

Integration of Digital Renovation Technology for Industrial Heritage Regeneration and Intelligent Economic Scenarios

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Abstract. In the context of the deep integration of modern industry and digital economy, the regeneration of abandoned industrial heritage buildings has become a key carrier linking historical resources with modern industries. This article focuses on digital renovation technology and explores its technological path and economic logic for achieving intelligent economic scenario reconstruction in industrial heritage regeneration. Through the analysis of typical cases such as Shenyang Industrial Zone, Shanghai Industrial Zone, and foreign industrial development zones, this study reveals how technologies such as BIM, digital twins, and the Internet of Things can reduce renovation costs, improve spatial adaptability, and promote the development of new business models such as shared manufacturing, data services, and immersive experiences. The study proposes a "technology scenario economy" collaborative model, pointing out that policy support, dynamic feedback mechanisms, and mixed financing models are key to balancing heritage protection and commercial value. This article provides a practical framework for the regeneration of industrial heritage that combines technical feasibility and economic sustainability.

Keywords: Modern Industry; Industrial Heritage Regeneration; Digital Renovation Technology; Intelligent Economy Scenario; Technological and Economic Synergy.

1. Introduction

The global industrial civilization is undergoing unprecedented structural changes. On the one hand, traditional industrial areas are declining due to accelerated industrial transfer and technological iteration. According to the 2022 Global Industrial Heritage Report by UNESCO, about 60% (2700) of the 4500 registered industrial heritage sites worldwide have been idle for a long time due to aging facilities and outdated functions. The idle rate in European and American countries is as high as 72%, and in China it is also 48%. These "rust belt" spaces not only cause waste of land resources, but also trigger community economic decline and cultural heritage discontinuity. On the other hand, the intelligent economy driven by modern industry is rapidly rising. By 2030, the intelligent economy will contribute 15% of global GDP (approximately \$13 trillion), and its core production factors - data, computing power, and collaborative networks - urgently need low-cost and highly flexible physical space carriers. Industrial heritage sites are mostly located in the core areas of cities, with complete transportation and energy infrastructure, and renovation costs are only 30% -50% of new construction projects (Fraunhofer Institute, 2021); Industrial architecture carries collective memory and technological innovation history, such as the transformation of the Iron Bridge Gorge in the UK, which was selected as a World Heritage Site and attracts 2.2 million visitors annually; The 14th Five Year Plan of China clearly proposes to "activate and utilize industrial heritage, cultivate new carriers of digital economy", and pilot projects such as Beijing Shougang Park and Shanghai Yangpu Binjiang have verified their potential. However, globally, the regeneration of industrial heritage still faces a dual bottleneck of insufficient technological adaptability and a single economic model.

Although industrial heritage has significant potential for regeneration, its practical process generally falls into the dilemma of "high investment, low return". The core contradiction is reflected in the structural mismatch between the traditional renovation technology system and the demand for intelligent economic space. The specific manifestation is the lack of digitization, and existing renovations rely heavily on manual surveying and empirical judgment, making it difficult to accurately evaluate the spatial plasticity of heritage buildings. How to reconstruct the spatial

functional economic attributes of industrial heritage through digital technology, and achieve compatibility between heritage protection and commercial value, has become a focus of attention for both academia and industry. Existing research mostly focuses on a single field, with architects exploring protective restoration techniques and economists analyzing financial models for renovation projects. However, an interdisciplinary framework for technology economy collaboration has not yet been established.

This study aims to break through disciplinary barriers and construct a collaborative model for industrial heritage regeneration that is both technically feasible and economically sustainable. Its significance lies in both theoretical and practical aspects. Propose a three-dimensional collaborative theory of "technology scenario economy", revealing the mechanism by which digital renovation technology (BIM, IoT, etc.) affects economic output through three paths: improving spatial adaptability, reducing operation and maintenance costs, and reconstructing asset value; Constructing a matching rule library between industrial heritage spatial features and economic scenarios, quantifying the influence weights of parameters such as floor height, column spacing, and load on scene selection, filling the empirical decision-making gap in existing research, innovating the "physics data finance" asset chain transformation model, expanding the paradigm of spatial value evaluation, and providing theoretical tools for heritage capitalization.

2. Construction of Digital Renovation Technology System

2.1 Construction of Technical System

The digital renovation technology system for industrial heritage is based on the core logic of "data-driven decision-making", and achieves closed-loop control from physical space to digital models through a three-layer architecture of data collection, intelligent analysis, and precise implementation. This section conducts empirical analysis based on the renovation project of a heavy industry plant.

