



## Article

# Digital Twin Technology for Personalized Rural Tourism Product Development: A Case Study Approach

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**Abstract:** Modern rural tourism is confronted with increased challenges to find customized products for varied visitor needs while traditional processes are burdened by long cycles and limited real-time analysis opportunities. This study examines the use of digital twin technology in customized rural tourist product innovation by case study of a Jiangsu Province location that has been adapting since March 2023. Qualitative field research through eighteen interviews, participant observation, and documentary analysis is noted to reflect four-layered architectural convergence by utilizing 120 IoT sensors producing 2.8 million daily data points makes a significant impact in terms of 72% cycle reduction, portfolios quadrupling, and 64% to 91% accuracy improvement in need-matching. Commercial feasibility is confirmed through economic performance through 37% visitor and 44% revenue augmentation worth ¥41.3 million. Theoretical knowledge of digital twin deployment to tourism service situations is supported by evidence and offers practical guidelines for implementation by destination managers to aim for technology-facilitated competitive advantage.

**Keywords:** digital twin technology; rural tourism development; tourism personalization; product innovation; case study methodology



## 1. Introduction

The international tourism sector has been profoundly impacted by unprecedented technological change and shifting demand patterns, especially as digital innovation revolutionizes conventional service delivery mechanisms (Sharma and Sharma, 2025). Information technology has enhanced destination performance and created new possibilities for marketing traveler experiences (Zhu and Shang, 2021). Contemporary visitors are calling for experiences that are tailored to their unique requirements instead of packaged groups, subjecting destination managers to tremendous pressure to come up with new product design strategies that will meet individualized visitor demands without compromising operational effectiveness.

Slow design cycles, expensive experimentation, and limited online demand testing greatly weaken the conventional rural tourism product development cycles, and hence the scope for responding dynamically to emerging markets and customer feedback (Bekele and Raj, 2025). Through simulation, predictability, and scalability for improvement optimization, digital twin technology—which can create virtual copies of real-world locations with real-time data synchronization—has unparalleled potential to solve issues such as these (Florido-Benítez, 2024). Knowing how to leverage these technologies at modest expenses to develop tailor-made travel offerings according to various traveler interests is an acceptable research agenda (Liu et al., 2024).

The research investigates digital twin technology adoption for customization of rural tourism services based on a systematic case study, implementation processes, and performance effects. The research extends current digital twin applications in manufacturing and urban planning to the tourism services industries, considering current knowledge gaps in virtual-physical system integration to deliver customized services in rural regions with sparse resources. The research offers destination managers practical advice on how to pursue digital transformation initiatives and demonstrates how rural destinations can use emerging technologies to become more competitive and realize sustainable development.

## 2. Literature Review and Theoretical Framework



## 2.1. Digital Twin Technology and Rural Tourism

Digital twin technology is a novel idea of connecting physical and virtual worlds through creating dynamic, data-driven copies that can be utilized to enable real-time monitoring, simulation, and prediction in different application fields (de Almeida and Boavida-Portugal, 2025). Applications of digital twins with tremendous potential to enhance visitor experience and solve challenges of sustainability through more efficient planning of resources and environmental monitoring have, in the tourism applications domain, been restricted primarily to cultural heritage management and city destination planning. End-to-end virtual models that support sophisticated analysis and planning capabilities are made possible by technology's ability to integrate various data sources, such as IoT sensors, geospatial information systems, and historical operational data (Rahmadian et al., 2023).

Rural tourism product development is challenged by some limitations of technology infrastructure, peak and trough seasonality of demand, and the balance between delivering true experience and traditional tourist amenities and customization requirements. Smart rural tourism development involves strategic application of information technology for improving the competitiveness of the destination through the enhancement of service quality, operation efficiency, and increased ability to respond to changing markets (Litavniece et al., 2023). Existing strategies will seek to leverage the application of big data analysis and AI in offering real-time insights from tourism behavioral patterns to enable destinations to create customized products from disaggregated tourist interests and sustainability. Traveler's life cycle offers certain touchpoints that become accessible through digital strategy to create maximum value from pre-travel planning and booking activities to in-destination experience and post-journey engagement activities (Ye et al., 2025).

