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Application and Practice of Internet of Things Technology in Intelligent Operation and Management of Property Services

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Abstract

In the era of the digital economy, the Internet of Things (IoT) technology has become a core driving force for the transformation and upgrading of the property service industry to achieve refined operation. Traditional property services are plagued by pain points including low operational efficiency, slow service response, difficult cost control and inadequate safety prevention and control. Through the coordinated operation of the perception layer, network layer and application layer, IoT technology can realize intelligent perception, data-driven analysis and automatic management and control across full scenarios of property services. Combined with the actual operation and management of property companies, this paper discusses application paths and practical approaches of IoT technology in core scenarios such as intelligent security, intelligent operation and maintenance of facilities and equipment, smart environmental management and intelligent customer service response. It also analyzes difficulties in technology implementation and puts forward optimization strategies. This study aims to empower property services with IoT technology, improve operational and management efficiency, cut operating costs, enhance owners' service experience, and provide practical references for the intelligent transformation of property service enterprises.

Keywords: Internet of Things Technology; Property Services; Intelligent Operation; Facility Operation and Maintenance; Intelligent Security; Service Upgrading

1. Introduction

As an important component of urban services, the operation and management level of the property service industry is directly related to owners' living experience and the harmony and stability of communities. With the continuous improvement of residents' demands for quality of

life, the traditional labor-oriented property service model can hardly meet owners' requirements for efficient, convenient, accurate and safe services. Meanwhile, enterprises are confronted with industry-wide challenges such as rising labor costs, low management efficiency and great difficulties in service standardization. Against the backdrop of the rapid development of new-generation information technologies, IoT technology, featured by "interconnection of all things, intelligent perception and data-driven operation", offers brand-new solutions for the transformation and upgrading of property services (Liu, 2018; Zeng, 2023).

As the general manager of a property company, in coordinating daily enterprise operations and formulating development strategies, I have gained an in-depth understanding of the transformative value of IoT technology for the property service industry. Integrating IoT technology into the whole process of property services covering security, operation and maintenance, customer service and environmental management can realize the shift from "passive response-oriented services" to "proactive prediction-oriented services", as well as the upgrade from "extensive labor-based management" to "data-driven refined management" (Liu, 2024). Based on practical experience of IoT technology implementation in enterprises, this paper systematically sorts out application scenarios and key practical points of IoT technology in property service operation and management, so as to provide replicable and implementable paths for intelligent transformation of property service enterprises in the industry.

2. Core Value of Empowering Property Services with IoT Technology

The Internet of Things refers to a network technology that connects any object to the Internet through information-sensing devices such as radio-frequency identification, infrared sensors, global positioning systems and laser scanners in accordance with agreed protocols for information exchange and communication, so as to realize intelligent identification, positioning, tracking, monitoring and management of objects. Its application in the field of property services is not merely the intelligent upgrade of individual devices, but the technical integration across full scenarios and whole workflows (Zhao et al., 2020). Its core value in property services is reflected in the following four aspects:

2.1. Improve Operational and Management Efficiency and Reduce Labor Costs

IoT technology enables automatic and intelligent management and control of every link in property services and replaces a large number of repetitive manual operations. For instance, intelligent security systems support 24-hour unattended monitoring; intelligent facility and equipment operation-maintenance systems automatically monitor equipment operating status; and intelligent meter-reading systems realize automatic data collection of water and electricity meters, which substantially cuts manpower input for posts such as security guards, engineering staff and meter readers. Meanwhile, centralized management via the IoT platform facilitates data exchange and instruction coordination across service scenarios, eliminates information silos among departments, boosts cross-departmental work efficiency, and lowers overall enterprise operation and management costs (Liu, 2024; Zeng, 2023).

2.2. Optimize Service Response Mechanism and Enhance Owners' Experience

In traditional property services, owners submit demands via phone calls or WeChat, which brings problems such as delayed responses and opaque processing procedures. The intelligent customer service and demand response platform built with IoT technology supports one-click submission of owners' demands, automatic work-order dispatching, whole-process tracking and completion evaluation (Song, 2024; Wang & Li, 2023). Service response time is shortened from hour-level to minute-level. Furthermore, intelligent perception by IoT devices enables proactive services. For example, upon detecting emergencies such as water leakage in owners' homes or elevator failures, the system triggers automatic alarms and pushes notifications to relevant staff for early intervention and rapid handling, greatly improving owners' service experience and satisfaction.

2.3. Strengthen Safety Prevention and Control Capabilities and Guard against Various Risks

Safety management constitutes the core work of property services, covering community security, fire control management, safety of facilities and equipment, and public environmental safety. By deploying intelligent sensing devices, IoT technology achieves real-time monitoring, automatic early warning and rapid disposal of safety risks. For example, intelligent fire-fighting systems monitor real-time data of smoke sensors, temperature sensors and gas concentration, and trigger immediate alarms while linking sprinkler and ventilation equipment once anomalies occur. Intelligent security systems adopt face recognition, vehicle recognition and abnormal behavior monitoring to effectively guard against potential safety hazards such as intrusions of outsiders, random vehicle parking and theft. The intelligent monitoring system for facilities and equipment keeps real-time track of the operating status of key equipment including elevators, water pumps and power distribution rooms, predicts equipment failures in advance, and prevents safety accidents caused by equipment shutdown (Zhao, 2023).

2.4. Realize Data-Driven Decision-Making and Improve Refined Management

The IoT platform collects real-time operational data of every link in property services, including operational data of facilities and equipment, owners' service demand data, safety prevention-and-control data and cost consumption data. Through analysis and mining of such data, property enterprises can accurately grasp community operation status, characteristics of owners' service demands and patterns of cost consumption, which provides scientific data support for formulating business strategies, adjusting service schemes, optimizing cost control and improving management systems (Wang & Li, 2023). For example, analysis on owners' service demand data helps add targeted high-frequency service items; analysis on equipment operational data optimizes equipment maintenance plans and reduces maintenance costs; analysis on property fee collection data supports differentiated collection strategies and raises the collection rate. The capability comparison of the two property service models is shown in Table 1.

Table 1. Comparison of Traditional and IoT-Enabled Property Service Models

Comparison Dimension	Traditional Property Service Model	IoT-enabled Smart Property Service Model
Operation & Management Mode	Extensive labor-based management	Data-driven refined management
Service Response Mode	Passive repair receiving, hour-level response	Proactive prediction & early warning, minute-level closed-loop handling
Safety Prevention Means	Mainly human-based defense, post-incident disposal	Human-technical-intelligent integrated defense; pre-warning and real-time monitoring
Labor Cost	Large manpower input with numerous posts	Scientific decision-making supported by multi-dimensional operational data

3. Specific Application and Practice of IoT Technology in Property Service Operation and Management

Based on the actual operation and management of property companies, IoT technology is applied in core scenarios including intelligent security, intelligent operation and maintenance of facilities and equipment, smart environmental management, intelligent customer service and smart energy consumption management (Liu, 2024; Zhao et al., 2020). Through full-link construction of "sensing device deployment + network transmission + platform management + application implementation", the intelligent upgrade of property services is realized. The practical applications of each scenario are presented as follows:

3.1. Intelligent Security Scenario: Building an Omnidirectional and Dead-angle-free Community Security System

Community security ranks high on the priority list of property services. By deploying IoT sensing devices, an omnidirectional security system integrating "human defense, technical defense and intelligent defense" is constructed to realize the transition from "passive prevention" to "proactive early warning" (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2022). First, face-recognition and vehicle-recognition devices are installed at community entrances and unit gates to realize intelligent access management for personnel and vehicles. Outsiders are required to register with real-name information and obtain owners' confirmation before entry, which effectively prevents intrusions of strangers. Meanwhile, the vehicle-recognition system is linked with the community parking management system to realize automatic billing and frictionless access for vehicles and improve parking management efficiency. Second, high-definition intelligent cameras equipped with functions such as motion detection, abnormal behavior recognition and sound detection are deployed in public community areas, elevators and corridors. Once anomalies such as people climbing over walls, gatherings causing disturbances or unattended articles are detected, the system automatically pushes alarm information together with location

information to security guards' handheld terminals for on-site rapid disposal. Third, intelligent security devices such as door-window magnetic contacts, infrared sensors and gas-leakage alarms are installed in owners' homes. Owners can conduct remote control via mobile apps. In case of forced prying of doors or windows or gas leakage, the system sends alarms to both owners and the property monitoring center, and notifies community security staff to conduct on-site verification so as to safeguard owners' home safety.

3.2. Intelligent Operation and Maintenance of Facilities and Equipment: Realizing Full-life-cycle Management of Key Equipment

Facilities and equipment in property services, including elevators, water pumps, power distribution rooms, fire-fighting facilities and monitoring equipment, underpin normal community operation. The traditional operation-maintenance mode relies on regular manual inspections, which suffers from delayed inspections, late detection of failures and high maintenance costs. IoT-enabled intelligent operation and maintenance of facilities and equipment builds an intelligent management platform to realize real-time monitoring of equipment operating status, automatic failure early warning, intelligent dispatching of maintenance work-orders and full-life-cycle management (Liu & Chen, 2024; Zhang & Zhao, 2022). Firstly, elevator operation monitors, video surveillance equipment and emergency call devices are installed inside elevators to collect real-time data such as running speed, car position, door opening-closing status and fault codes. When faults such as elevator entrapment, overspeed or buffer-striking occur, the system automatically sends alarms to engineering maintenance staff and the monitoring center. Meanwhile, fault information is pushed to owners' mobile apps to inform them of fault causes and disposal progress. In addition, elevator operation data are analyzed to predict the replacement time of vulnerable components and formulate advance maintenance plans so as to reduce elevator failure rates. Secondly, temperature-humidity sensors, current-voltage monitors and pressure sensors are deployed in key facility areas such as water pump houses, power distribution rooms and fire-fighting pump houses to monitor real-time equipment operating parameters. The system triggers automatic early warnings and alerts maintenance staff for troubleshooting upon parameter anomalies, avoiding water supply suspension, power outage and failure of fire-fighting systems caused by equipment malfunctions. Thirdly, electronic archives for facilities and equipment are established to record procurement information, installation information, operational data, maintenance records and fault handling records, realizing digital full-life-cycle management of equipment and providing data support for equipment renewal and maintenance plan formulation.

3.3. Smart Environmental Management Scenario: Creating Green and Livable Community Public Environment

Community public environmental management covers cleaning, greening, waste classification and public-area disinfection. The traditional management mode depends on manual inspections and subjective judgment, resulting in insufficient refinement and untimely services. Empowered by IoT technology, environmental management achieves intelligent perception of environmental conditions, automatic triggering of service demands and precise control over service procedures (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2022). Firstly, garbage bin overflow sensors are deployed in public community areas to monitor bin filling

status in real time. When reaching the early-warning threshold, the system automatically pushes removal notifications with specific bin locations to cleaning staff's handheld terminals, realizing on-demand cleaning services, improving cleaning efficiency and preventing environmental pollution caused by overflowing garbage. Secondly, soil moisture sensors and ambient temperature-humidity sensors are installed in green belts to monitor soil moisture and environmental conditions. Based on monitored data, the system automatically judges irrigation demands of plants and links intelligent irrigation systems for on-demand watering, which guarantees plant growth while saving water resources. Meanwhile, pest and disease risks in green belts can be detected in a timely manner so that greening maintenance staff can carry out prevention and treatment to improve greening management. Thirdly, disinfection check-in devices are deployed in public areas. Cleaning staff are required to complete on-site check-ins after finishing disinfection work, and check-in information is uploaded to the IoT platform in real time. Managers can view disinfection completion status, covered areas and working hours on the platform to ensure effective implementation of disinfection work and safeguard public health in communities.

3.4. Intelligent Customer Service Scenario: Building an Efficient and Transparent Owner Demand Response System

Owner customer service serves as a core window of property services and directly affects owners' satisfaction. By building an IoT-based intelligent customer service platform and integrating online and offline service channels, closed-loop management featuring one-click demand submission, intelligent work-order dispatching and whole-process tracking is realized (Song, 2024; Wang & Li, 2023). Firstly, online owner service platforms including mobile apps and WeChat Mini Programs are developed. Owners can complete property fee payment, repair applications, complaint submission, visitor reservation and community activity registration via the platforms without visiting property service centers, realizing "handling services without going out". Secondly, intelligent dispatching and whole-process tracking of owner demands are realized. After owners submit repair requests or complaints, the system automatically assigns work-orders to corresponding staff according to demand types and locations. Staff receive and process work-orders via handheld terminals. Every step including order receiving, processing and completion is uploaded to the platform in real time, and owners can check work-order progress transparently via the platforms. Thirdly, an owner service evaluation system is established. Upon work-order completion, owners can evaluate service quality through the platform, and evaluation results are linked with staff performance assessment to urge staff to improve service quality. Moreover, by analyzing owner evaluation and demand data, weak links in services can be identified, and service procedures can be optimized in a targeted manner to lift overall service standards.

3.5. Smart Energy Consumption Management Scenario: Realizing Refined Control of Community Energy Consumption and Energy Conservation

Community energy consumption covers water, electricity, gas, public lighting and elevator operation, constituting a major component of property service costs. The traditional energy-consumption management mode adopts manual meter reading and extensive control, leading to inaccurate energy data, severe waste and difficult cost control. The smart energy-consumption management system built with IoT technology supports automatic collection, real-time monitoring,

analytical early warning and energy-saving control of energy data (W. Liu, 2018; Zeng, 2023). Firstly, intelligent remote-transmission modules are installed on metering devices such as public-area electricity meters, water meters and gas meters to realize automatic collection and real-time upload of energy-consumption data, replacing manual meter reading and improving data accuracy and timeliness. Meanwhile, the platform conducts statistical analysis on energy-consumption data of different areas and equipment, generates energy-consumption analysis reports, and accurately identifies consumption patterns and waste points in communities. Secondly, intelligent lighting controllers and human-body induction sensors are deployed for public lighting systems to realize intelligent control. For instance, human-body induction enables "lights on upon human arrival and lights off upon human departure" in stairwells and underground parking lots; street lamps in communities automatically adjust brightness according to light intensity and time, which greatly cuts energy consumption of public lighting. Thirdly, energy-saving schemes are formulated through analyzing energy-consumption data, such as upgrading high-energy-consumption equipment and sending gentle reminders to owners for unreasonable energy-use behaviors. Refined management reduces community energy consumption and further cuts property service costs.

4. Difficulties and Optimization Strategies for IoT Technology Implementation in Property Services

Although IoT technology brings remarkable value improvement to property services, property service enterprises still face multiple challenges in practical implementation, including high capital investment, difficult technology integration, insufficient staff competence and data security risks (Liu, 2024; Song, 2024). Combined with enterprise practical experience, targeted optimization strategies are put forward as follows.

4.1. Difficulty 1: Large Up-front Capital Investment, Limited Affordability of Small- and medium-sized Property Enterprises

The implementation of IoT technology requires deployment of a large number of sensing devices as well as construction of network transmission and platform management systems, which involves substantial up-front capital input. Small- and medium-sized property enterprises with limited financial strength can hardly afford high transformation costs, which becomes the primary barrier for technology implementation (Zeng, 2023).

Optimization Strategies: Adopt a phased and progressive construction mode. Priority shall be given to transformation of core and high-demand scenarios such as intelligent security and intelligent facility operation-maintenance. Cost savings and efficiency gains generated from core scenarios can be reinvested into technical upgrades for other scenarios. In addition, property enterprises may cooperate with IoT technology service providers and adopt the mode of "equipment leasing plus platform service fee" to ease up-front capital pressure. Furthermore, enterprises can apply for special subsidies by making use of government digital transformation support policies to alleviate financial burdens.

4.2. Difficulty 2: Poor System Connection, Great Challenges in Technology Integration and Data Interoperability

IoT devices and systems for different property service scenarios are mostly supplied by various vendors, resulting in inconsistent device interfaces, poor system compatibility and divergent data formats. These problems hinder data interoperability and functional coordination among systems, create “information silos”, and prevent IoT technology from giving full play to its overall value (Wang & Li, 2023).

Optimization Strategies: Formulate unified technical standards and interface specifications at the initial stage of IoT system construction, and select service providers with system integration capabilities to guarantee seamless connection of devices and systems across scenarios. Build a unified IoT management platform to integrate systems and data of intelligent security, facility operation-maintenance, smart environmental management and intelligent customer service onto one single platform for centralized management, data sharing and collaborative application. Moreover, establish a long-term mechanism for technical docking and maintenance, and sign long-term cooperation agreements with service providers to guarantee smooth system upgrade, maintenance and docking in later stages.

4.3. Difficulty 3: Shortage of Professional Technical Personnel, Inadequate Staff Competence in Operation and Management

The operation and management of IoT systems require compound talents equipped with both property service knowledge and IoT technical expertise. Most employees of traditional property enterprises are engaged in security, cleaning and engineering maintenance posts and lack capabilities to operate and manage IoT technologies. Consequently, constructed IoT systems cannot deliver full functional value, and even suffer from idle systems and unattended equipment failures.

Optimization Strategies: Establish a comprehensive staff training system and carry out position-specific IoT training. For example, staff in monitoring centers receive training on platform operation and alarm handling; engineering maintenance staff are trained for equipment monitoring and troubleshooting; customer-service staff get training on intelligent customer-service platform operation and work-order processing to improve employees’ technical operation capabilities. Meanwhile, introduce IoT professionals and set up an in-house technical operation-maintenance team responsible for daily operation, maintenance and optimization of IoT systems to underpin stable system performance. In addition, incorporate IoT system operation capabilities into employee performance assessment to encourage staff to proactively learn relevant technologies.

4.4. Difficulty 4: Prominent Data Security Risks, Vulnerability of Owner Information and Enterprise Data to Leakage

The application of IoT technology involves massive owner information (face-recognition data, identity information, household information, etc.) and enterprise operational data (energy-consumption data, financial data, service data, etc.). In the processes of data collection, transmission, storage and utilization, such data face security risks including hacker attacks, data leakage and unauthorized use, which may not only infringe owners’ privacy rights but also disrupt normal enterprise operations.

Optimization Strategies: Build a comprehensive data security protection system. In data collection, follow the "minimum necessity" principle, collect only information required for property services, clearly inform owners of purposes, modes and scope of data use, and obtain owners' consent. In data transmission, adopt encryption technologies to guarantee transmission security. In data storage, deploy secure databases with strict access permissions and encrypted data storage to prevent unauthorized access and data theft. In data utilization, establish an approval system for data use and prohibit unauthorized data access. Meanwhile, deliver data-security training for employees to raise their awareness of data protection. Furthermore, conduct regular security inspections and vulnerability repairs for IoT systems to guard against cyber-attacks and data-security hazards in a timely manner.

5. Conclusion

As a core component of new-generation information technologies, IoT technology brings new development opportunities for the transformation and upgrading of the property service industry. Its application in property service operation and management effectively addresses pain points of traditional property services such as low efficiency, slow service response, high costs and prominent risks, and realizes the transformation of property services from "extensive labor-based management" to "intelligent refined management". As the general manager of a property company, when formulating enterprise development strategies, we should take empowering property services with IoT technology as a core development orientation, and promote phased and scenario-based implementation of IoT technology in light of enterprise realities and owners' service demands.