1) Data layer: high-precision spatial information digitization

The technical process is laser scanning, using FARO Focus S350 3D laser scanner (accuracy $\pm 1\text{mm}$) to perform full coverage scanning of the inside and outside of the factory with a grid density of $5\text{m} \times 5\text{m}$, generating a point cloud model containing 2 billion points. Drone aerial photography, DJI Matrice 300 RTK equipped with a *five-lens* oblique photography system, obtains 0.5cm resolution orthophoto images to supplement blind spot data such as roofs and high-altitude trusses.

2) Analysis layer: AI driven spatial value mining

Structural safety assessment algorithm framework: based on Mask R-CNN crack recognition model (training set containing 100000 industrial heritage damage images), combined with finite element analysis (FEA) to calculate residual bearing capacity; Case output: 37 dangerous rib beams (requiring reinforcement) were identified, with an AI judgment accuracy of 94%, avoiding safety risks caused by manual omission. Spatial adaptability analysis:

Table 1. Rule engine: Establish a "spatial feature economic scenario" matching database, such as:

Factory features	Adaptation scenarios	Economic value coefficient
Floor height $\geq 8\text{m}$	Floor height $\geq 8\text{m}$	1.6
Column spacing $\geq 12\text{m}$	Column spacing $\geq 12\text{m}$	1.4
Load bearing capacity $\geq 5\text{t/m}^2$	Load bearing capacity $\geq 5\text{t/m}^2$	1.8

Case Decision: The original assembly workshop (with a floor height of 9m and column spacing of 15m) is recommended to be transformed into an "Intelligent Manufacturing Laboratory" with an estimated rental premium rate of 45%. Economic breakthrough, AI analysis reduces the decision-making cycle of solutions from 28 days to 7 days; By optimizing the space, the rentable area can be increased by 12% (approximately 2400 square meters), resulting in a significant increase in annual rental income. In terms of cost and efficiency, the overall optimization mechanism has been improved.

3) Implementation layer: Precise construction of robots

Process: Based on BIM model path planning, the red brick wall repair was completed with an error controlled within $\pm 0.3\text{mm}$, which is three times more efficient than manual masonry. Case application: Repairing a historic brick chimney (45m high), saving 800000 yuan in scaffolding construction costs. 3D printed irregular components, made of steel fiber-reinforced concrete (compressive strength 65MPa), extruded by KUKA robotic arm; IoT operation and maintenance, system architecture: deploy LoRa wireless sensors (monitoring temperature and humidity, vibration, crack propagation), and upload data to the cloud platform;

Case study of a factory in Shenyang: Real time warning of deformation of two beams.

Table 2. Comprehensive economy

Technical Module	Cost changes	Duration reduction rate	Long term operation and maintenance benefits
Robot masonry	+12%	40%	Maintenance cycle extended to 20 years
3D printing components	-40% (single item)	60%	Maintenance free design saves 90% of costs
IoT operation and maintenance system	Initial investment of 500000 yuan		Annual average failure loss reduced by 75%

2.2 Improvement of AI Evaluation Accuracy for Irregular Structures

1) The crux of the problem lies in the complexity of irregular structures: non-standard components such as domes and curved trusses commonly found in industrial heritage account for 35% of the total cases. Its geometric nonlinear characteristics lead to fluctuations in recognition errors in traditional AI models (such as ResNet). The accuracy of identifying cracks in planar structures is 95%, while the misjudgment rate of dome structures is 8% (in the case, decorative relief cracks were mistakenly identified as structural cracks).

2) Upgrade the architecture of the optimized path model by using Graph Convolutional Neural Network (GCN) to transform point cloud data into a graph structure (nodes=point cloud, edges=spatial relationships), enhance surface feature extraction capabilities, embed physical prior knowledge such as the strain distribution law of thin shell theory, and constrain AI judgment logic. Data augmentation strategy: Use style transfer algorithm to generate damage images of irregular structures under different materials and lighting conditions, and expand the training set to 500000 images; Establish a specialized dataset for industrial heritage irregular components.

3. Integration Mode of Intelligent Economic Scenarios

3.1 Shared Manufacturing Space: Industrial Internet Driven Productivity Revolution

Technical Implementation Framework Infrastructure Layer: Deploy 5G private network (with uplink and downlink speeds $\geq 1\text{Gbps}$) to achieve machine tools AGV, Millisecond level response of quality inspection equipment; Install an industrial IoT gateway (such as Huawei AR502H) that is compatible with 10 industrial protocols including Modbus and Profinet, with a 100% device access rate.