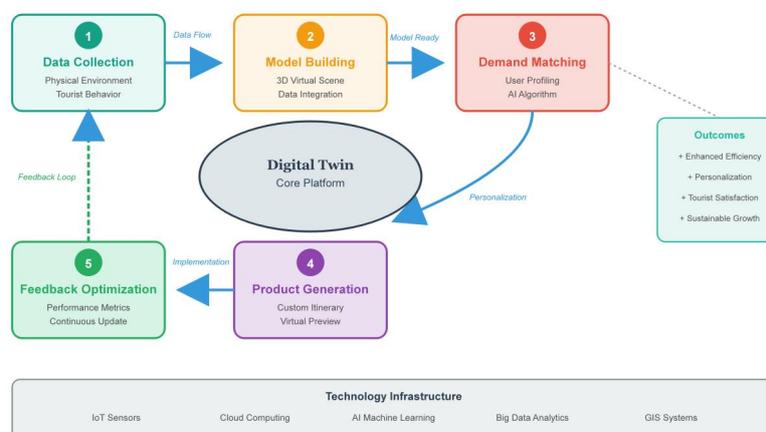
There is still quite limited empirically informed data documented in literature regarding the ways in which digital twin technology could be applied within the facilitation of differentiated product development in situations with lower sophistication of technology infrastructure, thereby providing avenues toward consideration of adaptive routes for addressing innovation objectives and pragmatic consideration of practicability (Baroroh et al., 2023).

## 2.2. Conceptual Framework

The proposed conceptual model unites digital twin with rural tourism product development requirements under a five-step cyclical approach with continuous evolution and adaptation as a top agenda. The Data Collection is the foundation on which information flows capture physical environment readings, patterns of tourist behavior, and levels of resource availability through IoT installations, mobile apps, and prevailing operating systems. Model Building translates collected facts into advanced three-dimensional virtual replicas of spatial relationships, temporal patterns, and functional characteristics that accurately depict real destination attributes with sufficient realism to support meaningful analysis and experimentation. Demand Matching applies machine learning methods to construct large tourist profiles from demographic information, historical preferences, and self-stated needs, enabling smart matching of individual expectations against available destination attributes and activity provision. Product creation combines match results with personalized, real-life travel plans and service solutions that can be virtually experienced in high-fidelity virtual worlds before making a decision. Iterative refinement may be possible following feedback and preference changes. In order to improve system accuracy and responsiveness through use, feedback optimization involves recording implementation outcomes, traveler satisfaction, and operating performance metrics for future model improvement and algorithm readjustment. The overall framework is illustrated in **Figure 1**.

**Figure 1**

*Digital Twin Application Framework for Personalized Rural Tourism Product Development*





## 3. Methodology

### 3.1. Case Selection and Data Collection

This study employs a qualitative case study methodology to examine the ways in which digital twin technology can be applied to the development of personalized rural tourism products. The case study, which gave preference to locations with established digital transformation projects and maintained their original rural features, was finally selected from a typical rural tourist village in Jiangsu Province that has been fully equipped with smart tourism amenities since 2023. The chosen dataset possesses abundant cultural heritage such as traditional architecture and intangible cultural assets, gets significant yearly tourist flow of over 200,000 visitors, and has developed basic digital infrastructure such as IoT sensor networks, cloud computing systems, and integrated data management systems.

Data gathering included several sources to provide optimum insight and methodological rigor through processes of triangulation. In-depth, semi-structured interviews were held with 18 stakeholders comprising destination managers in charge of strategic planning and technology introduction, technical staff in charge of system operation and maintenance, and various tourist segments such as family tourists, young experience-seekers, and senior leisure travelers, with interviews lasting from 30 to 60 minutes and all interviews being taped with participant permission for later transcription and analysis. Participant observation comprised three field visits across peak and off-peak seasons between March and September 2024 that facilitated direct observation of technology-in-use contexts, visitor-system interactions, and operational workflows in real tourism settings. Documentary evidence comprised operational reports, visitor satisfaction surveys, system performance logs, and policy documents associated with digital transformation initiatives, as indicated in **Table 1**.

**Table 1**

*Case Site Profile and Data Collection Overview*

Characteristic	Details
Location	Rural tourism village, Jiangsu Province, China
Area	8.5 square kilometers



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Primary Resources	Traditional architecture, agricultural landscapes, cultural heritage sites
Annual Visitors (Pre-DT)	180,000 person-times
DT Implementation	March 2023 - Present
Digital Infrastructure	5G coverage, IoT sensors (120+ units), cloud platform, mobile application
Interview Participants	Managers (n=5), Technical staff (n=4), Tourists (n=9)
Observation Periods	March 2024, June 2024, September 2024 (3-4 days each)
Documents Analyzed	Operational reports (12), Policy documents (6), System logs, Survey data
Research Duration	March - October 2024