Based on practical experience of IoT technology application in enterprises, this paper explores application paths and practical approaches of IoT technology in core scenarios including intelligent security, intelligent operation and maintenance of facilities and equipment, smart environmental management, intelligent customer service and smart energy consumption management. It also puts forward optimization strategies targeting implementation difficulties concerning capital, technology, personnel and data security. Practices have proven that empowered by IoT technology, enterprises achieve significantly improved operational and management efficiency, reduced operating costs, greatly enhanced owners' service experience and satisfaction, and further elevated brand reputation.

In the future development of property services, IoT technology will be deeply integrated with artificial intelligence, big data, cloud computing and 5G technologies to realize higher-level intelligence of property services. Property service enterprises should continuously increase R&D and technical investment, optimize IoT application schemes, improve intelligent service systems, and strengthen talent training and team building to enhance enterprises' intelligent operation and management capabilities. Through in-depth empowerment of IoT technology, the property service industry will develop toward higher efficiency, greater convenience, better safety and higher livability, create high-quality living environments for owners, and contribute to urban services and community governance.

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Research on the Application of Internet of Things Technology in Water-Related Electromechanical Equipment and Smart Property Services

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Abstract

Traditional operation and maintenance of water-related electromechanical equipment and residential property services are often characterized by low operational efficiency, delayed fault responses, excessive energy consumption, and high labor costs. By integrating sensing, transmission, analysis, and intelligent control, Internet of Things (IoT) technology offers opportunities to improve equipment management and property operations. This paper outlines the technical architecture of IoT and examines its principal applications in two interconnected settings: the operation of water-related electromechanical equipment and the management of water-related facilities in residential communities. It also identifies implementation challenges, including limited equipment compatibility, data security risks, inadequate operation and maintenance systems, and insufficient integration across applications, and proposes corresponding measures. The analysis suggests that IoT-enabled systems can support real-time equipment monitoring, early fault warnings, and intelligent control, while improving the digital management of water-related property services, reducing operation and maintenance costs, and enhancing service quality. The discussion provides a practical reference for integrating smart water services with smart property management.

Keywords: Internet of Things; Water-Related Electromechanical Equipment; Smart Property Management; Equipment Operationand Maintenance; Intelligent Monitoring and Control

1. Introduction

1.1. Research Background

Against the backdrop of smart city development, smart water services and smart property management have become important components of more effective urban governance. Conventional operation and maintenance of water-related electromechanical equipment relies on manual inspections, scheduled maintenance, and repairs after failures occur. Pumping stations, pipe networks, and water pump units are geographically dispersed and operate under complex conditions. Manual monitoring makes it difficult to track equipment conditions in real time, potentially leading to abnormal water pressure, pipe leakage, equipment overload, and energy waste. These problems can compromise water supply reliability and waste water and electricity.

In residential communities, secondary water supply facilities, water supply and drainage networks, and other water-related electromechanical equipment are essential to everyday life. Conventional property-managed water services face inefficient meter reading, slow responses to faults, fragmented maintenance records, and limited control over energy consumption. These limitations make it difficult to meet the needs of modern smart communities. IoT technology can reduce information barriers in conventional operation and maintenance by supporting real-time data collection, intelligent analysis, and remote equipment control. It therefore provides a technical basis for upgrading water-related electromechanical systems and improving property services (Singh & Ahmed, 2021).

1.2. Research Significance

From a theoretical perspective, this paper proposes an integrated framework for applying IoT technology to water-related electromechanical equipment and property management. By examining the links between these settings, it contributes to discussions at the intersection of smart water services and smart property management.

From a practical perspective, IoT-enabled monitoring and control can support continuous observation of water-related equipment, identify faults and pipe leakage more promptly, and help reduce energy use and maintenance costs. These capabilities can also streamline property management workflows, accelerate fault resolution, and improve residents' experience of water services, offering practical pathways for digital transformation.

1.3. Domestic and International Research

International research and practice have explored IoT-based monitoring of water distribution networks and pumping-station equipment (Pagano et al., 2025). In settings such as Europe, North America, Japan, and South Korea, industrial IoT solutions have been used to support predictive maintenance, equipment scheduling, and energy-efficiency improvements. Such developments offer examples of how water infrastructure monitoring can be connected with intelligent property management.

Research on related applications in China is also expanding. However, existing work frequently addresses individual equipment upgrades or separate smart property applications rather than their coordinated deployment. Research on integrating water-related electromechanical equipment with

residential property water services remains comparatively fragmented. This paper addresses that integration by considering equipment management and property operations within a common application framework.

1.4. Research Content and Methods

This paper reviews the architecture of IoT technology, examines limitations of conventional operation and maintenance, analyzes major IoT application scenarios for water-related electromechanical equipment and residential property water services, and proposes strategies to address implementation challenges. It combines a literature review, scenario analysis, and problem-oriented analysis to connect technological considerations with practical management needs.

2. Relevant Concepts and IoT Technical Architecture

2.1. Core Concepts

Water-related electromechanical systems include pumping stations, water pump sets, secondary water supply equipment, pipe-network valves, water-quality monitoring devices, electrical control units, and other essential water supply and drainage facilities. Together, these systems provide the infrastructure required for reliable water supply (Menke et al., 2016; Silva et al., 2025).

Property-oriented IoT refers to the use of networked sensing devices, data platforms, and connected control systems to support the operation and maintenance of residential and industrial properties. Combined with big data and cloud computing, these technologies enable data-driven equipment management and more precise operational control (Pagano et al., 2025; Singh & Ahmed, 2021).

The integrated application of IoT in water services connects information systems used for municipal water infrastructure with those serving water facilities in residential developments. This integration can support unified monitoring, intelligent scheduling, and coordinated property-based operation and maintenance of water-related electromechanical equipment.

2.2. Four-Layer IoT Technical Architecture

The perception layer provides on-site data acquisition. Pressure, flow, temperature, and water-level sensors, together with smart water meters, collect information on equipment operating conditions, water quality, energy consumption, and pipe-network status.

The network layer supports data transmission and the delivery of control instructions through a combination of optical fiber and wireless communication. Technologies such as 5G and narrowband IoT (NB-IoT) enable communication between connected devices and management platforms.

The platform layer uses cloud-based data services to store, process, and analyze information collected from connected devices. It can support anomaly detection, early-warning models, and data-informed decisions about equipment operation and maintenance.

The application layer provides interfaces for maintenance personnel, property managers, and residents. Through dashboards and mobile applications, users can access remote monitoring, fault alerts, automatic meter reading, energy-consumption analysis, and maintenance management services.

Table 1. Four-Layer Architecture of IoT: Functions and Key Equipment

Layer	Core Function	Main Hardware and Technologies
Perception Layer	On-site data collection	Pressure, flow, and water-level sensors; smart water meters
Network Layer	Data transmission and control instructions	5G, NB-IoT, LoRa, optical fiber
Platform Layer	Data storage, analysis, and early warning	Cloud computing, big data analytics, early-warning algorithms
Application Layer	User-facing visualization and services	Monitoring dashboards, mobile apps, operation and maintenance systems

3. IoT Applications in Water-Related Electromechanical Equipment and Smart Property Management

3.1. Applications in Water-Related Electromechanical Systems

IoT technology enables continuous monitoring and intelligent control of water pump units. Sensors can collect real-time data on temperature, vibration, electrical current, and pressure. Monitoring systems can identify potential problems, such as equipment overload, and send early-warning notifications to relevant personnel. Pump operation can then be adjusted according to water demand, helping reduce energy consumption and equipment wear (Menke et al., 2016; Silva et al., 2025).

For pipe-network operation and maintenance, comparisons of flow and pressure measurements at different network nodes, combined with hydraulic models, can help locate potential leaks and shorten troubleshooting and repair times. In secondary water supply systems, IoT devices can monitor tank water levels, water quality, and supply pressure in real time. Automated water replenishment, pressure regulation, and remote fault diagnosis can help maintain a safe and stable water supply (Sadeghioon et al., 2014; Silva et al., 2025).

3.2. Applications in Residential Property Water Services

IoT-enabled smart water meters can automatically collect and transmit water-consumption data (Cominola et al., 2015). Depending on system configuration and applicable requirements, they can also support online billing, account top-ups, and remotely authorized service control or restoration. These functions can reduce the need for manual meter reading and improve the efficiency of property operations.

IoT platforms can integrate water supply and drainage pipelines, drainage pumps, firefighting water supply facilities, and other water-related equipment within residential developments (Pagano et al., 2025). Digital equipment records and visual monitoring interfaces support preventive maintenance and improve operational visibility. The platforms can also analyze household and communal water consumption, identify abnormal usage patterns, and provide evidence for water-saving upgrades and cost control. In addition, automated alerts can flag potential leaks, pipe blockages, and abnormal water pressure. A closed-loop process covering fault reporting, work-order assignment, maintenance, and verification can improve the consistency of property services.

4. Existing Problems in Practical Application

First, equipment compatibility remains a challenge. New and legacy devices often operate alongside one another, while older equipment may lack suitable interfaces for network connectivity. Differences in communication protocols and vendor specifications can create data silos, increasing the cost and complexity of system upgrades (Pagano et al., 2025).

Second, data security protections may be inadequate. Equipment operating records and residents' water-consumption data can be exposed to unauthorized access, leakage, or tampering when encryption, access controls, and data governance procedures are insufficient or inconsistently applied.

Third, operation and maintenance practices may not keep pace with technological upgrades. Conventional maintenance approaches can persist even after intelligent equipment has been installed, limiting its effective use. There may also be a shortage of professionals with expertise in both water services and IoT systems.

Fourth, integration across operational settings is often limited. Municipal water service systems and residential property water-management systems may function independently, with little data sharing or coordination of workflows. This separation makes end-to-end monitoring and joint operation and maintenance more difficult.

5. Optimization Strategies

First, organizations should standardize equipment communication and data exchange requirements. A phased upgrade strategy can prioritize critical facilities, add suitable interface modules to legacy equipment, and use common access platforms to improve interoperability and reduce data silos.

Second, organizations should establish data security measures throughout the information lifecycle. Encryption, network security controls, data backups, and role-based access permissions should be accompanied by regular security audits, incident response procedures, and clear responsibilities for protecting operational and resident data.

Third, organizations should strengthen digital operation and maintenance capabilities. Predictive monitoring should complement, rather than eliminate, professional on-site inspections. Targeted

staff training and recruitment can help build teams with expertise in both water infrastructure and IoT systems.

Finally, water service providers and property management organizations should develop interoperable coordination mechanisms or shared management platforms. Better information exchange between municipal and residential water systems can support joint monitoring, coordinated maintenance, and more effective management across organizational boundaries.

6. Conclusions and Prospects

The application of IoT technology to water-related electromechanical equipment and residential property water services offers ways to address the limitations of conventional operation and maintenance, including delayed responses, high operating costs, and fragmented management. Its main potential benefits lie in continuous equipment monitoring, earlier detection of faults, improved energy management, and more coordinated maintenance.

Nevertheless, equipment incompatibility, data security risks, shortages of appropriately trained staff, and inadequate coordination across systems can limit these benefits. Gradual equipment upgrades, stronger security governance, improved maintenance practices, and better data interoperability are therefore important. As artificial intelligence and edge computing continue to develop, IoT-enabled water and property management systems may support more accurate fault prediction, demand-responsive energy scheduling, and closer coordination between municipal infrastructure and residential services.

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Investigation and Analysis of the Age-Friendly Dilemma of Smart Elderly Care Services under AI Empowerment

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Abstract

Against the backdrop of population aging and the widespread adoption of digital technologies, artificial intelligence (AI) is increasingly being integrated into home- and community-based eldercare. However, many older adults continue to face a digital divide, while smart eldercare products often provide only superficial age-friendly adaptations and fail to match users' needs. This study examines older residents of urban communities and their family members. Drawing on a literature review, a questionnaire survey, and semi-structured interviews, it investigates the development of AI-enabled smart eldercare services and the difficulties older adults encounter when using smart devices and related services. Informed by digital divide theory, active aging theory, and supply-and-demand matching theory, the study analyzes the factors underlying these difficulties and proposes a smart eldercare service model that uses age-friendly short videos as a delivery medium and intergenerational collaboration as its core mechanism. It further develops operational strategies across six dimensions: content, target groups, channels, technology, implementation, and operations. Survey findings are used to assess the model's feasibility. The proposed approach offers communities and social organizations a low-cost, practical framework for more inclusive smart eldercare services, with the aim of narrowing the digital divide and supporting active aging.

Keywords: Smart Eldercare; Artificial Intelligence; Age-Friendly Design; Digital Divide; Intergenerational Collaboration

1. Introduction

Population aging is a long-term demographic trend in China, and home- and community-based care are currently the predominant forms of eldercare. Advances in artificial intelligence (AI) and other intelligent technologies have accelerated the development of smart eldercare and expanded the range of digital services. At the same time, the digital divide affecting older adults has become increasingly visible. Although many older adults are willing to use digital products, existing designs

often fail to accommodate their needs and abilities. Age-related physiological changes, insufficient ongoing guidance, and concerns about information security can prevent them from benefiting from digital eldercare services. Existing research has focused largely on hardware development and macro-level policies, with less attention to basic, inclusive, and lightweight online services. This study therefore explores a cost-effective, user-friendly, and sustainable model for age-friendly smart eldercare based on short-video media and intergenerational collaboration.

This study focuses on older residents of urban communities. A review of the literature is used to synthesize research on smart eldercare, age-friendly adaptation, and the digital divide. Primary data are collected through questionnaires and semi-structured interviews to identify older adults' needs in daily care, emotional support, and digital learning, and to examine barriers to age-friendly AI-enabled eldercare. On this basis, the study develops a service model that combines short-video resources with intergenerational collaboration, proposes operational strategies across multiple dimensions, and assesses their feasibility. It concludes by summarizing the findings, discussing limitations, and outlining directions for future research. The study contributes to research on inclusive smart eldercare and efforts to bridge the digital divide. In practice, it offers communities and social organizations a low-cost, actionable framework for age-friendly digital eldercare services, with the aim of helping older adults participate more fully in the digital society and supporting active aging.

2. Theoretical Framework

2.1. Digital Divide Theory

Digital divide theory encompasses not only disparities in access to hardware but also differences in digital skills and user experience. Older adults are particularly affected by these disparities (Pan & Qiu, 2021). Physiological and cognitive changes, together with a lack of systematic learning resources, can make it difficult for older adults to benefit from smart eldercare services. Reports by the U.S. National Telecommunications and Information Administration (NTIA) have also documented disparities in digital access and skills. This perspective provides a theoretical basis for examining the difficulties older adults encounter when using smart eldercare services.

2.2. Active Aging Theory

Active aging is commonly understood in terms of three dimensions: health, participation, and security (World Health Organization, 2002; Xiong, 2025). Beyond material security, this perspective emphasizes older adults' social participation and well-being, including their opportunities to participate in digital society. Accordingly, AI-enabled smart eldercare should address not only hardware and functional needs but also emotional companionship, digital learning, and opportunities for self-development. The World Health Organization's policy framework highlights social participation and personal development, aligning with this study's focus on intergenerational collaboration, emotional support, and digital inclusion.

2.3. Supply and Demand Matching Theory

Supply-and-demand matching theory emphasizes aligning service provision with actual user needs. Drawing on Walras's theory of general equilibrium, it focuses on the dynamic balance between supply and demand (Walras, n.d.). At present, AI-enabled smart eldercare products and services may fail to address the needs of older adults living alone, creating a mismatch between supply and demand. This study applies this perspective to smart eldercare to examine the causes of age-friendly adaptation challenges and to inform the optimization of eldercare service models.

3. Research Design: Smart Eldercare and Age-Friendly Adaptation

AI technologies are increasingly being integrated into community-based eldercare. Smart devices and digital services are becoming more widespread, expanding the ways in which care services are delivered. However, many smart products are designed primarily for younger users and are updated rapidly, while their operation can be complicated.

Many older adults have limited digital skills and adopt new technologies at a slower pace. Existing age-friendly adaptations are often superficial and do not adequately address their actual needs. A theoretical discussion alone cannot capture the practical challenges of implementing smart eldercare. Accordingly, this study combines quantitative questionnaire data with qualitative interview data to examine how older adults in urban communities use AI-enabled smart eldercare services. The findings provide an empirical basis for identifying challenges and developing strategies. This chapter describes the survey population, research objectives, instruments, and implementation process.

3.1. Definition of the Research Population

The survey targeted permanent residents aged 60 years and older in urban communities. Eligible participants had lived in the community for an extended period, were in sufficiently stable physical condition, and could communicate independently. Individuals who were temporary residents or visitors, had severe cognitive impairments, or were unable to communicate were excluded to help ensure the validity of the sample. The survey used stratified sampling across four dimensions: age, living arrangements, educational attainment, and digital proficiency. It therefore covered older adults with a range of characteristics. The specific strata and selection criteria are presented in Table 1.

Table 1. Respondent stratification dimensions and grouping criteria

Stratification dimension	Specific category	Selection rationale
Age	60–69 years	Physical functioning, learning speed, and acceptance of digital technologies can vary substantially across age groups. Stratification helps capture these differences.
	70–79 years	
	80 years and older	

Living arrangements	Living alone	Living arrangements affect the availability of family support for digital tasks and day-to-day guidance.
	Living with a spouse	
	Living with children	
Educational attainment	No formal schooling	Educational attainment can influence reading comprehension, cognitive demands, and the capacity for independent learning.
	Primary school	
	Junior high school	
	Senior high school or above	
Digital proficiency	Digital-operation proficiency	Proficiency in using smart devices helps identify differences in the age-related barriers experienced by different groups.
	Beginner	
	Basic-function user	
	Proficient user	

3.2. Research Design

This study adopted a mixed-methods approach combining questionnaire surveys and semi-structured interviews.

3.2.1. Questionnaire Design

The questionnaire was designed to examine AI-enabled, intergenerationally supported smart eldercare. It targeted urban community residents aged 60 years and older and their family members and was distributed online and offline. It covered three practical areas: home safety, emotional loneliness, and the digital divide associated with limited age-friendly resources. Participants were grouped by age (60–69, 70–79, and 80 years and older), living arrangement (living alone, with a spouse, or with children), educational attainment (no formal schooling, primary school, junior high school, or senior high school and above), and digital proficiency (beginner, basic-function user, or proficient user). The survey included older adults who had lived in the community for an extended period, were in stable physical condition, and could communicate normally. It excluded temporary residents or visitors, those with severe cognitive impairments, and those unable to communicate. The questionnaire collected data on the use of and preferences for smart eldercare services, perceived gaps between service supply and demand, digital-learning characteristics, operational difficulties, and psychological concerns. These data provide quantitative support for the subsequent analysis and service-model development.

3.2.2. Interview Guide Design

Because questionnaires provide primarily quantitative data, they may not capture the depth of older users' experiences. Semi-structured interviews were therefore conducted as a complementary

qualitative method. Interviewees were selected at random from among the questionnaire respondents to represent different age groups, educational backgrounds, living arrangements, and levels of digital proficiency. The interview guide covered three areas: experiences with and preferences for smart eldercare devices; difficulties, resistance, and barriers encountered when learning to use smart devices; and suggestions for improving products, community-based eldercare support, and digital assistance. Questions were adapted flexibly to each respondent's pace of communication, and responses were recorded objectively to preserve the authenticity of the data. Table 2 summarizes the overall framework and core elements of the survey design.