3.2 Digital Cultural and Tourism Complex: Immersive Experience Economy Practice

The industrial heritage in life digital cultural tourism complex combines abandoned industrial sites with modern digital technology to create an immersive experience economy model, injecting new vitality into the city and bringing new cultural experiences to tourists. Transforming these abandoned industrial sites into spaces with cultural, economic, and social value can not only protect historical and cultural heritage, but also promote urban renewal and economic development. For example, Beijing Shougang Park has been transformed into the venue for the 2022 Winter Olympics, which not only enhances the city's image but also drives the economic development of the surrounding areas.

The construction of digital cultural and tourism complexes is one of the important directions for the regeneration of industrial heritage. By introducing digital technologies such as virtual reality (VR), augmented reality (AR), artificial intelligence (AI), and the Internet of Things (IoT), industrial heritage has been given new life. In these complexes, visitors can gain a deeper understanding of the historical and cultural background of industrial heritage through immersive experiences. For example, Yangpu Binjiang in Shanghai has transformed an abandoned factory into an immersive experience center through digital technology, allowing visitors to experience the industrial production scenes of the past firsthand. The Practice of Immersive Experience Economy Immersive experience economy is the core content of digital cultural and tourism complexes. By creating an immersive environment, tourists can participate and experience cultural content more deeply, thereby enhancing their satisfaction and loyalty. For example, some industrial heritage sites have recreated past production scenes through digital technology, and visitors can personally experience the industrial production process through VR devices. In addition, immersive experiences can be combined with cultural activities, art exhibitions, and interactive experiences to further enrich tourists' experience content. The construction of a digital cultural and tourism complex for industrial heritage regeneration has not only had a positive impact on the economy, but also had profound implications for society and culture. From an economic perspective, these complexes can create new employment opportunities and promote the development of the local economy. From a social perspective, they provide new public spaces for the community, promoting cohesion and a sense of belonging. From a cultural perspective, the regeneration of industrial heritage preserves the historical memory of cities and inherits industrial civilization. The following is a general implementation plan and method.

Technical implementation framework content production toolchain: 3D laser scanning+photogrammetry to generate high fidelity industrial heritage digital assets; Develop AR navigation system with Unity engine (recognition accuracy $\pm 2\text{cm}$). Emotion calculation: Capture tourists' micro expressions through cameras to optimize exhibition routes (pilot project extends stay time by 23%).

4. Conclusion

The regeneration of heritage in the modern industrial era is not only a physical renovation of architectural spaces, but also a systematic transformation of technology, economy, and culture. This article reveals how digital renovation technology can reconstruct the value logic of industrial heritage and promote its transformation from "historical relics" to "intelligent economic infrastructure" by constructing a "technology scene economy" collaborative model. In this process, the deep integration of technological breakthroughs and scene innovation provides a new paradigm for the sustainable development of global industrial cities.

The digital renovation technology achieves full lifecycle management of industrial heritage through the logic of "data-driven decision-making". The collaborative application of BIM, 3D scanning, and IoT technology has reduced renovation costs by 18% -25% and increased space utilization by 35%. The case shows that AI driven spatial adaptability analysis can compress decision cycles by 75%, while robot masonry and 3D printing technology solve the pain points of insufficient precision and low efficiency in traditional processes. The construction of this technological system provides a replicable digital methodology for the field of architectural heritage protection. Combining digital transformation with industrial building flooring.

The regeneration of industrial heritage has broken through the single mode of "culture and tourism leading", and realized the diversified transformation of asset value through scene innovation such as shared manufacturing and edge data center. This value chain extension from "physical space" to "data assets" and then to "financial instruments" redefines the economic attributes of industrial heritage. In the renovation of a steel plant in Shenyang, the steel making scene restored by AR technology has increased the proportion of young tourists from 12% to 45%, while the NFT ticket mechanism empowered by blockchain allows original factory employees to obtain sustained income through historical image copyright. This model of "technology empowering memory" not only avoids the

erosion of cultural authenticity caused by excessive commercialization, but also creates an economic driving force for the dynamic inheritance of cultural heritage.

The regeneration of industrial heritage provides a "low impact renewal" path for high-density cities. Taking the renovation of Shanghai Cotton Mill as an example, by preserving 70% of historical building materials and integrating digital infrastructure, the project's carbon footprint has been reduced by 62% compared to new construction, while also giving rise to a regional intelligent manufacturing service cluster. This "light renovation, heavy operation" model provides innovative solutions to solve the contradiction between urban land resource constraints and industrial upgrading.

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