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## 3.2. Data Analysis

Thematic analysis was the major method of analysis, entailing systematic identification, analysis, and interpretation of patterns in qualitative datasets by a cyclical coding process from descriptive initial codes to interpretive thematic categories. 45,000 interview transcripts were open coded to yield initial concepts that were directly technology implementation, operational issues, user experience, and outcome perception related, while subsequent axial coding established relationship between concepts and selective coding combined categories into relevant thematic frameworks that opposed research questions. There were some strategies that increased research validity such as methodological triangulation through the use of convergent evidence from interviews, observation, and documents, investigator triangulation where two researchers independently coded subsets of data to determine inter-coder reliability, and member checking where early findings were presented to a group of specially selected participants to enable interpretive accuracy and contextual appropriateness of inferences drawn from their donated data.

## 4. Results and Analysis

### 4.1. Digital Twin System Architecture and Implementation



The digital twin platform built a four-layer full-stack architecture with physical sensing combined with virtual model capability. The Physical Sensing Layer used 120 IoT sensors over the 8.5-square-kilometer area, 45 environmental sensors reading temperature, humidity, and air quality every 15 minutes, 28 tourist volume counters at strategic entrances and exits, and 47 positioning beacons utilized for aiding real-time tracking of tourists with  $\pm 3$ -meter accuracy. An estimated 2.8 million data points were generated daily by this sensor network, which recorded comprehensive details about resource-use dynamics, human movement patterns, and environmental conditions.

Data Integration Layer provided 99.7% system availability and less than 2-second response time under high loads on cloud computing infrastructure, which had 12,000 processor cores and 500TB of storage. Moreover, the platform synchronized and normalized data streams of databases with five years of operation history, online booking systems, social media sentiment streams, and mobile application logs. 78% completion rates, it generated 156,000 individual visitor profiles, allowing sophisticated segmentation and preference modeling for every visitor segment.

In order to train machine learning models that would feed recommendation engines with personalization, the Intelligence Layer used three years of history with 540,000 visitor records. The combination of content-based engines and collaborative filtering provided 87% prediction accuracy in suggesting visitor needs to the available resources. To redeploy staff, rebalance resource deployment, and modify recommended routes in response to evolving weather conditions, traffic accidents, or service disruptions, dynamic optimization algorithms took into account real-time information. The systems offered over 15,000 monthly personalized trip plan recommendations with an 8.3-minute average user interaction time.

Application Layer delivered customized experiences across several touchpoints, including web-based trip planning tools for pre-trip planning, interactive visitor center kiosks and at prime attractions, and mobile apps accessed by 68% of visitors. The rates of booking adjustments fell from 37% to 12% with the introduction of virtual preview capability through immersive 360-degree visualizations, showing much larger levels of visitor expectation and experience match. Detailed performance metrics are presented in **Table 2**.

## **Table 2**

*Digital Twin System Performance Metrics by Component*



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Component Category	Quantity/Capacity	Key Performance Indicator	Achievement Level
Environmental Sensors	45 units	Data accuracy rate	96.2%
Flow Monitoring Devices	28 locations	Destination coverage	100%
Positioning Beacons	47 units	Location precision	±3 meters
Cloud Storage Capacity	500 TB	System uptime	99.7%
Processing Cores	12,000 units	Response time	<2 seconds
Tourist Profile Database	156,000 records	Profile completeness	78%
Recommendation Algorithms	4 models	Prediction accuracy	87%
Mobile App Active Users	42,000	User engagement rate	68%
Virtual Tour Modules	15 experiences	Satisfaction score	4.5/5.0

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## 4.2. Operational Outcomes and Performance Improvements

The outcomes of the implementation demonstrated the value of digital twins in rural tourism contexts by indicating notable advancements in several areas. The cycle time was reduced from 18 to 5 days (72% reduction), which significantly increased the efficiency of product development and made it possible to respond quickly to new market trends and seasonal orders. From seven standard alternatives, the destination diversified its product into 28 versions with various themes, such as adventure vacations, wellness getaways, cultural experiences, and farm stays.

Due to virtual prototyping replacing costly physical testing, design iteration cost fell by 34%, from ¥120,000 to ¥79,000.

Personalization capacity was much higher than legacy manual capability. Need-match precision improved through September 2024 visitor surveys assessing congruence between stated preferences and then-served experiences from 64% to 91%. Traveler satisfaction ratings rose from 3.9 to 4.6 on a 5.0 scale, suggesting product quality has remained stable. Net Promoter Score rose from 38 to 67, reflecting more targeted brand advocacy and word-of-mouth potential. The repeat visitation rate



increased two-fold from 14% to 31%, reflecting higher destination loyalty created through experiences that matched or exceeded personal expectations.