Table 2. Summary of the core elements of the research design

Research module	Specific design content	Research function
Research population	Permanent residents aged 60 years and older in urban communities	Ensure comprehensive sample coverage and a reasonable sample structure that reflects the characteristics of older adults in urban communities.
Research objectives	Examine current use of smart eldercare services, summarize older adults' usage patterns, identify barriers to age-friendly adaptation, and collect relevant empirical data.	Define the main research focus and provide an empirical basis for analyzing the issues and developing recommendations.
Research methods	Questionnaire survey (quantitative) and semi-structured interviews (qualitative)	Balance the breadth of the survey data with the depth of interview findings and address the limitations of relying on a single method.
Questionnaire structure	Basic information	Use a staged structure to cover current usage, barriers, and user needs.
	Current use of smart eldercare services	
	Barriers to use	
	Suggestions for improvement	
Interview topics	User experiences	Explore subjective difficulties and underlying issues that questionnaires alone may not reveal, thereby enriching the findings.
	Reasons for operational difficulties	
	Suggestions for service improvement	
Implementation process	Preparation → Field visits → Data organization and analysis	Standardize the research process and ensure that the data are accurate, valid, and complete, thereby strengthening the rigor of the study.

4. Survey Findings on Age-Friendly Adaptation in Smart Eldercare

4.1 Analysis of Survey Findings

Regarding home safety, many respondents reported limited ability to respond to emergencies at home and expressed concern about falls, sudden illness, and accidents in which no assistance is available (Wu & Li, 2024). They therefore showed strong demand for one-touch emergency calls, alerts to abnormal conditions at home, and remote safety monitoring. Responses to the home-safety questions varied across risk categories. Falls were the most frequently reported concern (40%, 800 respondents), followed by sudden illness (30%, 600 respondents). A further 20% (400 respondents) were concerned about being unable to obtain help after an accident, while 10% (200 respondents) reported limited emergency-response and self-rescue capabilities (Figure 1). These findings suggest that falls and sudden illness are the two principal home-safety concerns. However, many smart eldercare products currently available on the market do not provide adequate age-friendly design, making independent use difficult for older adults.

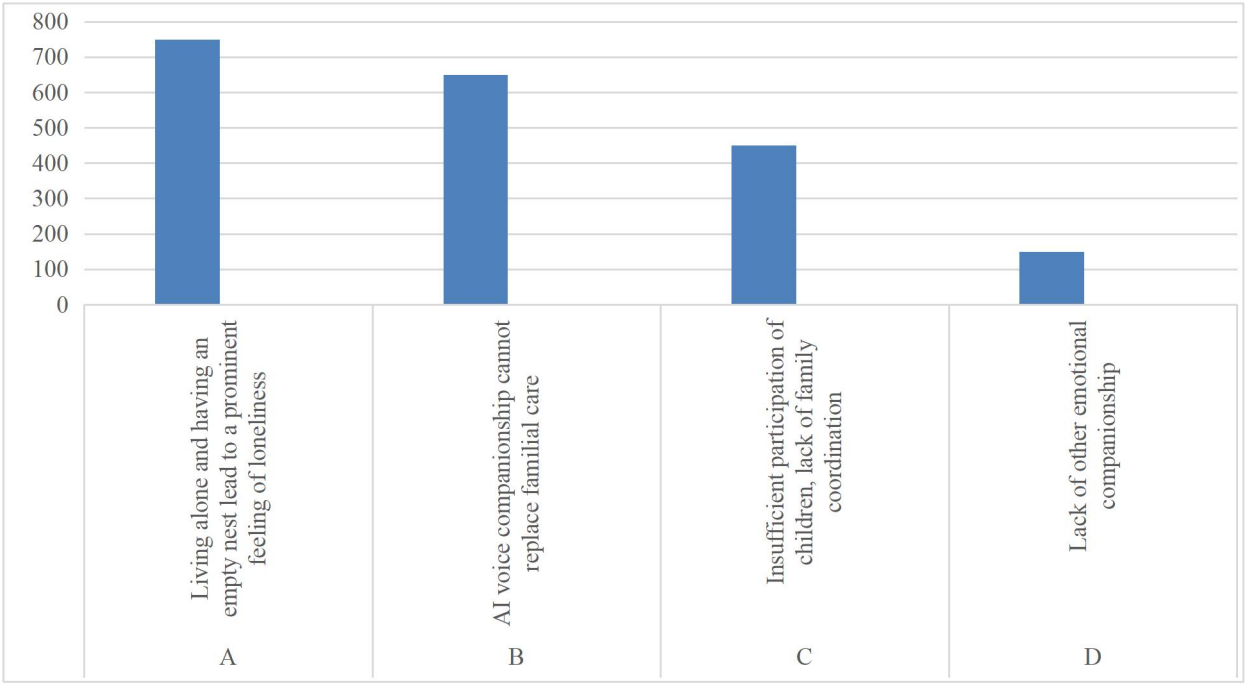


Figure 1. Home safety

With respect to emotional support and companionship, loneliness was a prominent concern among older adults living alone or in empty-nest households. Respondents indicated that AI-based voice interaction alone could not replace care from family members and expressed a preference for intergenerational companionship involving children and greater family coordination (Shen & Guan, 2025). Specifically, 37.50% (750 respondents) identified loneliness associated with living alone or in an empty-nest household as their primary emotional concern. Another 32.50% (650 respondents) said that AI voice companionship could not replace care from family members and questioned the emotional value of such systems. In addition, 22.50% (450 respondents) reported insufficient involvement from their children and a lack of family coordination, while 7.50% (150 respondents) reported other forms of unmet companionship needs (figure 2). These findings suggest that a lack of family companionship is a major source of emotional distress among older adults in empty-nest

households and that AI technology alone cannot compensate for the absence of genuine family affection.

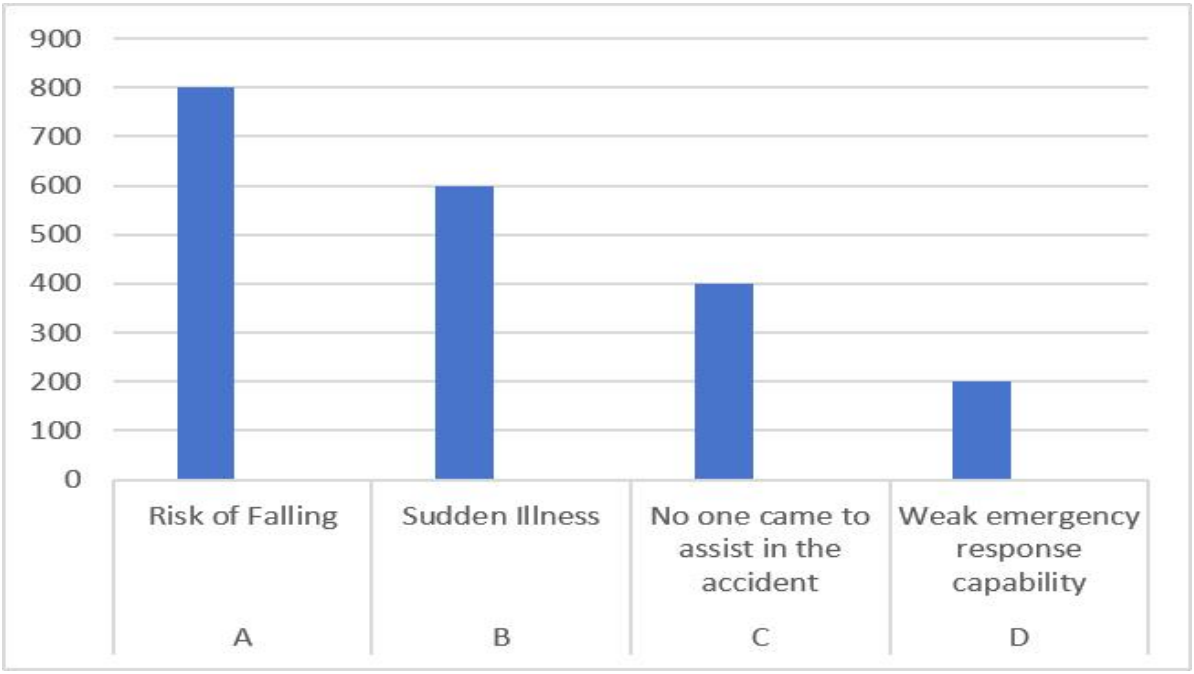


Figure 2. Emotional companionship

Regarding the digital divide, most older adults expressed a willingness to learn how to use smart eldercare devices. However, age-friendly learning resources were scarce, learning channels were limited, and instructional content was often difficult to understand. These barriers could create anxiety, reflected in the sentiment that people 'want to learn but do not know how, and want to use the technology but are afraid to try' (Pan & Qiu, 2021). Specifically, 35.00% (700 respondents) cited a shortage of age-friendly instructional resources and limited access to digital-learning opportunities; 27.50% (550 respondents) reported limited learning channels and a lack of systematic instruction; 22.50% (450 respondents) found the instructional content difficult to understand or insufficiently adapted to older learners; and 15.00% (300 respondents) felt intimidated, wanting to learn but not knowing how or wanting to use the technology but being afraid to try (figure 3). The scarcity of learning resources and limited access to instruction appear to be the main barriers to narrowing the digital divide.

Respondents generally showed a high level of acceptance of eldercare models that incorporate short-video instruction and support through multiple channels. Nevertheless, they raised concerns about ease of use, functional complexity, and technical reliability, all of which may undermine trust in AI-enabled eldercare services (Tang, 2025; Zheng, 2023). The distribution of concerns about AI-enabled smart eldercare products was similar to that of concerns about the digital divide. Specifically, 35.00% (700 respondents) considered these products difficult to operate and associated with a high learning threshold; 27.50% (550 respondents) found their functions too complex to master; 22.50% (450 respondents) were concerned about technical reliability and possible malfunctions; and 15.00% (300 respondents) expressed insufficient trust in AI-enabled eldercare services (Figure 4). Operational difficulty and functional complexity were the most frequently reported barriers to adoption.

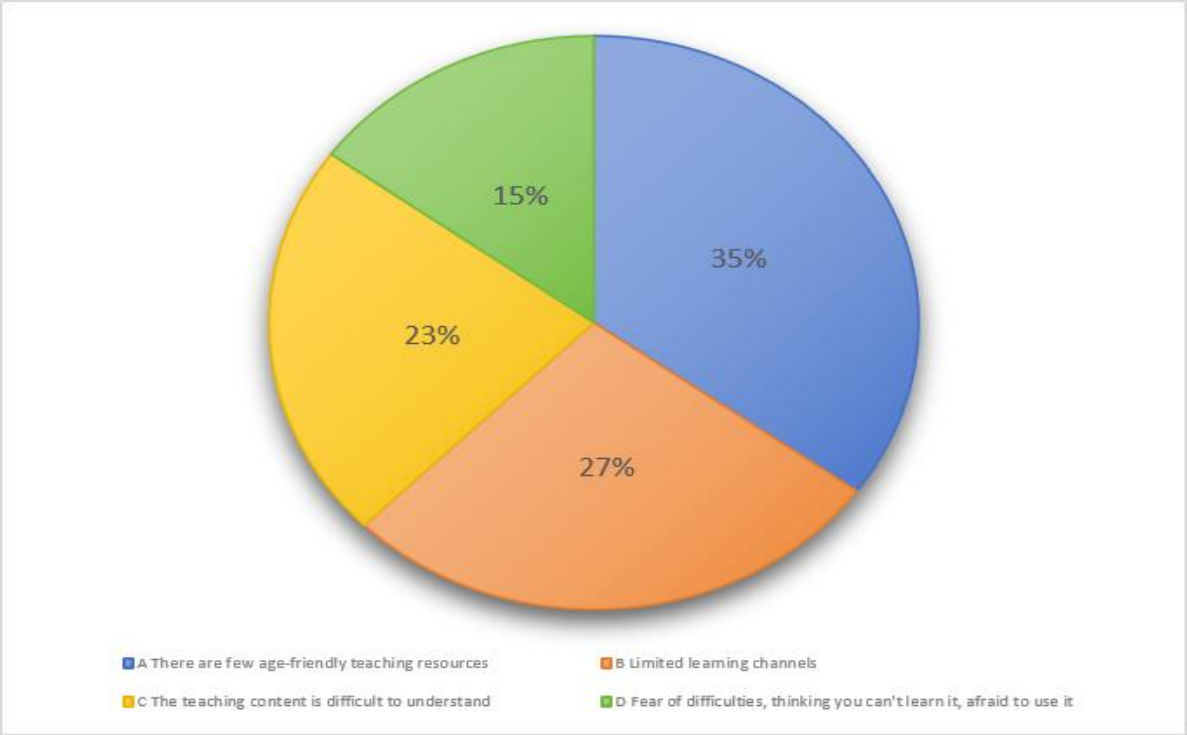


Figure 3. Digital divide

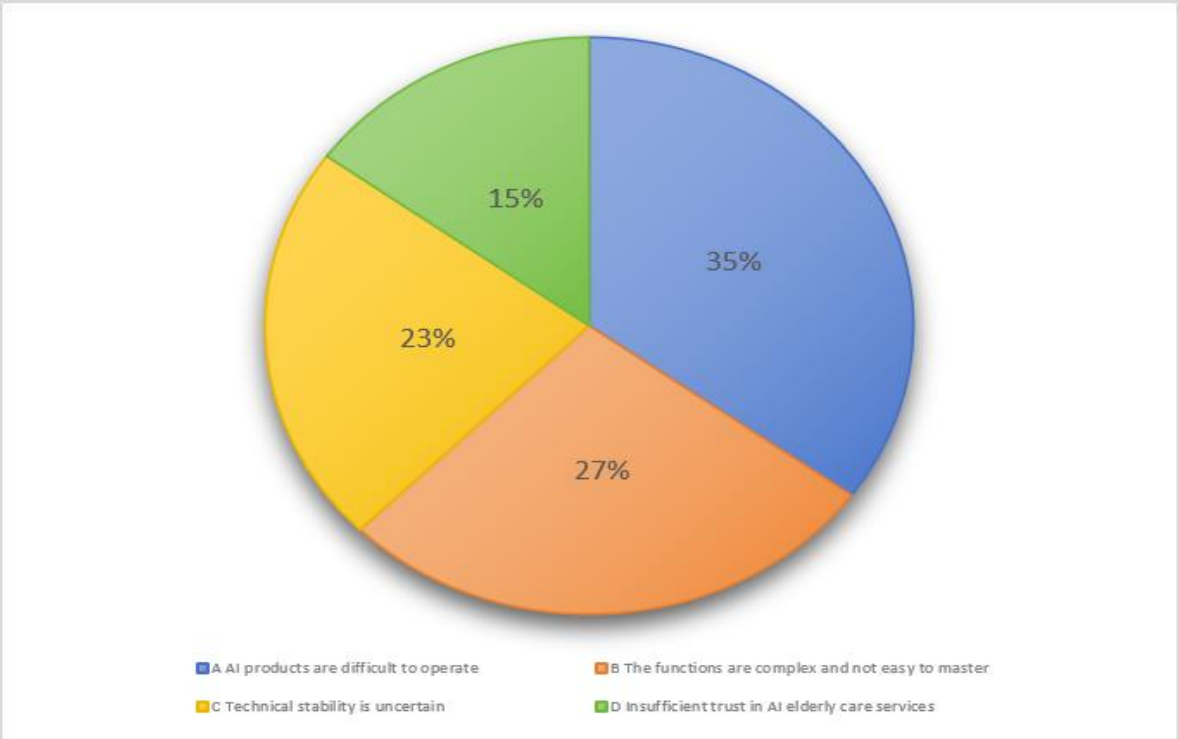


Figure 4. AI eldercare use and trust

4.2. Summary of Survey Findings

The survey findings can be summarized in four points. First, home-based eldercare involves several safety risks, and older adults have a strong need for emergency assistance, yet existing AI-enabled smart eldercare products are not sufficiently adapted to their needs. Second, AI-based companionship has limitations and cannot replace companionship from family members, leaving

some emotional needs unmet. Third, older adults are willing to learn digital skills, but age-friendly instructional resources remain scarce and the digital divide persists. Fourth, although older adults and their family members generally express acceptance of smart eldercare services, complex operations and safety concerns constrain wider adoption.

5. Strategies For Improving the Age-Friendliness of Smart Eldercare Services

To address these challenges, the study proposes strategies focused on four areas: emergency safety, emotional support and companionship, digital learning, and ease of use. The proposed measures include streamlining AI-enabled smart eldercare functions, strengthening human-centered emotional services, expanding age-friendly educational resources, and simplifying operational processes. Collaboration across multiple scenarios and stakeholder groups is intended to address existing mismatches between the supply of and demand for smart eldercare services.

5.1. Improving Age-Friendly Design to Enhance Home Safety

To address the safety risks associated with home-based eldercare, the strong demand for emergency assistance, and the limited age-friendly design of existing AI-enabled smart eldercare products, the study proposes adapting smart devices and terminals to older users' needs (Guo et al., 2025; Xiong, 2025). The proposed adaptations focus on home emergency assistance and safety monitoring. Unnecessary functions should be removed, while one-touch emergency calling and risk alerts should be added. Short videos on home safety and emergency response should use large text and voice narration to support independent learning among older adults. At the community level, an integrated service model could combine online tutorials, AI-assisted emergency consultation, and in-person home assistance. These measures are intended to strengthen home-safety protections, improve the age-friendliness of smart eldercare products, and reduce risks in home-based care.

5.2. Intergenerational Companionship: Addressing Emotional Needs

To address the limitations of AI companionship services—including limited emotional responsiveness, weak contextual engagement, and an inability to replace family companionship—the study proposes a diversified intergenerational support system. Family interaction would form its core, complemented by community social activities and volunteer assistance (Wang et al., 2025; Zhao & Shi, 2024). Short-video media could provide online channels for intergenerational interaction, enabling older adults to share aspects of daily life with family members and communicate remotely. Regular interactions could help maintain emotional connections and alleviate the sense of disconnection caused by living apart (Zhou, 2014; Zhou & Ding, 2020). A community-based digital social platform could encourage older adults to document daily life through short videos, showcase personal skills, and participate in community activities, thereby expanding opportunities for social engagement (Du & Yang, 2024; Lian et al., 2026; Shen & Guan, 2025). In addition, a support mechanism involving family members and young volunteers could provide regular online companionship and in-person home visits to older adults who live alone or in empty-nest households (Wu & Jiang, 2021). This human-centered, context-sensitive approach could complement the emotional support that intelligent devices cannot provide and strengthen the humanistic dimension of smart eldercare services.

