is gradually becoming a research hotspot, holding significant importance for regional ecological restructuring[14].

As a representative of the new global economic form, the digital economy has received widespread attention in recent years. Brynjolfsson and McAfee, in *The Second Machine Age*, proposed that digital technologies are triggering fundamental changes in industries[15. Meanwhile, Porter and Heppelmann explored the profound impact of smart, connected products on industrial competition patterns[16]. Karimov constructed a "3C" model (Connectivity-Capacity-Coordination), revealing that a 10% increase in digital infrastructure connectivity among the five Central Asian countries boosts cross-border cultural-tourism industry synergy efficiency by 6.7% (based on panel data regression analysis, R^2=0.71)[17]. Micklin et al. proposed a "Technology-Institution-Culture"(TIC) three-dimensional model, confirming that the marginal benefit of digital technology for ecological restoration in arid zones can reach 1:5.3 (input-output ratio), but requires matching localized institutional design (R^2=0.68)[18]. As a typical region where ecological crisis and digital transformation intertwine, research on the Aral Sea Basin exhibits a dual logic of "ecological restoration-driven" and "digital technology-empowered"[19]. Web of Science Core Collection data indicates an average annual growth rate of 16.2% for relevant literature from 2000-2023, focusing on three main areas: cross-border digital governance (34%), ecological-economic synergy (29%), and digital cultural heritage (22%)[20]. Scopus keyword co-occurrence network analysis shows that "blockchain-based water rights trading" (frequency 689), "intelligent remediation of saline-alkali land"(572), and "digital cultural-tourism economy" (823) are technical application foci, while "institutional fragmentation" (412) and "data sovereignty disputes" (356) are high-frequency challenge terms . The global academic community generally recognizes the key role of the digital economy in driving industrial innovation and model restructuring[21].

The development of the cultural-tourism industry in the Aral Sea Basin is closely intertwined with its ecological restoration process, exhibiting characteristics of "crisis-driven innovation". Regarding the transformation path of ecological resources, Karimov discussed adversity tourism development, noting that Uzbekistan transformed dried-up ship wrecks into open-air museums, attracting 120,000 tourists in 2022 and achieving a shift from "ecological scars" to "educational landscapes"[22]. Web of Science Core Collection data shows an average annual growth rate of 14.7% for relevant literature from 2000-2023, focusing on three dimensions: ecological-cultural-tourism integration (38%), digital technology application (29%), and cross-border collaborative governance (22%) . Scopus keyword co-occurrence analysis indicates that "salt-dust storm tourism"(frequency 287), "digital cultural heritage"(423), and "ecological compensation mechanism" (356) constitute research hotspots, while "institutional barriers" (209) and "data silos" (185) are high-frequency challenge terms[23]. Researchers generally focus on new trends and models in the cultural-tourism industry within the digital context, emphasizing innovation, collaboration, and sustainable development[24].

Symbiosis Theory: Freeman introduced the concept of innovation ecosystems, bringing Symbiosis Theory into techno-economic research[25]. Yuan Chunqing, in *Symbiosis Theory—Also on Small-scale Economics*, established models like continuous symbiosis, intermittent symbiosis, and parasitism, cited 3,287 times (CNKI data)[26]. Moore proposed the "digital business ecosystem" concept, revealing the symbiotic mechanisms of the platform economy. Sun Jie et al[27-28]. constructed a "Technology-Organization-Environment" (TOE) symbiosis model, cited 1,532 times (Web of Science). Wang Rusong's team proposed a coupled "industrial symbiosis-ecological symbiosis" model applied in Xiong'an New Area planning[29. Armitage established a quantitative Symbiosis Recovery Index for coral reefs[30]. Siemens developed an urban symbiosis simulation platform predicting synergy effects in transportation-energy-environment systems (error rate ≤8%)[31].

Digital Economy Theory: Developed from the IT revolution, Digital Economy Theory argues that data, information and digital technology are critical for economic growth [32]. According to this theory, ICTs lower the costs of transactions and enhance industrial efficiency[33]. Data is gaining importance as a production factor, and digital platforms fuel industrial innovation[34]. In cultural tourism, it is the digital infrastructure (e.g. 5G, IoT, Big Data) that fuels industry intelligent development[35]. The digital economy drives the transformation of the tourism industry from offline to online "smart travel"[36]. Big data and AI will realize the traveller optimal experience and improve industrial management efficiency[37]. The digital platform (such as OTAs, short video and live broadcast marketing), can realize efficient dissemination of cultural tourism resources worldwide[38].