Broader destination development impacts were triggered by social and economic spillovers. Under enhanced value capture, visitors rose 37% from 180,000 to 247,000 person-times, and visitor revenue rose 44% from ¥28.7 million to ¥41.3 million, far exceeding volume growth. Aggressive premium service matching and wise upselling suggestions caused visitor spending to rise by 22%, from ¥159 to ¥194. Direct employment opportunities rose by 51%, from 142 to 215, enhancing community well-being and local economic recovery. A comparative analysis is presented in **Table 3**.

**Table 3**

*Comparative Performance Analysis Before and After Digital Twin Implementation*

Performance Indicator	Pre-Implementation (2022)	Post-Implementation (2024)	Change (%)
Product Development Cycle	18 days	5 days	-72%
Annual Product Variants	7 offerings	28 offerings	+300%
Design Iteration Cost	¥120,000/product	¥79,000/product	-34%
Need-Matching Accuracy	64%	91%	+42%
Tourist Satisfaction Score	3.9/5.0	4.6/5.0	+18%
Net Promoter Score	38	67	+76%
Repeat Visitation Rate	14%	31%	+121%
Annual Visitor Volume	180,000	247,000	+37%
Tourism Revenue	¥28.7M	¥41.3M	+44%
Average Spending/Visitor	¥159	¥194	+22%
Direct Employment	142 positions	215 positions	+51%

### 4.3. Critical Success Factors and Implementation Challenges



Three key enablers made the deployment possible. First and foremost, a robust infrastructure with 98% 5G coverage, enough cloud storage to manage heavy traffic, and the integration of incompatible data sources using standard APIs. Second, long-term organizational investment via formal change management, executive sponsorship, and intensive training initiatives. Third, stakeholder-invested relations between bureau personnel, suppliers, operators, and local residents guaranteeing step-by-step implementation.

There were significant deployment challenges. Start-up capital spending of ¥3.2 million was 15% over estimate and required additional government funding. There were data quality, model revision, and integration technical issues that required significant adjustments to calibration and algorithm processes. Human capital limitations by missing combined staff required outside recruitment of specialist staff, which introduced cost dependencies and made transmission of knowledge more difficult.

## 5. Conclusion

### 5.1. Principal Findings

The study examined digital twin technology usage in customized rural tourism product design based on a case of Jiangsu Province destination, which is renewing holistically since March 2023. Four-layered architectural convergence with physical sensing, data processing, smart analytics, and application delivery is facilitating deep operational enhancements, with development cycles being cut in half 72% while portfolio variety increases four times to twenty-eight offerings. Personalization opportunity via IoT sensor network and machine learning algorithms handling 156,000 visitor profiles introduces need-matching accuracy improvement from 64% to 91%, economic metrics confirming commercial viability via 37% visitor growths and 44% revenue growths to ¥41.3 million and 51% employment growths.

### 5.2. Theoretical and Practical Contributions

This research applies digital twin ideas to the tourism service sector, where real-time reaction is required due to personalization requirements. Through data



collection, model establishment, demand matching, product design, and feedback optimization, the conceptual model provides methodical guidance for virtual-physical synchronization that takes into account the needs of a wide range of clients. Research with solid evidence shows that helping resource-poor rural destinations overcome their competitiveness deficits through unique positioning that highlights locally unique resources and genuine experiences pays off in tangible ways in terms of revenue, satisfaction, and efficiency metrics.

### 5.3. Managerial Implications

Cooperative destination management companies must comprehend that digital twins require joint efforts towards organizational competence, technological infrastructure, and collaborative stakeholder engagement. Significant investments in computing power, high connectivity, and interoperable architecture are still required, as is a consistent, long-term dedication to the development of human capital. Although cooperative stakeholder relations create implementation environments supportive of long-term achievement through mutual transformation goals, managers must view implementation as an ongoing learning process that acknowledges incremental progress toward accuracy with the operation of experience.

### 5.4. Research Limitations and Future Directions

The limitations of generalizability resulting from single-case analysis in particular circumstances that might not be typical of other places with distinct resource constraints are acknowledged in this study. More research on comparative multi-case studies of implementation differences and longitudinal studies that track performance paths is necessary to better understand sustainability dynamics in increasingly complex technology-facilitated tourism environments.

**Conflict of interest:** The author declares no conflict of interest.

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