5.3. Age-Friendly Education: Bridging the Digital Divide

Although many older adults are willing to develop their digital skills, they face a shortage of age-friendly learning resources, limited learning channels, and difficulties integrating into digital environments (Wang et al., 2025). The study therefore proposes a standardized, sustainable, and lightweight system for supplying age-friendly digital-learning resources. Short videos offer several advantages: they are concise, easy to disseminate, and easy to reproduce. A comprehensive resource library could cover basic digital operations, access to online public services, online social and recreational activities, and the use of smart devices (Du & Yang, 2024; Lian et al., 2026; Tang, 2025). Content should be designed around older adults' cognitive and learning needs, using slower narration, step-by-step demonstrations, and large, highlighted text. Community eldercare centers could offer regular digital-skills classes, using standardized instructional videos as the main teaching resource and supplementing them with one-to-one guidance from volunteers and hands-on practice (Guo et al., 2025). Peer-learning groups for older adults could also provide regular digital-skills training and online-safety education. Combining self-directed learning, peer learning, and guided instruction in this way could improve older adults' digital literacy and help narrow the digital divide (Zhao & Shi, 2024; Wen, 2020).

5.4. Streamlining Operations and Strengthening Safety Safeguards

Although older adults and their family members generally express a high level of acceptance of smart eldercare services, cumbersome operations, complex system structures, and concerns about network and device security may constrain wider adoption. Volunteer teams could therefore provide practical guidance, safety education, and channels for feedback (Zheng, 2023; Liu, 2024; Xu & Xu, 2024). For operational support, volunteers could help older adults configure smart devices, close pop-up windows, add shortcuts, and learn common functions such as voice control. They could also create simple instructional videos for later reference. For safety education, large-print materials and short educational videos could explain privacy protection and fraud prevention, while volunteers could help older adults adjust device permissions to address family members' security concerns. For outreach and feedback, community demonstrations could invite older adults and their family members to try the services in person (Zhao, 2023; Liu, 2026). Difficulties encountered during use could be recorded, organized into a problem list, and regularly shared with the project team to guide service improvements, reduce barriers to adoption, and support the delivery of inclusive smart eldercare services.

5.5. A Collaborative Operating Mechanism for the Multidimensional Service System

The three core modules are intended to operate in coordination, supported by collaboration among multiple stakeholders to ensure the long-term delivery of services (Wang, 2026). These stakeholders include families, communities, social organizations, and short-video platforms. Families provide support and companionship; communities coordinate volunteer services and public outreach; and short-video platforms improve age-friendly features and provide content suited to older adults. A dynamic feedback mechanism should collect views from older adults and their family members and use them to adjust service content continuously. Such collaboration could support a low-cost, inclusive smart eldercare model and contribute to active aging.

6. Conclusions and Future Directions

6.1. Conclusions

This study examined challenges in adapting AI-enabled smart eldercare services to older adults' needs, drawing on a survey of older residents in urban communities. By combining a literature review, questionnaires, and semi-structured interviews, and drawing on the three theoretical perspectives discussed above, the study developed a smart eldercare service model that combines short videos with intergenerational collaboration. The findings suggest that older adults have diverse care needs. In addition to basic care, they have needs related to health management, online services, and social and recreational activities. Many are willing to use smart eldercare services but lack convenient learning channels, making short videos a potentially accessible learning medium. Existing smart eldercare products do not always accommodate older adults' physical and cognitive abilities, contributing to a mismatch between service supply and demand. Smart hardware alone is insufficient to meet the needs of older adults; collaboration among families, communities, and other stakeholders is also necessary. The integrated model of daily care, emotional support, and digital inclusion proposed in this study reflects these needs and may offer a low-cost reference for inclusive smart eldercare.

6.2. Limitations and Future Directions

This study has several limitations. The sample was drawn exclusively from urban communities and did not include older adults in towns or rural areas, which limits the generalizability of the findings. The proposed service model was developed through theoretical analysis and survey research but has not been evaluated through long-term community-based pilots; its practical effectiveness therefore remains to be tested. In addition, the analysis did not fully explore differences in needs across older-adult groups, and comprehensive data-validity checks have not yet been completed. These limitations indicate areas for further improvement.

Against the backdrop of population aging, AI-enabled smart eldercare is likely to become more refined and inclusive. Future efforts should deepen age-friendly adaptations, strengthen links between community-based digital support and intergenerational assistance within families, and establish a robust system for industry oversight and safety supervision. By making effective use of short videos as a lightweight medium, intergenerational eldercare models could be further developed to help narrow the digital divide, support older adults' participation in digital society, and promote active aging.

Author Contributions:

Conceptualization: X.Z, M.Y, H.H, J.L, Z.L; Methodology: Z.L; Software: M.Y, H.H, J.L; Validation: Z.L; Formal analysis: X.Z, M.Y, H.H, J.L, Z.L; Investigation: Z.L; Data curation: X.Z, H.H, J.L; Original draft preparation: X.Z, M.Y, H.H, J.L, Z.L; Writing—review & editing: H.H, J.L; Visualization: X.Z, M.Y, H.H, J.L, Z.L; Project administration: J.L; All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement:

Before the questionnaire distribution and interviews, the research objectives, content, and information usage were explained to the research subjects, and all respondents voluntarily participated in the survey and interviews; The collected original data were de-identified, and no sensitive information that could directly identify individuals was retained.

Data Availability Statement:

Relevant materials for this study may be obtained upon request from the corresponding author. To protect the personal information of respondents, original questionnaires and interview records will not be disclosed; Aggregated data and analysis results after desensitization will be provided under reasonable application conditions.

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Conflict of Interest:

The authors declare no conflict of interest.

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Living Inheritance or Digital Alienation ? The Ethical Dilemma and Path Selection of the Inheritance of Intangible Cultural Heritage Digital People

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Abstract

Digital technologies are increasingly used to document, interpret, and disseminate intangible cultural heritage (ICH), and AI-enabled digital humans have emerged as a new medium for its communication and transmission. This study classifies ICH digital humans into three functional types: performance and dissemination, craft-skill replication, and educational assistance. It examines the ethical tensions that arise when the logic of technological reproduction intersects with the people-centred and practice-based character of living heritage transmission. Based on a questionnaire survey conducted between May 10 and June 10, 2026, the study obtained 521 valid responses from participants with different ages, educational backgrounds, and occupations. The questionnaire covered five dimensions: respondent characteristics, perceptions of ICH transmission, awareness and use of ICH digital humans, digital-ethics concerns, and preferences for future governance. The findings point to three interrelated dimensions of potential digital alienation: distortion of cultural content and authenticity through standardised reproduction; structural imbalance in transmission arising from the interaction of technological and commercial pressures; and divergent public evaluations associated with demographic and cognitive differences. In response, the study proposes three pathways: differentiated standards and meaningful participation by ICH bearers; a human-centred human–machine model supported by transparent content review and commercial oversight; and targeted public education that addresses differences in age and educational background. These findings offer empirical insights into the responsible use of digital humans in ICH safeguarding and transmission.

Keywords: Intangible Cultural Heritage; Digital Humans; Digital Ethics; Public Perceptions; Living Transmission

1. Introduction

UNESCO's Convention for the Safeguarding of the Intangible Cultural Heritage defines ICH as practices, representations, expressions, knowledge, and skills that communities, groups, and individuals recognise as part of their cultural heritage and continually recreate in response to their environment, interaction with nature, and history (UNESCO, 2003). This definition places communities and practitioners at the centre of safeguarding and emphasises transmission and revitalisation rather than the static preservation of cultural products. Accordingly, living transmission depends on interpersonal teaching, embodied practice, performance, and the integration of heritage into everyday life (Alivizatou, 2012; Kirshenblatt-Gimblett, 2004; Smith, 2006). The Convention also calls for the active participation of communities, groups, and individuals in safeguarding activities, a principle further articulated in UNESCO's ethical principles for safeguarding ICH (UNESCO, 2015).

Digital technologies have created new opportunities to document, present, and communicate ICH across geographical and generational boundaries. Recent studies have examined the use of augmented reality, social media, digital reading, and AI-generated narratives to improve access to cultural heritage and support audience engagement (Galani & Vosinakis, 2024; Hua et al., 2024; Liu et al., 2025; Zhang & Xu, 2024). Research has also explored public participation in digital heritage management and the factors associated with the adoption of digital ICH experiences (Ye et al., 2025; Zhang et al., 2024). These developments demonstrate the potential of digital technologies to broaden access and create new forms of cultural experience. However, increased visibility and technical reproducibility do not necessarily ensure the continuity of the social relationships, embodied knowledge, and local contexts through which living heritage is transmitted.

Research on the digital safeguarding of ICH has developed along several related lines. One strand examines the technical possibilities of digital documentation, three-dimensional reconstruction, augmented reality, and interactive presentation. For example, Galani and Vosinakis (2024) investigated the use of augmented reality and digital characters to communicate traditional craft practices, while Zhang and Xu (2024) developed a grounded-theory model of cultural heritage communication on social media. More recent studies have examined the adoption of digital ICH experiences and the use of AR/VR storytelling, social media, and AI-generated narratives in the Chinese context (Hua et al., 2024; Liu et al., 2025; Ye et al., 2025). Scoping and comparative reviews have further mapped the growing range of digital methods used for ICH documentation, preservation, education, and cultural innovation (Ren & Lam, 2026; Wei et al., 2026).

A second strand addresses the ethical and social implications of technological intervention. AI systems may reproduce or amplify representational biases embedded in cultural collections and training data, while the use of AI in cultural heritage raises questions about transparency, accountability, human oversight, and the protection of cultural values (Foka & Griffin, 2024; Tiribelli et al., 2024; UNESCO, 2022). Research specifically focused on ICH has also discussed the need to balance AI-enabled documentation and innovation with cultural authenticity, community participation, and the protection of practitioners' rights (Fu et al., 2025; Tan et al., 2026). Despite these advances, there remains a need for empirical research into how members of the public with different demographic backgrounds perceive the functions, risks, and appropriate boundaries

of ICH digital humans. In particular, it is important to distinguish between concerns derived from theoretical discussion and perceptions reported by actual audiences. This study addresses this gap through a questionnaire survey and a comparative analysis of public perceptions.

Against this background, this study examines whether ICH digital humans can support living transmission or whether their application may generate forms of digital alienation. It focuses on three dimensions of potential alienation: the cultural content and authenticity of inheritance, the structure and organisation of transmission, and public understanding and value judgements. Using questionnaire data, the study explores differences in perceptions across age, educational, and occupational groups and considers how these findings can inform the responsible development of ICH digital humans.

2. Three Forms and Technical Logics of ICH Digital Humans

The safeguarding and transmission of ICH continue to face practical challenges, including the ageing of some heritage bearers, limited opportunities for succession, unequal access to training, and the difficulty of documenting tacit knowledge. These challenges are particularly significant for practices that depend on oral instruction, bodily movement, and repeated hands-on learning. Digital technologies can help record and organise knowledge, preserve audiovisual materials, and make heritage content accessible to wider audiences. However, documentation and digital presentation cannot, by themselves, replace the social relationships and embodied practice involved in living transmission (Tan et al., 2026; Wei et al., 2026). Digital preservation therefore needs to be considered alongside community participation and the continued practice of heritage bearers (UNESCO, 2003, 2015).

Against this background, ICH projects have increasingly adopted technologies such as motion capture, three-dimensional reconstruction, AI-generated content (AIGC), and large language models. These tools can support the recording, presentation, and interpretation of heritage knowledge and may provide additional channels for public engagement. Recent reviews identify applications across documentation, classification, restoration, exhibition, education, and cultural innovation (Ren & Lam, 2026; Wei et al., 2026). Nevertheless, the contribution of these technologies depends on how they are designed and governed, particularly whether they remain aligned with the needs and values of the communities concerned (Tan et al., 2026).

According to their principal functions and application objectives, ICH digital humans can be grouped into three types: performance and dissemination, craft-skill replication, and educational assistance.

2.1. Performance and Dissemination

Performance-and-dissemination digital humans are designed to extend ICH presentation beyond physical venues. They may deliver online explanations, perform digitally adapted versions of traditional arts, participate in livestreams, or appear in short videos and virtual exhibitions. These applications can broaden audience access and reduce some of the practical constraints associated with offline performances, including venue capacity, travel, scheduling, and production costs.

Digital characters and augmented-reality installations have, for example, been used to communicate traditional craft processes and connect heritage narratives with physical places (Galani & Vosinakis, 2024). Recent research has also examined the combination of AR/VR storytelling, social media participation, and AI-generated narratives in the communication of Chinese ICH (Liu et al., 2025).

However, performance-and-dissemination applications also raise questions about authenticity and representation. A digital human that merely reproduces a performer's appearance or movements may present a stylised representation without conveying the social relationships, contextual knowledge, and practical judgement involved in transmission. Entertainment-oriented adaptations may also simplify cultural content to attract attention or platform traffic. In addition, the use of a person's likeness, voice, performance data, and other personal or cultural materials requires clear rules concerning consent, rights, and data use (Tiribelli et al., 2024; UNESCO, 2022). Digital performance can therefore support visibility and documentation, but it should not be treated as equivalent to the full process of living transmission.

2.2. Craft-Skill Replication

Craft-skill replication digital humans are intended to record and reproduce techniques, movements, and procedural knowledge, particularly where the number of practitioners is small or a practice is considered vulnerable. Three-dimensional reconstruction and motion-capture technologies can record the movements and sequences involved in traditional crafts, martial arts, and performing arts. These records may serve as digital documentation, learning resources, or reference materials for future practitioners. Recent research reviews identify digital documentation and restoration as important stages in the safeguarding of ICH (Fu et al., 2025; Wei et al., 2026).

Nevertheless, the ability to reproduce visible movements does not necessarily mean that a digital system can transmit the knowledge and judgement acquired through long-term practice. A recording may capture the external form of a technique without fully representing the tactile experience, situational adaptation, aesthetic judgement, or cultural meanings communicated through interaction between practitioners and learners. If digital instruction were to replace rather than complement face-to-face teaching, learners could become proficient at imitating visible actions while remaining unfamiliar with the knowledge and values that inform them. Digital replication should therefore be understood as a supplementary documentation and learning resource, not as a substitute for the embodied transmission of skills (Alivizatou, 2012; Tan et al., 2026).

2.3. Educational Assistance

Educational-assistance digital humans are designed to answer questions and introduce basic knowledge about ICH. They may provide explanations of historical background, terminology, tools, techniques, and related cultural practices. By drawing on curated knowledge bases and large language models, they can support online learning, virtual exhibitions, and introductory educational activities. Research on social-media-based cultural heritage communication suggests that functional, sensory, interactive, and contextual experiences can shape how audiences understand and engage with heritage content (Zhang & Xu, 2024). Studies of digital ICH adoption also indicate that perceived usefulness and the quality of the digital experience are relevant to users' acceptance (Ye et al., 2025).

Educational-assistance digital humans should not, however, be treated as replacements for practical training or direct interaction with heritage bearers. Inaccurate source material, algorithmic bias, or generated responses that lack reliable grounding may distort the interpretation of ICH knowledge. Online explanations can also encourage fragmented learning if they are not connected to practical activities and contextual understanding (Figure 1). The key issue is therefore how to define the appropriate role of digital tools while preserving opportunities for hands-on practice and interpersonal transmission (Foka & Griffin, 2024; Fu et al., 2025; UNESCO, 2022).

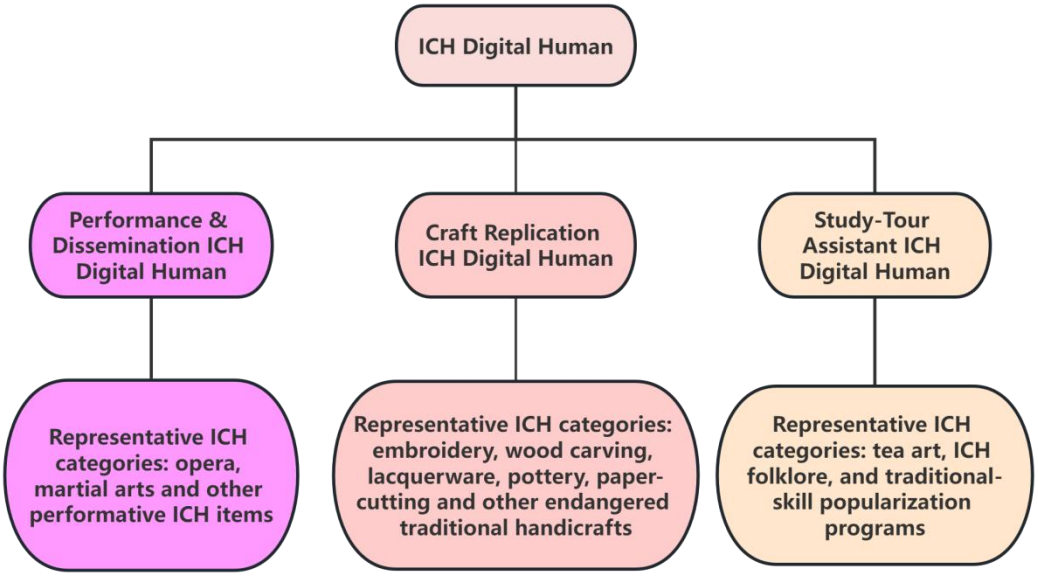


Figure 1. Overview of the Three Types of ICH Digital Humans

3. From Living Inheritance to Digital Alienation: Multiple Areas of Tension

Living transmission refers to the ongoing process through which ICH knowledge, skills, and cultural meanings are passed on and recreated through practice, interaction, and participation. It is rooted in the social and geographical contexts where heritage is practised and is connected to everyday life rather than being confined to museums or exhibition spaces. UNESCO's definition emphasises that ICH is continually recreated by communities in response to their environment and history (UNESCO, 2003). Heritage scholarship similarly treats heritage as a cultural process through which meanings are produced and negotiated, rather than as a fixed object that can simply be preserved (Kirshenblatt-Gimblett, 2004; Smith, 2006). The use of digital humans may support this process, but it may also create tensions when technological reproduction is treated as equivalent to living transmission.

The first tension concerns the difficulty of reproducing the tacit and individualised dimensions of traditional practice. In apprenticeship-based transmission, a practitioner does not merely demonstrate a sequence of actions; the learner also observes, asks questions, receives feedback, and gradually develops personal judgement through repeated practice. The style and expertise of individual bearers are shaped by experience and local traditions and cannot always be captured through standardised data collection. A rigid digital reproduction process may therefore freeze a

particular version of a practice and limit the scope for adaptation and innovation. This risk is especially relevant to crafts and performing arts in which individual interpretation and embodied experience are central (Alivizatou, 2012; Smith, 2006; Tan et al., 2026).

The second tension concerns the relationship between heritage practices and the places in which they are embedded. ICH is often closely connected to local environments, customs, materials, and community relationships. Digital exhibitions and virtual environments can make heritage more accessible, but standardised presentation formats may flatten regional differences and detach practices from the settings that give them meaning. Participatory approaches to heritage media emphasise the importance of place, community interpretation, and everyday practices in shaping cultural meaning (Giaccardi, 2012; Kirshenblatt-Gimblett, 2004). Digital presentation should therefore retain contextual information and make the relationship between a practice and its place visible.

The third tension concerns the unequal visibility that may arise from platform algorithms and commercial incentives. Recommendation systems and market-oriented production may concentrate attention on highly visible heritage items that are easy to package and present, while less familiar, locally specific, or commercially unattractive practices receive less exposure. This possibility is related to broader concerns about representational bias in AI systems and the influence of user-generated content and platform-mediated visibility on heritage communication (Foka & Griffin, 2024; Hua et al., 2024; Tiribelli et al., 2024). If digital promotion consistently favours a narrow set of highly marketable examples, it may reproduce rather than reduce inequalities in the visibility of different ICH practices.