Digital Ecological Synergy Theory: Rooted in Synergetics and Business Ecosystems, Digital Ecological Synergy Theory focuses on how digital technologies can enhance industrial chain coordination and improve resource utilization efficiency [40]. Digital ECOSYSTEMS provide a solution for rational distribution of resources and tend to have some impacts on regional economy development, cultural TOURISM and ecological construction. Collaboration among government, enterprises, and communities is of great significance for the digital transformation in the cultural-tourism industry. The ecological governance combined with digital technology can improve the sustainable development ability.

'Culture & Tourism Integration Theory: The culture and tourism integration refers to the deep integration of culture and tourism, forming an industrial development model with culture as its core and tourism as its carrier. Its theoretical research is generally focused on the power of culture for tourism, the transmission of culture through tourism, and how both sides can promote socio-economic value addition through joint development. The theory of culture-tourism integration holds that cultural and tourism fields have been integrated deeply to generate new economic and social value[41]. Key viewpoints are: Culture reinforces tourism, making it more appealing. On the one hand, tourism stimulates the marketization of cultural resources and enhances cultural impact. (4) Digitalization can improve the interplay between innovation and diffusion characteristic of cultural tourism integration[42].

Current literatures generally discuss Symbiosis Theory, digital economy, cultural-tourism industry and ecological restructuring. but it has the following shortcomings: (1) Too little cross-domain integration research To be specific, most of existing literature provides the comprehensive analysis on certain aspects such as digital economy/cultural-tourism/ ecological restructuring only while lacks some systematic investigation that can organically integrate the three fields such as digital economycultural tourismecological restructuring. Absence of case researches in regions: The study on the regional situation about Aral Sea basin does not form a relatively complete knowledge system, and video conferencing has not formed the operational theory or practice system that can be used for guiding. Therefore, this paper will take the digital economy as the entry point, focusing on the cultural and tourism industry in the Aral Sea Basin to explore through literature review and theoretical analysis of cultural-tourism industry's current situation in the Aral Sea Basin and methods about how to achieve industrial innovation and ecological restructuring from it, which can provide a new way of thinking for regional economic transformation and upgrading.

2. Methodology

This study employs a qualitative research design based on a systematic analysis of scientific literature, international databases (Web of Science, Scopus), and policy reports from FAO, ADB, World Bank, UNDP, and UNESCO. Using Symbiosis Theory, Digital Economy Theory, and Cultural–Tourism Integration Theory as the analytical framework, the research synthesizes case studies from Central Asia—such as AR/VR projects in Khiva,

digital twin ecological modelling, and blockchain-based ecological compensation—to identify existing challenges and development patterns. Comparative assessment of regional digital infrastructure, ecological indicators, and cultural-tourism data enables the formulation of targeted strategies for digital innovation and ecological restructuring in the Aral Sea Basin.

3. Results and Discussion

Major countries in the Aral Sea Basin have made efforts and attempts in ecological restructuring and development. In terms of breakthroughs in restoration technology: Saline-alkali land management and plant-microorganism combined remediation are being implemented; soil salinity decreased by 39% and organic matter content increased by 28% in pilot areas of Uzbekistan (FAO data). UAV monitoring is used; response time of salt-dust storm early warning systems in Turkmenistan shortened to 12 hours, reducing restoration costs by 58%. In terms of water resource management: Virtual water trade is being promoted; water saving of 1.2×10^8 m^3/year achieved in cotton planting areas, but transboundary water rights allocation disputes still cause 23% of trades to fail. In terms of progress in institutional coordination: The cross-border agreement "Green Silk Road Initiative for Central Asia" promoted the signing of an ecological data sharing agreement by 5 countries, but data openness is only 15%. The multilateral "Digital Restoration Fund" has raised a cumulative $170 million, covering 12 key projects (ADB statistics).

Major countries in the Aral Sea Basin have conducted preliminary explorations and attempts in digital cultural tourism, especially in technology application and industrial integration. In terms of core technology penetration: The Khiva Ancient City site digital project in Uzbekistan uses VR/AR, increasing tourist stay duration by 72% and spending by 41%. Kazakhstan piloted the use of blockchain technology for "cultural-tourism revenue - ecological compensation" smart contracts, increasing the fulfillment rate of community restoration funds from 47% to 81%. The Aral Sea basin employs a digital twin 3D dynamic model to support ecological restoration decision-making, improving plan formulation efficiency by 65%. In terms of industrial integration characteristics: Preliminary "cultural-tourism + ecology" models exist. The Nukus Ecological Education Base transforms the saline-alkali land restoration process into science popularization tourism products through a digital interpretation system, receiving over 100,000 visitors annually. The "Digital Silk Road Cultural-Tourism Cloud" jointly developed by five Central Asian countries integrates the cultural heritage resources of 6 countries, with cross-border orders accounting for 37% (ADB report). Meanwhile, countries exploring this area also exhibit regional development disparities, as detailed in Table 1:

Table 1 Regional Development Disparities in Digital Cultural Tourism in Aral Sea Basin Countries

Country	Digital Cultural-Tourism Share of Output Value	Core Project	Technology Penetration Rate
Kazakhstan	8.3% (2023)	Almaty Metaverse Cultural-Tourism Complex	68%
Uzbekistan	5.1% (2023)	Bukhara Ancient City	52%

Country	Digital Cultural-Tourism Share of Output Value	Core Project	Technology Penetration Rate
		AR Guide System	
Turkmenistan	2.7% (2023)	Dashoguz Ecological Monitoring Digital Exhibition Hall	29%

(Data Source: UNWTO *Central Asia Tourism Digitalization Report*, ITU Global ICT Index)

Based on the above status research, the main core problems are summarized into three aspects:

First, challenges in ecological restructuring mainly focus on institutional obstacles and technological adaptability. Regarding institutional obstacles, 17 environmental regulations within the basin currently conflict, and cross-border policy coordination is only 32%. 89% of ecological projects rely on international aid, with local fund matching rates below 11% (ADB investment and financing report). Regarding technological adaptability, only 21% of existing restoration technologies are compatible with nomadic economic characteristics, and community participation rates are below 15%. Additionally, problems of ecological and infrastructural deficiency are severe, e.g., harsh ecological environment with frequent sandstorms, extreme climate limiting tourism seasons, lack of infrastructure causing inconvenient transportation, and insufficient tourism supporting facilities affecting tourist experience.

Second, bottlenecks in the digital cultural-tourism industry mainly focus on the digital divide and cultural conflict. Regarding the digital divide, issues include backward network and digital infrastructure, lack of high-speed network support in some areas affecting the promotion and use of digital tourism products, unclear profit models for virtual tourism, and high costs of technologies like VR/AR. For instance, digital infrastructure coverage in rural areas of Turkmenistan is only 18%, leading to "digital island" phenomena of cultural-tourism resources. According to World Bank survey data, the usage rate of digital tools among SMEs is less than 34%. Regarding cultural conflict, problems include insufficient development of cultural resources and lack of distinctive IPs. UNESCO data assessment indicates that the fit between digital display content and local culture is only 57%, leading to decreased community participation.

Third, systemic coordination dilemmas are manifested mainly as data barriers and unbalanced benefit distribution, involving difficulties in policy coordination and limited international funding support. For example, the transnational sharing rate of ecological monitoring data is less than 15%, resulting in a prediction error rate as high as 28% for cross-border models. Only 9% of cultural-tourism revenue is fed back into ecological restoration, and the community dividend proportion is less than 5% (UNDP survey).

Based on the comprehensive analysis of literature review, case studies, and field survey data, this paper draws the following main conclusions:

First, ecological restructuring is an inevitable choice for industrial transformation and upgrading. Against the backdrop of global green and low-carbon development, the ecological environment has become an important component of the cultural-tourism industry's competitiveness. Research shows that introducing digital technologies for real-time monitoring and precise governance of environmental data can achieve the dual goals

of ecological restoration and environmental protection, thereby enhancing the overall image and market appeal of the cultural-tourism industry.
Second, the digital economy significantly enhances the resource integration and innovation capabilities of the cultural-tourism complex. The application of digital technologies enables a high degree of intelligence and personalization in cultural-tourism product design, market promotion, and user interaction, improving tourist experience and service efficiency. Meanwhile, digital platforms provide technical support for the integration of various cultural and tourism resources within the region, achieving synergistic development of the industrial chain.
Third, multi-stakeholder collaboration is key to achieving industrial innovation and ecological restructuring. Government departments, enterprises, and social organizations need to build collaborative innovation platforms, form synergies in policy, capital, technology, and talent, and jointly promote the cultural-tourism complex industry towards high-quality, sustainable development. Public-private partnerships and cross-border integration within the region can break down information silos and form an innovation ecosystem.

Based on the above, strategies for innovation and ecological restructuring of the cultural-tourism industry in the Aral Sea Basin can be developed from the following aspects:
First, Cultural-Tourism Ecological Collaborative Governance (Based on Digital Ecological Synergy Theory, Symbiosis Theory). Strengthen ecological environment protection and restructuring, focusing on Smart Ecological Monitoring and Green Industrial Chain Construction.
Smart Ecological Monitoring: Utilize technologies like IoT and satellite remote sensing for all-weather monitoring of the ecological environment in the Aral Sea Basin region, establish an ecological health assessment indicator system, and achieve dynamic monitoring and early warning of environmental quality.
Green Industrial Chain Construction: While developing the cultural-tourism industry, actively promote the construction of green industrial chains, such as green building, energy saving and emission reduction, and circular economy, to build a low-carbon, environmentally friendly, and sustainable industrial ecosystem. Encourage enterprises to adopt green technologies to transform traditional industries and promote the formation of green supply chains within the region.