4. Empirical Analysis of Ethical Dilemmas in the Use of ICH Digital Humans

The growing use of digital technologies in ICH safeguarding creates opportunities for documentation, communication, and education. At the same time, the implications of these applications for cultural authenticity, the role of heritage bearers, public understanding, and digital ethics require empirical examination. This section reports the results of a questionnaire survey designed to explore public perceptions of ICH digital humans and the ethical issues associated with their use.

The questionnaire covered five dimensions. The first collected respondents' demographic characteristics, including age, educational background, and occupation. The second examined perceptions of the current state of ICH transmission, including perceived challenges and the need for revitalisation. The third assessed awareness of and experience with ICH digital humans, including information channels and perceived advantages and suitable application scenarios. The fourth examined digital-ethics concerns, including cultural distortion, data privacy, copyright ownership, human substitution, and commercial imbalance. The fifth addressed development and governance preferences, including content supervision, copyright protection, and the provision of public-interest platforms.

The questionnaire was developed with reference to the study's objectives and the relevant literature. It included single-choice, multiple-choice, and open-ended questions. For the purposes

of this study, an ICH digital human refers to a virtual human representation developed or operated using technologies such as motion capture, AIGC, and large language models, with functions that may include performance and dissemination, skill replication, and educational assistance. Digital alienation refers to the risk that algorithms, commercial interests, or cognitive biases may distort the authenticity and transmission priorities of ICH, weaken the role of heritage bearers, or produce divergent public value judgements. Participation was voluntary, and the questionnaire was open to respondents of different ages, including those under 18. Responses with unusually short completion times, identical answers across all items, or internal inconsistencies were excluded. Data were collected from May 10 to June 10, 2026, through an online questionnaire platform and social communities, as well as offline at cultural centres, campuses, and cultural-tourism venues. A total of 552 questionnaires were distributed and 540 were returned. After the exclusion of invalid responses, 521 valid questionnaires remained. Descriptive statistics were produced using SPSS. Three key questionnaire items were selected for cross-tabulation and visualisation. Because the response options represented nominal categories rather than ordered levels, cross-tabulation was used to describe the distributions rather than to infer causal relationships.

Table 1. Demographic Characteristics of Respondents (N = 521)

Variable	Category	Frequency	Percentage (%)
Age	Under 18	97	18.62
	18–25	124	23.80
	26–40	129	24.76
	41–60	93	17.85
	Over 60	78	14.97
Education	Below bachelor's degree	188	36.08
	Bachelor's degree	282	54.13
	Postgraduate degree or above	51	9.79
Occupation	Student	193	37.04
	Public-institution employee	55	10.56
	Private-sector employee	96	18.43
	Freelancer	43	8.25
	Educator	27	5.18
	Unemployed	28	5.37
	Other	79	15.16

The sample included respondents from several age, educational, and occupational groups. As shown in Table 1, respondents with a bachelor's degree accounted for 54.13% of the sample, while students represented 37.04% of respondents. The age distribution covered five groups, from under 18 to over 60. These characteristics allow the study to compare descriptive patterns across demographic categories. The questionnaire was distributed through a combination of online and offline channels to reach respondents with different backgrounds and levels of contact with ICH. The resulting responses provide primary evidence for describing public perceptions and identifying issues that may inform further research and governance discussions.

4.1. Public Awareness of ICH Digital Humans

Figure 2 presents respondents' familiarity with ICH across age groups. The distribution indicates differences in reported familiarity and engagement. Respondents in the under-18 and 18–25 groups were more likely to report limited familiarity, such as having heard of ICH without actively learning about or practising it. The 26–40 group showed a relatively higher level of deeper engagement, while respondents over 60 reported comparatively limited exposure to digital ICH content.

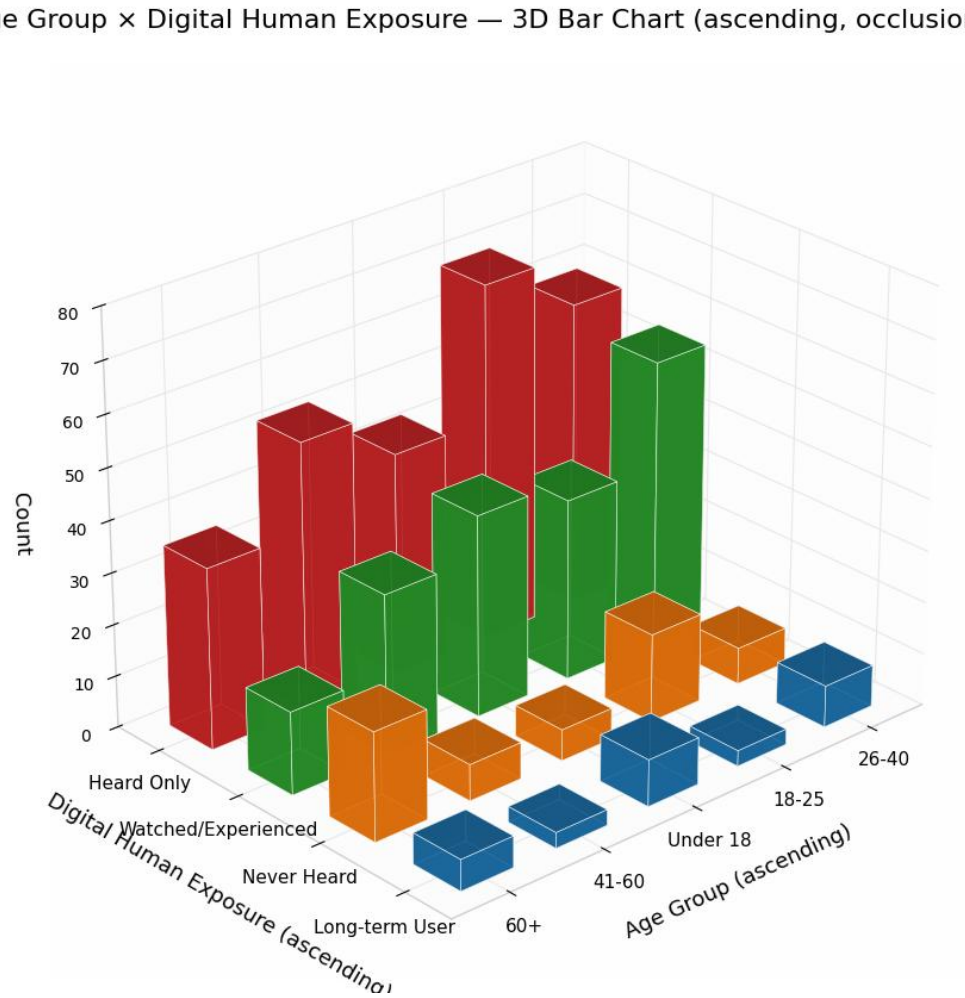


Figure 2. Age Group and Familiarity with ICH Digital Humans

Overall, many respondents remained at a relatively superficial level of familiarity, while the proportion reporting active learning or participation was smaller. The descriptive patterns suggest that younger respondents may encounter ICH more often through online media, whereas middle-

aged and older respondents may have fewer opportunities to access digital information about it. These patterns should be interpreted as differences in reported exposure rather than as evidence of fixed generational characteristics.

These age-related patterns may reflect differences in media habits, access to information, and opportunities for participation. Short-form digital content can introduce younger audiences to heritage practices, but exposure does not necessarily lead to an understanding of their historical, social, and regional contexts. Research on social-media-based heritage communication highlights the importance of combining accessible presentation with contextual, sensory, and interactive experiences (Liu et al., 2025; Zhang & Xu, 2024). Digital communication should therefore seek not only to attract attention but also to provide pathways from initial exposure to sustained learning and participation.

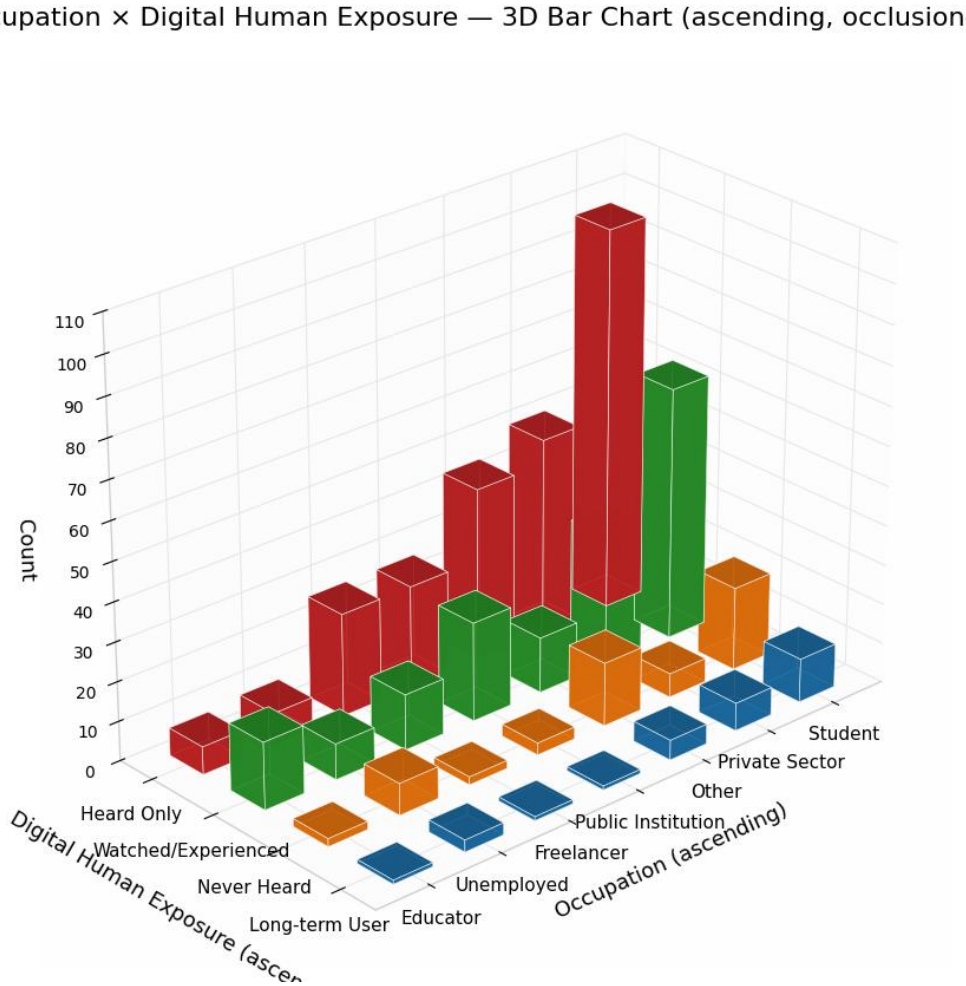


Figure 3. Occupational Group and Familiarity with ICH Digital Humans

Figure 3 compares familiarity with ICH digital humans across occupational groups. The descriptive distribution suggests that students rely relatively heavily on online platforms for information about ICH, while public-institution employees and educators show a comparatively higher level of deeper engagement. Private-sector employees, freelancers, and some other occupational groups report lower levels of sustained engagement. These differences may reflect variations in information access and opportunities for participation, although the cross-tabulation does not establish the reasons for those differences. Research on digital participation in heritage

management similarly emphasises the importance of access, digital literacy, and opportunities for meaningful engagement (Zhang et al., 2024; Ye et al., 2025).

Figure 4 examines how respondents with different levels of ICH familiarity evaluate the advantages of digital humans. Respondents with lower levels of familiarity place relatively greater emphasis on convenience and the potential to attract younger audiences. Respondents who are more familiar with ICH or actively engaged in its practice place greater emphasis on functions such as the detailed recording of techniques and the preservation of heritage-related resources. The overall pattern suggests that respondents recognise the communication value of digital technologies, while those with greater experience of ICH may pay closer attention to their documentation and safeguarding functions.

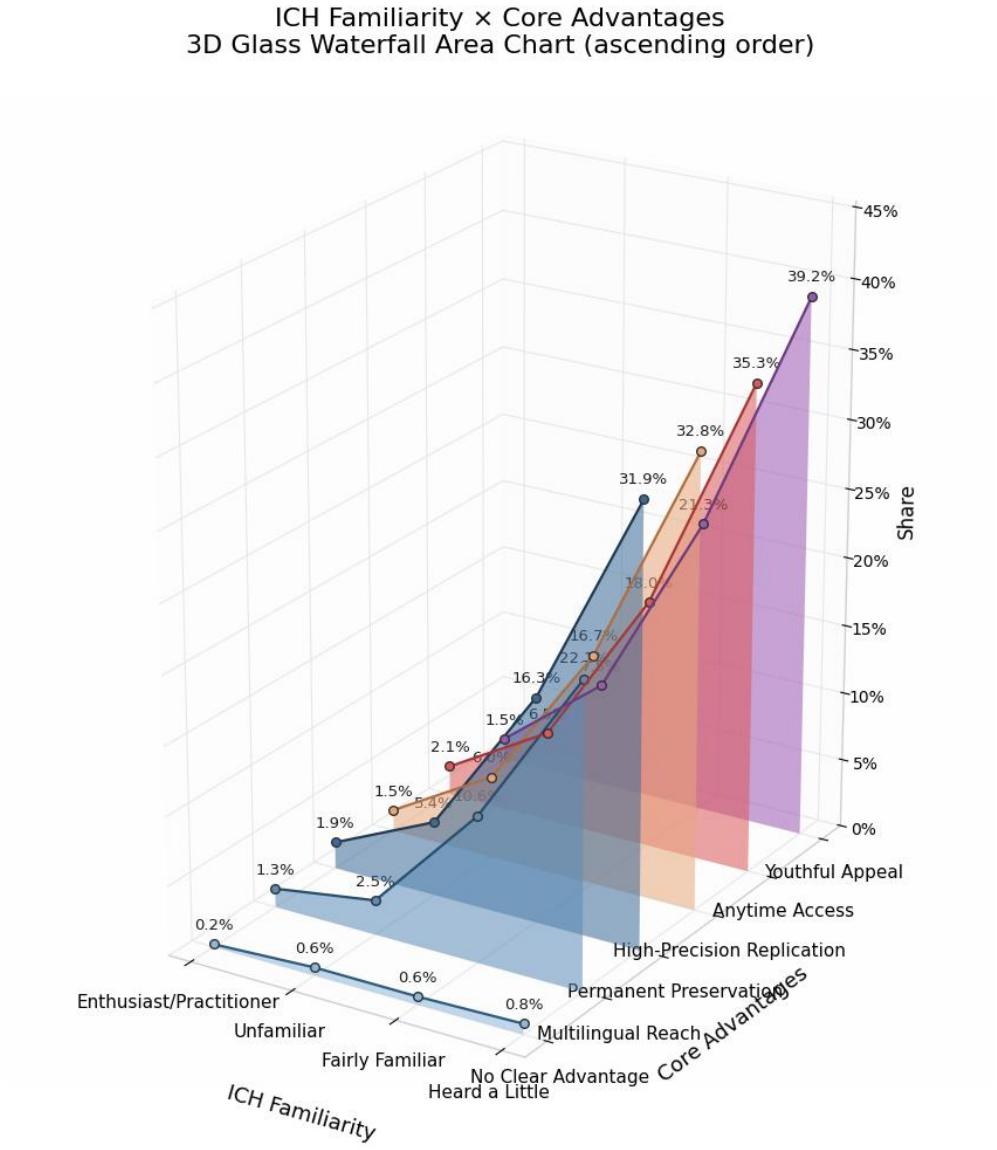


Figure 4. ICH Familiarity and Perceived Advantages of Digital Humans

This pattern points to a potential tension between accessibility and authenticity. Digital communication can reduce barriers to initial exposure, but convenient access and visually convincing reproduction do not necessarily provide the contextual knowledge or practical

experience required for deeper understanding. The design of ICH digital humans should therefore consider both communication effectiveness and the needs of heritage bearers and practitioners.

4.2. Perceived Conflicts Between Living Inheritance and Digital Alienation

Figure 5 compares respondents' recognition of the relationship between digital humans and living transmission with their perceptions of related ethical risks. The distribution indicates that respondents who were partially supportive or neutral often expressed concerns about issues such as cultural distortion. Those who were less supportive reported fewer concerns in absolute terms, which may partly reflect differences in their level of engagement with the topic. The pattern suggests that acceptance of digital technologies and awareness of their potential risks are not necessarily opposites. Public attitudes should therefore not be reduced to a simple division between support and opposition. Some respondents appear willing to accept the convenience of new technologies while remaining alert to risks involving cultural misrepresentation, commercial intervention, and the weakening of heritage bearers' roles. Such concerns are consistent with wider discussions of AI ethics in cultural heritage, particularly the need to address bias, transparency, and human oversight (Foka & Griffin, 2024; Tiribelli et al., 2024).

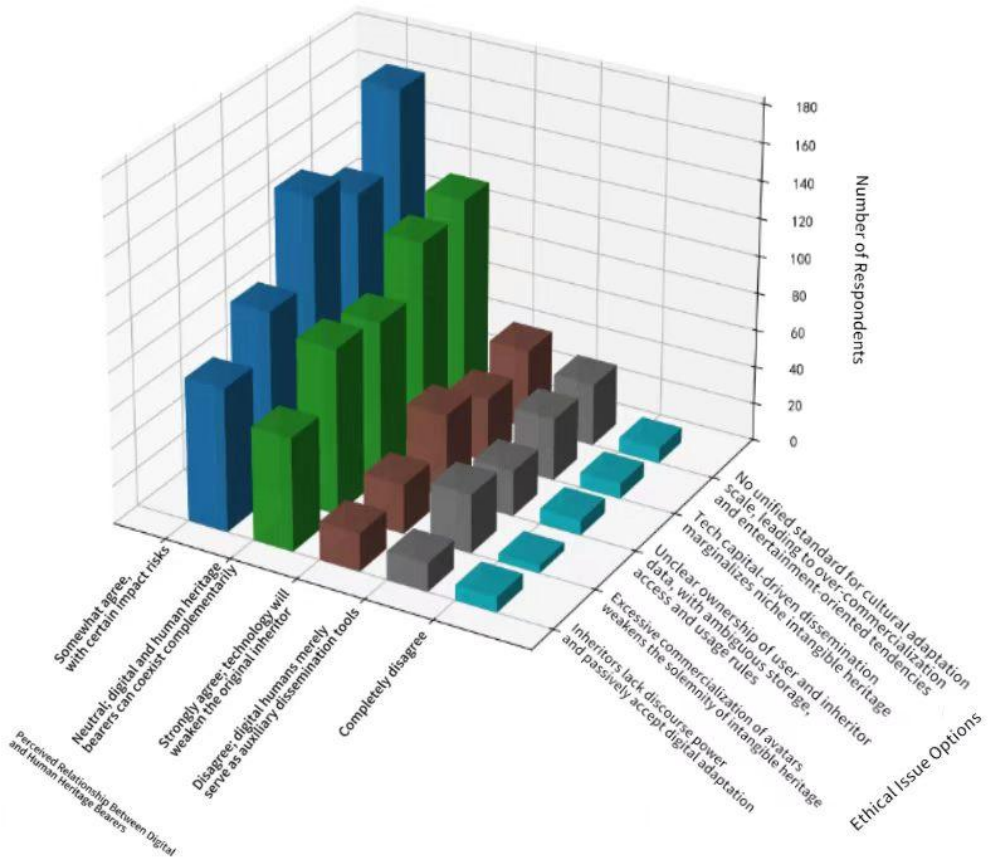


Figure 5. Perceived Ethical Risks by Attitudes Toward ICH Digital Humans

Figure 6 examines occupational differences in concerns about entertainment-oriented adaptations of ICH digital humans. Among the occupational categories in the questionnaire, student respondents showed the strongest concern, followed by freelancers. Private-sector employees and

public-institution employees expressed comparatively lower levels of concern, while educators' responses were more mixed. Respondents in the 'other' category were more likely to select neutral or less-concerned options. These are descriptive differences in the survey sample and should not be interpreted as evidence that occupation itself causes particular attitudes.

The results highlight a possible tension between market-oriented communication and the practice-based logic of living transmission. When digital content is designed primarily to maximise traffic, highly visible and easily packaged forms of heritage may receive more attention than practices that require longer explanations or sustained participation. Research on user-generated content and AI-mediated heritage representation has also raised questions about how platform visibility, authenticity, and representational bias shape public engagement (Foka & Griffin, 2024; Hua et al., 2024).

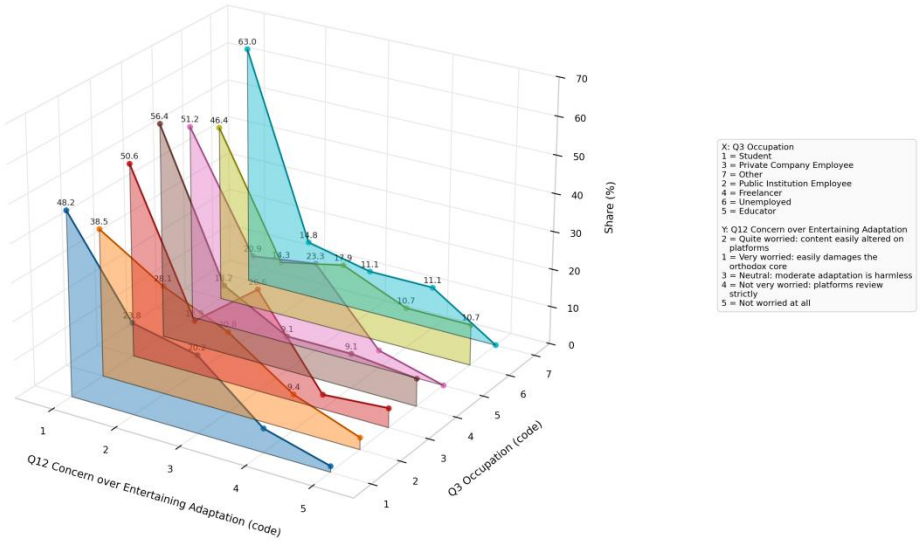


Figure 6. Concerns About Entertainment-Oriented Adaptation by Occupational Group

Figure 7 presents differences across educational groups in perceptions of whether digital humans may weaken the value of living transmission. Respondents at all educational levels recognised that digital technologies could affect existing transmission practices. Responses among those with higher educational attainment were more varied, while respondents with lower educational attainment appeared more likely to select options indicating concern about technological impact. The distribution suggests differences in how respondents evaluate the relationship between digital tools and traditional transmission.

Educational background may be associated with differences in how respondents interpret the opportunities and risks of digital inheritance. However, the cross-tabulation is descriptive and does not demonstrate that educational attainment causes a particular attitude. Nor does it establish that one group has a more accurate understanding than another. Research on youth participation and digital ICH adoption highlights the relevance of digital literacy, prior experience, and opportunities for participation when interpreting public responses (Ye et al., 2025; Zhang et al., 2024).

The findings do not support a simple conclusion that digital technology inevitably causes cultural alienation. Rather, they point to concerns about how technology is selected, designed, and applied.

Standardised reproduction, insufficient community participation, and the displacement of offline practice may create risks when digital tools are used without appropriate safeguards. A complementary relationship between digital media and face-to-face transmission is therefore important for preserving the conditions under which ICH remains a living practice.

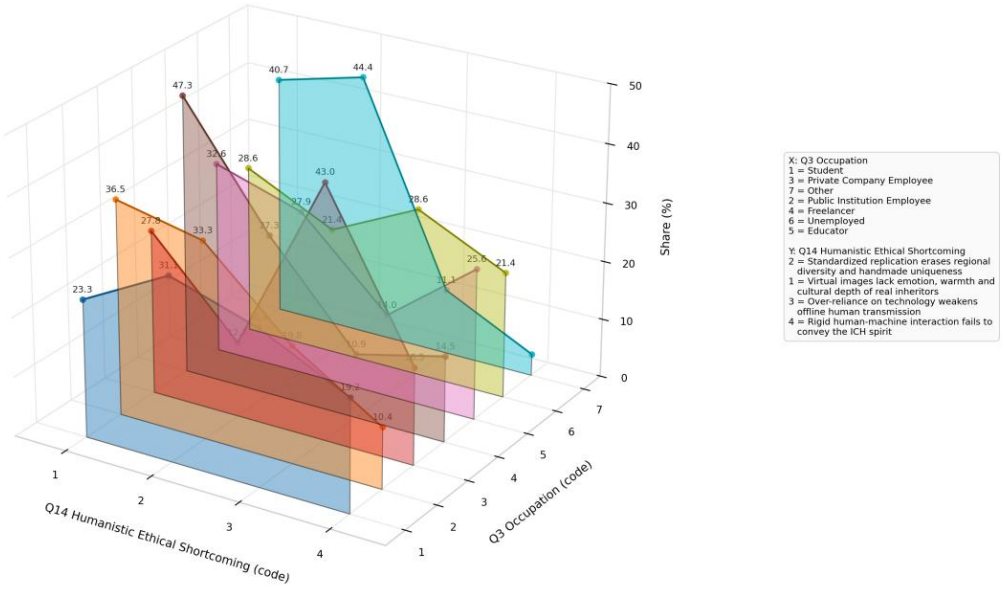


Figure 7. Perceived Impact of Digital Humans on Living Transmission by Educational Group

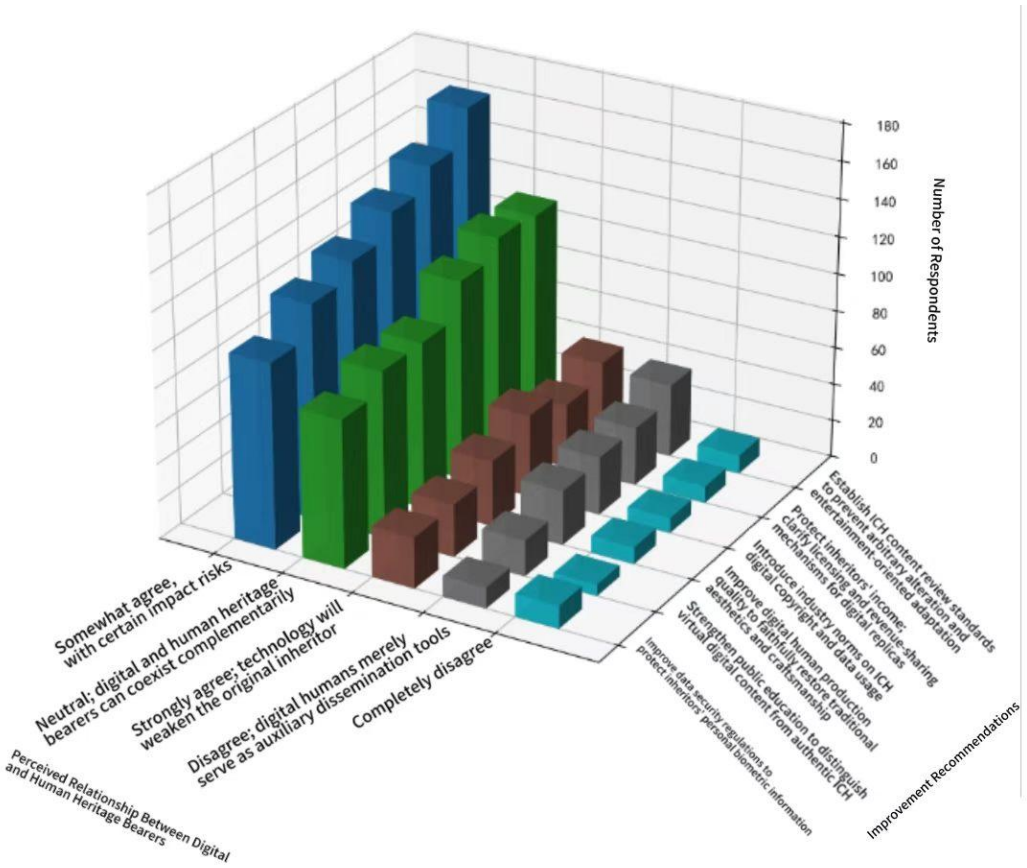


Figure 8. Attitudes Toward Digital-Human Inheritance and Preferred Improvement Measures

Figure 8 examines respondents' preferences for improving the governance of ICH digital humans. Across the attitude groups, respondents showed interest in measures such as content-review standards, protection of heritage bearers' rights and income, and clearer rules for digital copyright and data use. Support for these measures was particularly visible among respondents who were partially supportive or neutral. Complete opposition to the use of digital humans was less common in the sample.

These responses suggest that public concerns are not limited to whether digital humans should be used; they also concern the conditions under which such systems should operate. Governance measures involving consent, transparency, rights protection, and human oversight are consistent with UNESCO's ethical principles for ICH safeguarding and its Recommendation on the Ethics of Artificial Intelligence (UNESCO, 2015, 2022). Recent research on AI and ICH likewise emphasises the importance of community participation and responsible data governance (Fu et al., 2025; Tan et al., 2026).

4.3. Public Expectations for the Development of ICH Digital Humans

Figure 9 compares expectations about the future development of ICH digital humans across age groups. Overall, respondents tended to expect some further development while favouring an assistive role for digital humans rather than complete replacement of face-to-face transmission. Respondents under 18 expressed the most optimistic expectations. Those aged 18–25 were also generally positive but appeared more supportive of an auxiliary role. More than 30% of respondents in the 26–40 and 41–60 groups were optimistic about further development, while respondents over 60 expressed more cautious expectations.

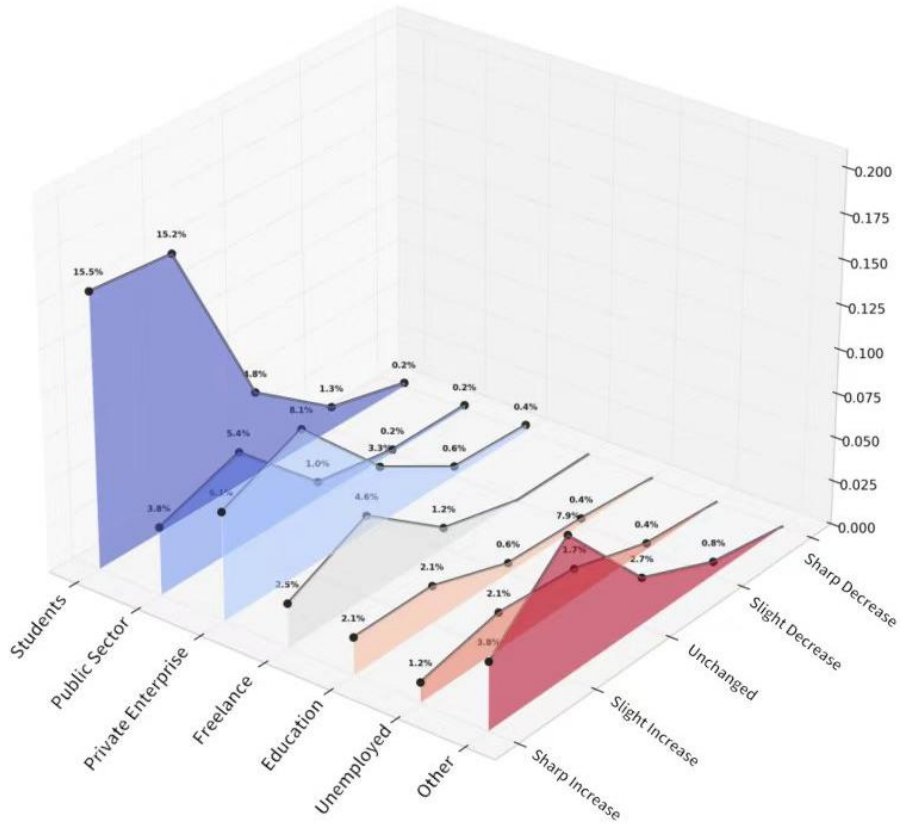


Figure 9. Expectations About the Development of ICH Digital Humans by Age Group

The results indicate differences in expectations across age groups, but they also point to a shared concern about the relationship between technological assistance and human-led transmission. Respondents generally recognised the potential of digital tools while expressing reservations about replacing heritage bearers and practical learning. This position accords with recent research showing that the adoption of digital ICH experiences depends on users' perceptions of usefulness and experience, while safeguarding requires continued attention to authenticity and community involvement (Ye et al., 2025; Tan et al., 2026).

5. Key Challenges: Digital Alienation and the Preservation of Living Heritage

5.1. Stratified Value Perceptions and the Social Differentiation of Digital Inheritance

The survey indicates that respondents' age, educational background, and occupation are associated with differences in how they evaluate ICH digital humans. These differences may contribute to divergent public judgements about the value and risks of digital inheritance. They should, however, be understood as patterns in the surveyed sample rather than as evidence that demographic characteristics directly cause particular perceptions. Research on digital ICH adoption and youth participation similarly identifies prior experience, digital literacy, and opportunities for engagement as relevant factors in shaping responses (Ye et al., 2025; Zhang et al., 2024).

Across age groups, younger respondents expressed relatively strong concern about risks such as cultural distortion and entertainment-oriented adaptation. Older respondents reported lower levels of familiarity with digital ICH content and may have had fewer opportunities to encounter or evaluate these applications. These findings suggest that public education should address both the opportunities and limitations of digital technologies, rather than assuming that greater concern necessarily indicates opposition or that lower concern indicates acceptance.

Educational differences were also visible in the response distributions. Respondents with lower educational attainment appeared more likely to express concerns in a less differentiated way, whereas respondents with higher educational attainment displayed a wider range of views. These patterns should not be interpreted as a ranking of groups' cognitive abilities. Instead, they indicate that information access, prior knowledge, and familiarity with digital technologies may shape how people evaluate the risks and benefits of ICH digital humans.

Age and educational background may overlap, but the present cross-tabulations do not isolate their independent effects. Further research using multivariate analysis would be needed to examine these relationships more rigorously. More broadly, limited public understanding of ICH and digital technologies may make it difficult to distinguish between appropriate digital support and forms of intervention that undermine cultural context, authenticity, or the role of heritage bearers.

5.2. Cognitive Bias: Fragmented Communication and Shallow Understanding of ICH

ICH is rooted in local environments, practitioners' skills and personal styles, and forms of transmission such as apprenticeship and oral instruction. These characteristics make ICH a dynamic cultural process rather than a fixed body of information. Digital media can extend its reach and create opportunities for participation, but the communication format may also favour short, visually

engaging, and easily shareable content. Research on participatory heritage media and digital reading highlights the importance of connecting online content with social practice, embodied experience, and contextual understanding (Giaccardi, 2012; Zhang & Xu, 2024).

Online presentation may separate heritage practices from the places, materials, relationships, and routines through which they acquire meaning. When digital content provides only a simplified account of a practice, audiences may recognise its name or appearance without understanding its history or cultural context. Digital communication can therefore increase the breadth of exposure without necessarily increasing the depth of understanding. This concern reinforces the need to connect digital presentation with local knowledge and community participation (Kirshenblatt-Gimblett, 2004; Liu et al., 2025; Smith, 2006).

5.3. Instrumental Value and the Boundaries of Digital Intervention

Standardised reproduction and template-based content generation may make ICH digital humans easier to develop and deploy, but they can also reduce the visibility of regional differences and individual practitioners' styles. Digital systems may struggle to represent tacit knowledge, context-dependent judgement, and the cultural meanings embedded in practice. These risks are not inevitable consequences of digitisation; they depend on data selection, system design, governance, and the extent to which heritage bearers participate in the process (Foka & Griffin, 2024; Fu et al., 2025; Wei et al., 2026).

One major concern identified in the survey is over-reliance on technology at the expense of face-to-face transmission. Respondents generally regarded digital humans as tools that can assist communication and learning, rather than as substitutes for human practitioners. The appropriate role of digital humans is therefore instrumental: they may support documentation, explanation, and access, but should not displace apprenticeship, practical training, or the authority of the communities that sustain ICH. This distinction is consistent with the people-centred principles of ICH safeguarding (UNESCO, 2003, 2015, 2024).

The survey suggests that many respondents accept the convenience of digital communication while remaining concerned about whether standardised reproduction can capture the experience and style of heritage bearers. Respondents also expressed concern about entertainment-oriented adaptations and the potential weakening of cultural content. The group with relatively high risk awareness was not necessarily the group most opposed to digital humans; some respondents who were partly supportive or neutral also expressed strong concerns about copyright, commercial intervention, and content review. These findings are consistent with broader discussions of AI ethics and digital ICH adoption (Tiribelli et al., 2024; Ye et al., 2025).

Taken together, the findings suggest that the central issue is not the existence of digital-human technology itself, but the boundaries and conditions governing its application. Without clear standards, community involvement, and appropriate oversight, digital tools may reproduce cultural biases or encourage forms of presentation that prioritise visibility over meaningful transmission.

6. Pathways to Mitigation: Toward Human–Machine Collaboration

6.1. Safeguarding Authenticity and the Cultural Core

Respondents' concerns focused on the possible homogenisation of content, the loss of regional characteristics, and the weakening of interpersonal transmission. They also recognised that current digital systems may provide limited interaction and may not fully reproduce the practical details or contextual knowledge involved in ICH. Recent reviews emphasise that digital safeguarding is most effective when technical methods are aligned with community participation and the needs of heritage bearers (Ren & Lam, 2026; Tan et al., 2026).

A first step is to establish differentiated documentation and reproduction standards for different ICH categories. Rather than relying on a single template, project teams should identify the specific skills, materials, regional characteristics, and cultural meanings associated with each practice. Digital models should be designed around the requirements of the relevant heritage domain and should make clear which aspects have been recorded, interpreted, or reconstructed. Such an approach can help preserve diversity and reduce the risk that standardised formats will obscure the distinctive features of individual practices (Ren & Lam, 2026; Wei et al., 2026).

Heritage bearers and relevant communities should participate throughout the process of data collection, content design, model development, review, and subsequent use. Their involvement is important for identifying technically accurate representations, explaining tacit knowledge and cultural protocols, and determining which materials may be shared publicly. Collaboration with researchers, educators, and technical specialists can further improve the quality of digital representations. This approach is consistent with the participatory principles of the 2003 Convention and UNESCO's ethical guidance for ICH safeguarding (UNESCO, 2003, 2015; Tan et al., 2026).