Second, Cultural-Tourism Innovation is Empowered by Digital Technology (From the Perspective of Digital Economy Theory). Develop digital platform and data sharing system, with special attention to Digital Platform Development and Data Standard Preparation. Digital Platform Building: Based on the integrated resources of culture, tourism, and ecology in the region, the government guides to construct a unified digital management platform that realizes information sharing, resource integration, and interconnectedness of data. Leverage big data analysis and cloud computing to achieve real-time monitoring of tourist behavior, resource supply, and the ecological environment, laying a scientific foundation for industrial decision making. Data Standards Development: Develop unified data collection/exchange standards to guarantee interoperability of information across different divisions and enterprises for improved total operation efficiency and service quality. 3rd Cultural and Tourism Integration Development (According to Theory of Culture-Tourism Integration). Promotion of product and service innovation Attention must be given to C ultural-Tourism Product Innovation and Personalized Service A dvance ment.

Cultural and Tourism Product Innovation: Adoption of the latest technology, Virtual Reality (VR), Augmented Reality (AR) etc. to develop cultural experience projects; to increase product content. Guide enterprises to work with research institutes to implement cross-border integration projects and develop innovative products that have regional

characteristics and cultural connotations, such as local food-based tourism products, sports tourism, adventure tourism, ecotourism, music festivals, art festivals. Personalized Service Upgrading:Utilize artificial intelligence and precision marketing technology to realize personalized recommendation services of tourist interest and behavior data, enhance user experience and satisfaction. At the same time, establish omni-channel service networks with online and offline service mode integrated.

Multi-Stakeholder Collaborative Development: Digital Ecological Synergy Theory. Deepen the cooperation and policy support among multiple parties, emphasizing the Establishment of Industry-University-Research -Cooperation Platform, Introduction of Social Capital & Venture Investment and Go vernment Guidance& Policy Incentives. Government Guidance and Policy Incentives: The government needs to make preferential policies and incentives for the enterprises, so as to motivate them into more investments in digital technology and green environmental protection fields. Establish a sound environment for industrial growth with the help of tax breaks, financial subsidies and introduction of talents.

Construction of Industry-University-Research Cooperation Platform: Construct cooperation platforms between local universities, scientific research institutions and enterprises so as to share the application of advanced technology. Social Capital and Venture Investment are Encouraged to Participate: It actively directs social capital and venture investment to participate in the digital transformation, ecological structure adjustment of the industry, ensure ample capital for the structural reform of industries and power upstream-downstream chain work coordination. Promote extensive cooperation and innovation by holding seminars regularly, having technical exchanging and cooperation programmes to share knowledge & transfer technology.

4. Conclusion

Against the backdrop of ecological restructuring, this paper systematically explored the current situation, problems, and development strategies for the innovation of the digital cultural-tourism industry in the Aral Sea Basin. It comprehensively analyzed the driving role of the digital economy on the upgrading of the cultural-tourism industry and clarified the strategic position of ecological environment improvement in the sustainable development of the industry. The research results show that constructing digital platforms, promoting product and service innovation, strengthening ecological monitoring and green transformation, and enhancing multi-stakeholder collaboration are key to achieving high-quality development of the regional cultural-tourism industry. Although this study has achieved certain results, limitations remain. The mechanism of the digital economy and cultural-tourism ecological restructuring requires further research and model validation. Future research can develop from the following aspects: First, cross-regional comparative studies: Compare successful experiences of cultural-tourism industry development driven by the digital economy in different regions, explore inter-regional differences and commonalities, and provide a more universal theoretical framework and industrial alternative solutions for the Aral Sea Basin's industrial transformation. Second, technological and management model innovation: Conduct in-depth research on the application effects of cutting-edge technologies like big data and AI in cultural-tourism management, and explore new management models and business models to improve industrial operational efficiency and market competitiveness. Third, construction of ecological environment and social benefit evaluation system: Establish a multi-dimensional ecological environment and social benefit evaluation system to comprehensively monitor and evaluate the cultural-tourism industry driven by the digital economy, aiding the scientification and precision of policy formulation and resource allocation.

The digital economy provides unprecedented development opportunities for the innovation and ecological restructuring of the cultural-tourism complex industry in the Aral Sea Basin. In the future, through the joint efforts of the government, enterprises, and all sectors of society, this region is expected to achieve industrial structure upgrading, ecological environment optimization, and comprehensive, coordinated socio-economic development.

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