6.2. Reconstructing a Symbiotic System and Defining Application Boundaries

The respective roles of digital humans and heritage bearers should be clearly defined. Heritage bearers and communities should remain the primary agents of living transmission, while digital humans should serve as supplementary tools for documentation, communication, and learning. This human-centred model can combine the accessibility of digital technologies with the practical and social dimensions of face-to-face transmission. Digital systems should not be presented as autonomous or equivalent replacements for practitioners, particularly in contexts where knowledge depends on embodied skill, judgement, and community recognition (UNESCO, 2003, 2015; Tan et al., 2026).

Governments, cultural institutions, and platforms should establish transparent procedures for reviewing ICH-related digital content and supervising commercial applications. These procedures should address the provenance and permitted use of training data, informed consent, the use of likenesses and voices, copyright and related rights, attribution, revenue sharing where appropriate, and mechanisms for correcting inaccurate or culturally inappropriate content. AI governance frameworks emphasise transparency, accountability, human oversight, and the protection of human rights (UNESCO, 2022, 2024). Research on AI in cultural heritage also stresses the need to integrate ethical review into the design and deployment process (Fu et al., 2025; Tiribelli et al., 2024).

Public institutions, technology providers, and cultural enterprises should balance cultural safeguarding with the development of sustainable digital services. Commercial applications may contribute resources and expand public access, but commercial objectives should not override the cultural priorities identified by heritage bearers and communities. Platforms should provide channels for feedback and correction, while project operators should explain how digital content is produced and used. These measures can help reduce the risk that traffic-oriented production and commercial imbalance will distort the cultural meanings of ICH.

6.3. Providing Targeted Guidance to Address Cognitive Gaps

The survey indicates that familiarity with ICH digital humans and perceptions of their ethical implications vary across respondents. Public education should therefore be differentiated rather than delivered through a single communication approach. The aim should be to improve understanding of both ICH safeguarding and the capabilities and limitations of digital technologies, while avoiding the assumption that greater acceptance is always preferable.

For audiences with limited prior knowledge, introductory materials can explain what ICH is, why living transmission matters, and how digital tools can support documentation and access. These materials should use clear language and concrete examples while distinguishing between recorded information, expert interpretation, and AI-generated content. For audiences with greater prior knowledge, discussion forums and educational resources can support more detailed consideration of authenticity, data governance, copyright, and the role of heritage bearers. UNESCO's AI ethics recommendation highlights the importance of education, transparency, and human oversight in the responsible use of AI (UNESCO, 2022; Zhang et al., 2024).

Communication strategies should also take account of differences in age and media use. Younger audiences can be encouraged to move from short-form exposure to sustained learning and practical participation. Older audiences may benefit from accessible explanations of digital platforms, AI-generated content, and the ethical issues associated with digital reproduction. The aim is not to eliminate all differences in perception, but to improve the public's capacity to evaluate both the benefits and risks of digital transmission (Hua et al., 2024; Ye et al., 2025).

At the societal level, inclusive ICH education should be supported through schools, cultural institutions, community organisations, and public-interest digital platforms. Such initiatives should strengthen public understanding of ICH and provide opportunities for communities and practitioners to explain their own traditions. Public education should also communicate the principles of consent, attribution, cultural respect, and responsible data use. These priorities are consistent with UNESCO's ethical principles for safeguarding ICH and with recent research on community-engaged digital safeguarding (Tan et al., 2026; UNESCO, 2015).

7. Conclusion

Digital technologies provide new channels for documenting, presenting, and communicating ICH. ICH digital humans may help address practical challenges such as limited access to heritage content, constrained performance settings, and the difficulty of preserving records of endangered

skills. They can therefore make a useful contribution to the communication and documentation of living heritage. However, the logic of digital reproduction does not fully correspond to the people-centred, practice-based logic of living transmission. The use of digital humans consequently raises questions about cultural authenticity, the role of heritage bearers, and the conditions under which digital tools should be deployed.

Drawing on questionnaire responses from 521 participants, this study identifies three interrelated dimensions of potential digital alienation: the distortion of cultural content and authenticity through standardised reproduction; structural imbalance in transmission associated with technological and commercial pressures; and differences in public value judgements across demographic and cognitive groups. The findings also suggest that many respondents recognise the usefulness of digital humans while preferring an auxiliary rather than substitutive role for these systems. Concerns about cultural distortion and governance are therefore not confined to respondents who reject digital technologies outright. Digital alienation should not be understood as an inevitable outcome of technological development. It is better understood as a risk that may emerge when technology is applied without sufficient attention to cultural context, community participation, and appropriate governance. The central role of people in living transmission remains essential. The embodied knowledge, practical judgement, and human relationships developed through oral instruction and interpersonal practice cannot be fully replaced by digital reproduction.

To support the responsible development of ICH digital humans, this study proposes three pathways: establishing differentiated documentation and reproduction standards; ensuring the meaningful participation of heritage bearers and communities throughout the development and use of digital content; and clarifying the supplementary role of digital humans through content review and oversight of commercial applications. Targeted public education can also help address differences in familiarity and risk perception. Together, these measures can support a more balanced relationship between technological innovation and living transmission. Digitising ICH is not simply a matter of storing cultural materials in digital form, and the use of digital humans does not necessarily entail cultural distortion. Digital humans can support documentation, communication, and introductory education, but they should not replace the practitioners and communities that sustain ICH. By balancing the practical benefits of digital technologies with cultural authenticity, community participation, and responsible governance, digital innovation can contribute to the continued vitality of ICH.

Author Contributions:

Conceptualization, Ruimin Wang; methodology, Zixuan Huang, Ruimin Wang, and Wenxuan Jing; investigation, Zixuan Huang; resources, Ruimin Wang; data curation, Zixuan Huang, Ruimin Wang, and Wenxuan Jing; writing—original draft preparation, Zixuan Huang, Ruimin Wang, and Wenxuan Jing; writing—review and editing, Zixuan Huang, Ruimin Wang, and Wenxuan Jing; visualization, Zixuan Huang, Ruimin Wang, and Wenxuan Jing; supervision, Ruimin Wang; funding acquisition, Ruimin Wang. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement:

The study was reviewed and approved by the Ethics Committee of Beijing City University. All research procedures involving human participants, including questionnaire design, participant recruitment, data collection, and the management of research data, were conducted in accordance with the ethical principles for research involving human participants and the relevant institutional guidelines. Particular attention was paid to protecting participants' rights, privacy, and confidentiality throughout the research process. Participation in the study was entirely voluntary, and appropriate measures were taken to ensure that participants could make informed decisions about their involvement in the research.

Informed Consent Statement:

Informed consent was obtained from all participants prior to their participation in the study. Before completing the questionnaire, participants were informed of the purpose and nature of the research, the voluntary nature of their participation, and the intended use of the collected information. They were also informed of their right to decline participation or withdraw from the study without any adverse consequences. All information collected was used exclusively for academic research purposes and was handled in accordance with the applicable principles of confidentiality and data protection. For participants under the age of 18, informed consent was obtained from their parents or legal guardians, together with the minors' assent, in accordance with the approved research protocol.

Data Availability Statement:

The original contributions presented in this study are included in the article and its supplementary materials. Further inquiries can be directed to the corresponding author.

Conflict of Interest:

The authors declare no conflict of interest.

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Research on the Path of Practice-Based Education for Innovation and Entrepreneurship in Private Universities from the Perspective of the "Grand Ideological and Political Course": A Case Study of the "Daily Bread" Student Team

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Abstract

Implementing the requirements of building the "Grand Ideological and Political Course" is a key lever for private universities to fulfill the fundamental mission of fostering virtue through education. Innovation and entrepreneurship (I&E) education, as a critical component of applied-talent training, faces the practical problem of a disconnect between ideological-political education and professional practice. Grounded in the characteristics of private universities and taking Xi Jinping Economic Thought as the value foundation, this study takes the integrated reform of the professional course "Marketing," in which Xi Jinping Economic Thought is embedded, and the practical-training course "College Student Innovation and Entrepreneurship," as the practical vehicle, and combines the real start-up experience of the "Daily Bread" student team, to explore a three-in-one implementation path of value guidance, training-driven practice, and practice-based transformation. The study shows that relying on the "Grand Ideological and Political" practice field formed by "professional courses + practical training + innovation and entrepreneurship," and guiding students to conduct field investigations in society, offers a feasible way to mitigate the well-documented "two separate skins" phenomenon — the disconnection between ideological-political education and I&E practice, effectively stimulates students' internal motivation, and promotes the transformation of ideological value guidance into I&E practice. The study provides a practical reference for similar private universities to integrate the Grand Ideological and Political Course with innovation and entrepreneurship education.

Keywords: Grand Ideological and Political Course; Practice-Based Education; Innovation and Entrepreneurship; Private Universities

1. Introduction

General Secretary Xi Jinping has emphasized that the "Grand Ideological and Political Course" should be used well and that teaching should be closely integrated with social reality. Private universities aim primarily at cultivating applied talents; in the process of delivering innovation and entrepreneurship education, how to genuinely put ideological and political education into practice is an unavoidable practical issue. In daily teaching, it is not difficult to observe that the I&E classrooms of some universities still remain at the level of theoretical lectures: ideological and political content is simply attached outside the curriculum, while ideological-political education and entrepreneurial practice follow their own separate ways, forming the so-called "two separate skins" phenomenon — a disconnect between ideological-political education and entrepreneurial practice (Bin & Liu, 2026a).

Students in private universities tend to be active thinkers with a strong willingness to take action, but some lack clear plans for their professional study and future development. Ideal and belief education cannot rely on classroom preaching alone; it requires real practical scenarios as support. Integrating Xi Jinping Economic Thought (The Publicity Department of the CPC Central Committee & National Development and Reform Commission, 2022; Zhang, 2022) into I&E course teaching, taking social practice as the practical base of the Grand Ideological and Political Course, and guiding students out of the classroom and into the real market environment can align knowledge transmission with value shaping. Based on the real growth experience of the "Daily Bread" team at the authors' institution, this paper sorts out concrete practices for implementing curriculum-based ideological-political education, and provides a realistic sample for advancing the Grand Ideological and Political Course in the I&E field of private universities.

2. Theoretical Logic: Reconstructing the Curriculum Teaching System Based on "Three-Wide Education"

The core of curriculum-based ideological-political education lies in fostering virtue through education, and its difficulty lies in achieving deep integration of ideological-political content with professional teaching, rather than a simple overlay of content (Bin & Liu, 2026b; Wu, 2026). Considering the learning characteristics of students in private universities, the authors' institution has reformed the professional course "Marketing," integrated Xi Jinping Economic Thought into each teaching unit of the course, and constructed a teaching implementation path under the "three-wide education" (whole-person, whole-process, all-around education) framework (Bin & Liu, 2026b). In this reform, the two courses play complementary roles: "Marketing" is the professional carrier into which ideological-political content is systematically embedded, whereas "College Student Innovation and Entrepreneurship" is the practical-training outlet through which student teams translate classroom learning into real projects; the market-research tasks designed in "Marketing" provide the analytical foundation, while the I&E course provides project incubation, competition, and start-up support.

2.1. Content Integration and Method Innovation: Embedding Student Innovation and Entrepreneurship into Professional Practical Training

In the past, some I&E courses largely copied foreign business theories and cases, which were somewhat distant from the real environment of Chinese college students (Bin & Liu, 2026a). This curriculum reform is grounded in the reality of China's economic development: the core viewpoints of Xi Jinping Economic Thought (The Publicity Department of the CPC Central Committee & National Development and Reform Commission, 2022; Zhang, 2022) are decomposed and mapped to the corresponding teaching chapters of the course, and local realistic cases are used to explain entrepreneurial theory, so that students build an understanding of innovation and entrepreneurship that fits China's national conditions, rather than mechanically applying imported business models (Wu, 2026). For example, "Marketing" sets up two comprehensive practical-training tasks: "Research and Analysis of Entrepreneurial Opportunities in the Local Consumption Market" and "Design and Feasibility Analysis of College Student I&E Projects." The training content is embedded in professional knowledge, and college-student innovation and entrepreneurship is further embedded in the training process, so that the tasks are linked together and achieve a quantitative-to-qualitative improvement. This "professional course + practical training + innovation and entrepreneurship" configuration echoes the industry-education, major-innovation, and ideology-politics integration advocated in recent curriculum reforms (Wang et al., 2026; Zhang et al., 2026) (see Table 1).

Table 1. Integration Framework of the I&E Course Guided by Xi Jinping Economic Thought

Course Chapter	Practical-Training Content	Innovation and Entrepreneurship Practice
Chapter 5: Market Research	Research and analysis of entrepreneurial opportunities in the local consumption market	Design and feasibility analysis of college student I&E projects

2.2. Research Design and Case Selection

This study adopts a qualitative single-case study design. The "Daily Bread" team was selected through purposive sampling: it is a typical, information-rich case in which four students who entered the university with unclear academic and career plans progressed through the integrated "Marketing" + I&E reform and produced observable outcomes across three domains—academic performance, competition awards, and real start-up operation. Data were collected from five sources for triangulation: (1) participant observation by the course instructor (co-author Xin Peng), who taught the "Marketing" and "College Student Innovation and Entrepreneurship" courses and supervised the team throughout the 2025–2026 academic year; (2) semi-structured post-project conversations and reflections with the four team members; (3) project documents, including business plans, weekly sales and supply-chain records, and competition application materials; (4) documentary records, including practical-training assignment submissions, grade records, and chat records of the teacher–student WeChat group; and (5) external evidence, including company

registration documents, competition award certificates, and English-examination score reports. The findings below are organized around the three-wide education framework and are interpreted against this triangulated evidence base.

3. Practice Case: The Transformation and Growth of the "Daily Bread" Team

The "Daily Bread" team consisted of four students from the 2024 Financial Undergraduate Class 1: Zixin Yang, Yipeng Fu, Yipeng Liang, and Hai Pan. At the beginning of their enrollment, the four students had unclear self-positioning and no clear plans for the future. Through sustained curriculum-based ideological-political edification, especially the exercise of practical training, the students gradually built confidence and step by step embarked on the path of innovation and entrepreneurship practice.

3.1. The Turning Point: A Pragmatic Attitude in Practical-Training Assignments Brings a Growth Opportunity

After the practical-training assignment of the autumn 2025 semester was issued, many groups produced patchwork research reports generated by artificial-intelligence tools, lacked field visits, and produced content detached from reality. The "Daily Bread" team did not take the shortcut: the members visited commercial districts and communities around the campus on foot, and completed the data collection and video editing of the research assignment themselves. The process was expected, but the first-hand data were extremely valuable. Through observation, the students discovered a business opportunity and, starting from the innovation research, launched their entrepreneurial practice. In their post-assignment reflection, team members noted that, although the fieldwork was far more time-consuming than compiling an AI-generated report, the first-hand interviews and street observations gave them a concrete feel of local consumer demand that no desk-based search could provide.

3.2. Ideological Elevation: Transforming Theoretical Thought into Action That Solves Real Problems

In the "Daily Bread" practice, the project leader Zixin Yang, applying the market-opportunity analysis methods learned in the course, carefully observed campus consumption scenarios and identified a clear pain point in the supply of bakery products on campus: students who wanted to buy good-quality bread either had to pay high prices or travel long distances. Based on this reality, she tried a campus community group-buying model, connected supply-chain resources, and turned the "Daily Bread" idea from a concept in a research report into a real project, building a complete operating chain of financing, supply, sales, and delivery. This practically solved the real problem of students buying bakery food and practiced the people-centered development philosophy within the small campus scenario; Yang later reflected that reviewing weekly order data in the WeChat group had made the people-centered logic discussed in class feel tangible rather than abstract. As a core member of the project, Yang balanced entrepreneurial practice with academic study, ranking among the top five in her class in the final examination. She also participated in the External Relations Department of the university student union, connected with merchant resources related to the Beijing International Bread Festival, and completed the project's promotion—truly applying

what was learned in the classroom to real practice. Since the launch of "Daily Bread," weekly operating revenue has remained at least 10,000 RMB, which has greatly encouraged the other team members.

In the supply-chain work of the project, Hai Pan, based on the current market situation, avoided the already highly mature tracks and chose to look for opportunities in the gaps between existing business models. In December 2025, he registered the company "Pan Hai Shop." Although the project is small-scale, it achieved sustainable development through continuous iteration of operational concepts and refined operation. Its monthly operating revenue exceeded 10,000 RMB in its first full month of formal operation (January–February 2026) (see Figure 1). This practice shows that contemporary college students do not have to pursue grand goals blindly; making micro-innovations based on realistic conditions can equally inject fresh vitality into the market.

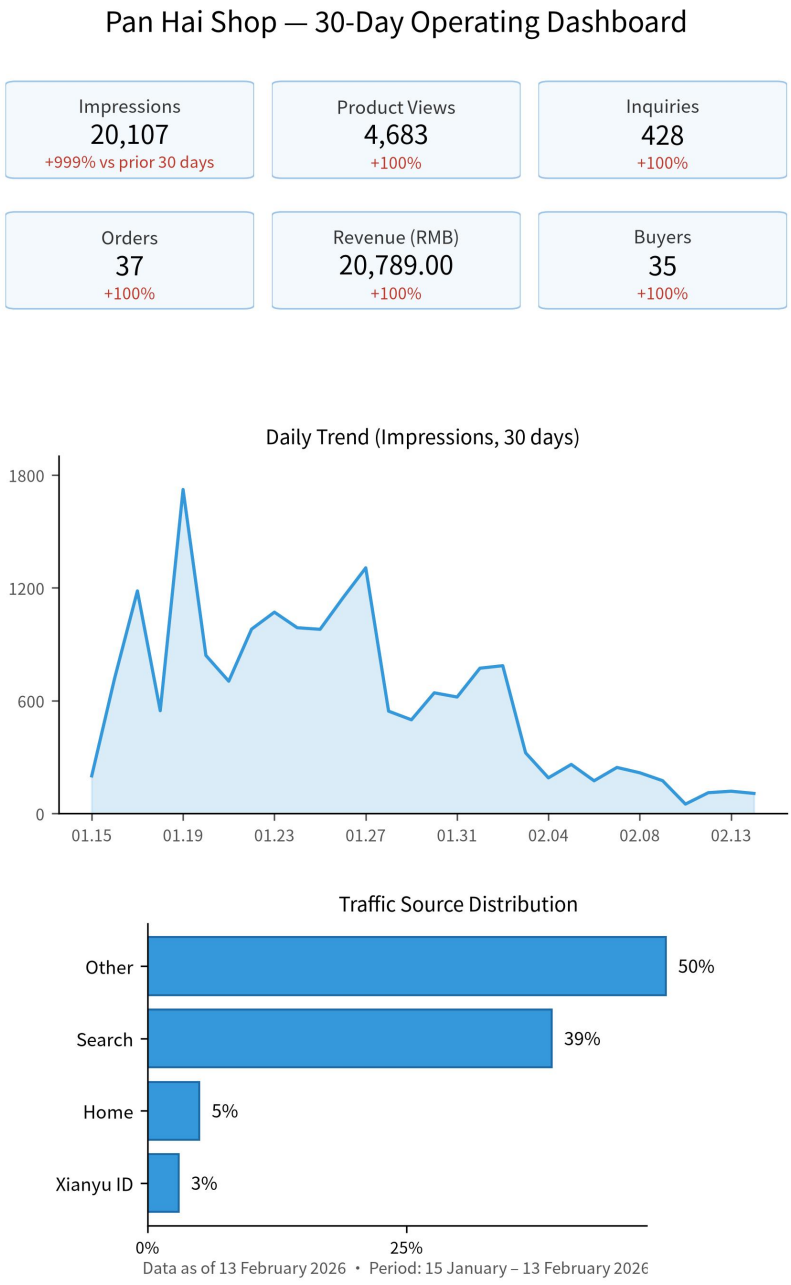


Figure 1. First-Month Operating Data of "Pan Hai Shop" (2026)

3.3. Mutual Growth of Teachers and Students: Two-Way Growth Through Teaching and Learning

In the age of artificial intelligence, teachers are no longer authorities who unilaterally output knowledge; they should become companions and guides for students' ideological growth, fulfilling the educational original intention of "nurturing children to do good"—which is precisely the foothold of the Grand Ideological and Political Course within professional courses. The teacher noticed the personal potential of Yipeng Fu and guided him to plan his personal development using the expectation-management ideas from the entrepreneurship course, encouraging him to improve his comprehensive expression ability. Under sustained guidance, Fu achieved outstanding results in both the CET-4 and IELTS examinations, as documented by his score reports. In addition, he joined a student club to participate in practice and secured a winter internship at the Beijing Branch of China Construction Bank. The changes observed in students further strengthened the teacher's commitment to teaching students in accordance with their aptitude and to developing teaching based on the times.

At the same time, students' real entrepreneurial practice has in turn fed back into classroom teaching. Many of the operating ideas explored by the "Daily Bread" team and "Pan Hai Shop" in practice are not covered in textbooks; these vivid local student cases have been added to the classroom teaching resource library, making I&E course teaching more closely fit the real situation of contemporary college students and truly achieving mutual growth through teaching and learning.

The WeChat group of the "Daily Bread" team has extended the time-space boundary of classroom teaching. The teacher uses the methods of Xi Jinping Economic Thought to analyze the real problems encountered by students in their projects; the steady progress of the students' entrepreneurial projects has also become the most intuitive embodiment of teaching outcomes. The teacher has shifted from simply lecturing knowledge to paying more attention to students' character and ideological shaping; originally confused students have gradually built confidence, and teachers and students have promoted each other, constituting a real educational scene. These chat records, retained throughout the project period, also form part of the documentary evidence analyzed in this study.

3.4. Results: From Course Assignments to Real Competitions and Start-Up Projects

Nurtured by curriculum-based ideological-political education and under the teacher's continuous guidance, the four students were no longer satisfied with completing course assignments; they actively applied the market analysis, consumer insight, and other knowledge learned in the I&E course to real projects.

First, the team formed a group to participate in disciplinary competitions and accumulated practical experience. The team registered for the university's "Yicai Fencheng" Cup Innovation and Entrepreneurship Competition. Hai Pan successfully led team members to win the Second Prize in Beijing in the "2026 iCAN College Student Innovation and Entrepreneurship Competition 'Shangdao Cup' Management Decision-Making Simulation Challenge," and will lead the team to Anhui in October 2026 to participate in the national final.

Second, the team applied for a new Undergraduate Innovation and Entrepreneurship Training Program to refine its business plan. Combining classroom learning with practical-training accumulation, the team has applied for a new Undergraduate Innovation and Entrepreneurship Training Program entitled "Shuijing Jingtu—Beijing Travel AI Companion: One-Click 'Jing' Precision Handling of What to Eat and Play," which is based on the development direction of the digital economy and explores intelligent itinerary-planning services. After several rounds of revision, the project plans to carry out pilot operation in 2026.

Third, the team landed physical projects to achieve the unity of knowledge and action. Drawing on the supply-side structural reform ideas learned in the course, Hai Pan registered a company, transforming the theoretical knowledge about entrepreneurial subjects learned in class into a real market entity that has achieved stable profitability. From a confused freshman at enrollment to an entrepreneurial practitioner with business practice awareness, the growth of "Pan Hai Shop" and the "Daily Bread" team intuitively reflects the actual effect of curriculum-based ideological-political education entering students' minds, hearts, and practice.

4. Lessons: Insights for Building the Grand Ideological and Political Course in Private Universities

The growth practice of the "Daily Bread" team illustrates that the ideological-political education embedded in I&E courses in private universities cannot remain at the level of verbal preaching; a complete educational closed loop from classroom theory to social reality must be built. Because this study is based on a single case at one institution, the lessons below are offered as an illustrative reference for similar private universities rather than as a universally validated model.

First, deeply excavate the ideological-political connotation to solve the question of what students "believe in." Curriculum-based ideological-political education must be persuasive and cannot talk theory in isolation from reality. Combining Xi Jinping Economic Thought with I&E education, conducting teaching based on the reality of the domestic market, and using perceivable real cases around students to explain China's development path clearly can resolve students' ideological and cognitive confusion. Requiring students in practical training to refuse copying online materials, refuse AI ghostwriting, and insist on field research is essentially cultivating students' truth-seeking and pragmatic attitude, which is also the most fundamental background of ideological-political education.

Second, broaden the practice field to solve the question of how students "do it." The Grand Ideological and Political Course advocates opening the doors of education and cannot confine teaching to the classroom (Dong, 2026). Practical-training projects are an important lever that pushes students into social reality to be tempered. Without this practical-training step, there would be no subsequent disciplinary-competition achievements, nor would the "Daily Bread" and "Pan Hai Shop" projects have been born. The assessment requirements of practical training force students out of their comfort zones to participate in practice personally; the sense of achievement gained after practice further mobilizes students' subjective initiative to continue exploring. The survival-in-the-gaps entrepreneurship model of "Pan Hai Shop" also provides a new reference for college

students' employment and entrepreneurship: entrepreneurship does not have to blindly pursue large scale; based on reality and relying on refined services and differentiated positioning, students can equally realize personal value. This pragmatic entrepreneurial concept is precisely the direction that current youth employment and entrepreneurship education should advocate.

Third, extend teachers' educational responsibility to solve the question of whether education has "temperature." The ideological-political education embedded in I&E courses is not only knowledge teaching but also includes emotional communication and guidance. The online communication group of the "Daily Bread" team broke the time-space constraints of the classroom; education extended from classroom teaching and problem-solving to continuous communication, encouragement, and correction after class, forming an educational community between teachers and students. Only when teachers see students' potential and awaken their inner confidence will students be willing to "love their teachers and believe in their way." Yipeng Fu's active planning of his academic path and Yipeng Liang's driving of ethnic-minority students to participate together in practice are educational outcomes gradually generated in the atmosphere of continuous teacher-student interaction.

5. Conclusions

Teaching is what the superiors practice and the subordinates imitate; nurturing children means raising them to do good. The course "College Student Innovation and Entrepreneurship" is not merely a skill course for teaching business techniques; it is also an important position for delivering Grand Ideological and Political education. This teaching reform integrates Xi Jinping Economic Thought into every module of the course and relies on practical training to put ideological education into practice; the growth of the several students in the "Daily Bread" team is precisely the realistic outcome of this educational path. This case suggests that, based on the reality of students in private universities, when curriculum-based ideological-political education is implemented carefully and consistently, students who are confused and puzzled at the enrollment stage can, under ideological guidance and sustained practical tempering, grow into courageous and enterprising youth. The observed achievements—Yang's top-five class ranking and the stable weekly revenue of "Daily Bread," Pan's registered company and first-month revenue above 10,000 RMB, Fu's English-examination results and banking internship, and the team's Beijing-level competition prize—are concrete outcomes documented within this case; they should not, however, be read as proof of the general effectiveness of the teaching model, which would require larger-scale comparative evidence. Rather, the "Daily Bread" case offers an illustrative example of how applied talent training in private universities can connect individual student growth with the development of the times.

Author Contributions:

Zixin Yang was responsible for the practical data collection of the "Daily Bread" and "Pan Hai Shop" cases, and participated in the drafting of the case-study section. Xin Peng was responsible for the research design, curriculum reform planning, and the writing and revision of the manuscript. All authors have read and agreed to the published version of the manuscript.

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The authors declare no conflict of interest.

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Mapping Beijing with Data: An AI Travel Companion for Personalized Dining and Sightseeing

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Abstract

As Beijing's cultural tourism market continues to expand and Generation Z becomes a major force in tourism consumption, conventional travel services have revealed clear limitations in information integration, personalized itinerary planning, and real-time responsiveness. Taking "Mapping Beijing with Data," an undergraduate innovation and entrepreneurship project, as its subject, this paper systematically examines the feasibility and implementation pathway of an AI-powered travel service platform from four perspectives: product functionality, core technical architecture, market-oriented business model, and potential risks. The analysis suggests that a technical solution built on a Beijing cultural-tourism knowledge graph and a dynamic-planning engine offers advantages in information-integration efficiency and the relevance of personalized recommendations. However, it also faces practical challenges involving data quality assurance, intensifying market competition, limited team experience, and data security and regulatory compliance. The project has promising implementation prospects, supported by both favorable policies and market demand. Sustained investment in technological iteration, resource integration, and compliance management will nevertheless be necessary for it to establish a foothold in the competitive cultural-tourism technology sector.

Keywords: Artificial Intelligence; Cultural-Tourism Integration; Knowledge Graph; Itinerary Planning; Business Model

1. Introduction

"Mapping Beijing with Data" is grounded in the realities of Beijing's cultural-tourism market. According to official statistics, Beijing received approximately 371.5 million tourist visits in 2024, including approximately 201.7 million visits by tourists from other provinces, and total tourism revenue reached RMB 672.24 billion (Beijing Municipal Bureau of Statistics & Beijing Survey Team of the National Bureau of Statistics, 2025). Despite this substantial market, visitors may still encounter notable service deficiencies. The project team's preliminary visitor survey reportedly

found that more than 68% of respondents identified three major pain points: fragmented cultural-tourism information that is difficult to integrate, the time and effort required for itinerary planning, and insufficiently personalized travel options. When preparing a trip to Beijing, visitors often have to gather information from multiple tourism platforms, social media channels, and businesses before assembling an itinerary themselves. After arriving, they may also encounter reservation restrictions at attractions, discrepancies between business recommendations and actual experiences, and traffic congestion between destinations. Conventional travel recommendation systems have long faced challenges involving information overload, context awareness, and the integration of user preferences into coherent itineraries (Gavalas et al., 2014; Chen et al., 2020). Many mainstream platforms provide basic information, such as opening hours and public-transit routes, but may be less capable of dynamically optimizing itineraries in response to variables such as current weather, visitor volume, and users' mobility needs. Niche local resources—including distinctive hutong businesses and intangible cultural heritage workshops—may also be less visible in generalized recommendation systems.

Artificial intelligence offers a potential way to address these problems. By combining large language models with knowledge graphs, an intelligent system can interpret compound requests such as "traveling with older adults and children," "minimizing walking," and "preferring mild food," rather than relying solely on keyword searches. Such a system could function as an around-the-clock local guide, identify distinctive local resources, and adjust itineraries in response to real-time traffic and queue conditions. Research on smart tourism has emphasized the value of integrating destination data and personalized services, while recent studies have examined the use of generative AI in tourist information search and decision-making (Gretzel et al., 2015; Jiang & Han, 2025; Stergiou & Nella, 2024). Policy support also facilitates implementation. In March 2023, the Ministry of Culture and Tourism of the People's Republic of China issued the Opinions on Promoting High-Quality Development of the Online Tourism Market, which encourages online tourism platforms to integrate tourism-related resources and apply technologies such as 5G, artificial intelligence, big data, cloud computing, and blockchain to improve services (Ministry of Culture and Tourism of the People's Republic of China, 2023). Against this backdrop, the "Mapping Beijing with Data" project, developed by the "Jingyun Zhichuang" undergraduate team at Beijing City University, aligns with broader policy priorities concerning digital innovation and the development of smart tourism.

The project identifies Generation Z as a priority consumer segment because its proposed services emphasize personalized, immersive, and digitally mediated travel planning. Previous research on smart tourism has highlighted personalization as an important way to improve the visitor experience, while recent studies have examined how travelers evaluate AI-generated recommendations in trip-planning contexts (Buhalis & Amaranggana, 2015; Kim et al., 2024; Stergiou & Nella, 2024). The project team's preliminary market assessment estimates that approximately 80% of its target users prefer personalized and immersive travel experiences and that demand for intelligent cultural-tourism services may grow by 35% annually. The team further estimates that China's intelligent cultural-tourism service market could exceed RMB 80 billion by 2027, with Beijing accounting for approximately 15%, equivalent to a potential market of RMB 12 billion. These figures should be

understood as preliminary project estimates rather than independently verified industry statistics and should be substantiated with transparent market data before being used as external market-wide claims. Subject to that validation, the market may offer opportunities for university entrepreneurship teams.

2. Product Design and Technological Innovation

"Mapping Beijing with Data" is positioned as an "AI travel companion for Beijing." Although this positioning is straightforward and accessible, the product architecture and technical solution have been developed systematically. Its principal features are outlined below.

2.1. Intelligent Itinerary Planning: from Manual Information Gathering to One-Click Generation

A major limitation of conventional travel preparation is the time and effort required to collect and verify information in advance. Travel guides published through different channels may contain conflicting details, and information such as business opening hours and waiting times can be difficult to verify. Research on tourism recommender systems has addressed these challenges through mobile, context-aware, and personalized recommendation methods (Gavalas et al., 2014; Chen et al., 2020; Chen et al., 2024). The project allows users to enter basic parameters—including travel dates, group size, interests, and budget—and generates a customized itinerary within three seconds. The output includes daily routes, transportation options, recommended durations at destinations, and dining and accommodation suggestions. Users can also revise the itinerary and have it dynamically optimized. For example, a university student planning a weekend trip to Beijing with a budget of RMB 800 and an interest in history and local cuisine could receive an itinerary that includes the Palace Museum and Jingshan Park on Saturday, followed by distinctive dining experiences in Nanluoguxiang; on Sunday, the itinerary could include the Temple of Heaven, Qianmen Street, and time-honored businesses in Dashilan. Transport guidance and dining recommendations would be provided, and the plan could be updated in response to real-time traffic. Recent work on smart-tourism itinerary recommendation also emphasizes the need to account for tourist preferences, points of interest, and contextual constraints when generating travel routes (Esper et al., 2025).

2.2. Aggregation of Cultural-Tourism Resources: Systematic Integration of Fragmented Information

Beijing's cultural-tourism resources are geographically dispersed and span a wide range of business types. Information about major attractions, such as the Palace Museum and the Great Wall, is relatively accessible, whereas information about distinctive hutong businesses, intangible cultural heritage experiences, and cultural-creative shops is more fragmented. The integration of information from multiple tourism stakeholders is a central feature of smart-tourism ecosystems and online tourism platforms (Gretzel et al., 2015; Ministry of Culture and Tourism of the People's Republic of China, 2023). The project team reports that it has aggregated resources from more than 8,000 service providers across attractions, dining, accommodation, intangible cultural heritage workshops, and cultural-creative retail. The database also records customer reviews, operating

status, reservation links, and promotional offers, enabling users to filter results by distance, rating, and popularity. The database is not based solely on online data collection; it is supported by field research. The team visited 20 major attractions and 50 distinctive businesses in Beijing, collected 500 valid questionnaires, and conducted in-depth interviews with 100 visitors.

2.3. Core Technology: a Knowledge-Graph Algorithm For Beijing's Cultural-Tourism Sector

The project's core technical component is a knowledge-graph algorithm tailored to Beijing's cultural-tourism resources. The workflow begins with web-crawling tools to collect publicly available data on tourism, businesses, and transportation. Natural language processing is then used to extract entities and relationships, followed by manual annotation to align and integrate the data. A four-dimensional knowledge graph covering attractions, businesses, transportation, and users is constructed, after which graph neural networks support reasoning and intelligent recommendations. Recent tourism research has explored knowledge-graph-based attraction recommendation, including models that represent tourists' long- and short-term interests (Jiang & Han, 2025). Other studies have examined personalized itinerary recommendation using textual information and preference-learning methods (Chen et al., 2020; Chen et al., 2024; Esper et al., 2025). Compared with conventional recommendation models, the project team's internal tests reportedly show an eightfold improvement in information-integration efficiency, itinerary-planning accuracy of 95%, a 40% increase in the relevance of personalized recommendations, coverage of more than 90% of the high-quality cultural-tourism resources identified by the team, and real-time data-feedback latency of less than one second. These figures are results from internal model testing; actual performance in deployment remains to be verified through operational data.

2.4. Value-Added Services: an Integrated Portal for Cultural-Tourism Needs

The product extends beyond itinerary planning and resource search by incorporating several supporting functions. It provides multilingual intelligent audio guides for more than 40 major attractions, including the Palace Museum and the Temple of Heaven; recommends less-visited destinations and distinctive dining options based on user profiles; and integrates services such as ticket reservations, accommodation booking, navigation, and emergency assistance. Mobile tourism recommender systems have long explored context-aware information and location-based services, while smart-tourism research emphasizes the integration of digital services across the visitor journey (Gavalas et al., 2014; Gretzel et al., 2015). Recent work has also identified travel services and destination management as important areas for generative-AI applications in tourism (Sigala et al., 2024). The aim is to bring the full travel journey into a single platform and reduce the need to switch between applications.

3. Market Prospects and Business Model

The project divides its intended market into three segments. Based on the team's target-market segmentation estimates, the core segment consists of travelers aged 18–35 and accounts for 60% of the intended market. These users are expected to be receptive to internet-based products, prefer differentiated travel experiences, and be comfortable using intelligent services while balancing value for money with distinctive experiences. Families traveling with children form an important

segment, estimated at 25%; they often travel in larger groups, face more itinerary constraints, and place a high priority on safety and convenience. Middle-aged and older travelers represent a potential segment of 15%. Although they may have considerable purchasing power, they may have different levels of familiarity with smart devices, so the product should offer a simplified interface. The project's preliminary estimates suggest that the conversion rate for paid personalized add-on services may reach 30% among younger travelers, while more than 40% of family travelers may be willing to pay for integrated services. These proportions are planning assumptions for the project, not observed shares of Beijing's tourism market. They suggest that a model combining free basic services with paid value-added services may be worth testing in Beijing's cultural-tourism market.

The project's revenue model combines four channels. First, merchant commissions: the platform would charge a commission of 5%–15% on transactions completed through it; the project team reports that 40 merchants have expressed an intention to cooperate. Second, the platform would offer paid value-added services, including premium customized itineraries at RMB 99 each, dedicated audio guides at RMB 29 per person, priority reservation access at RMB 19 per use, and an annual membership package at RMB 199. Third, it would generate revenue from targeted advertising through placements on the home page and within itinerary recommendations. Fourth, it would provide commissioned services for government and business clients, including digital service solutions and data-analysis outputs for cultural-tourism authorities and relevant enterprises. Diversified revenue streams may reduce dependence on any single business line, but operating across multiple channels requires sustained resources. For a student-led venture, whether its staffing and funding can meet operational needs is a key implementation consideration.

Coordinated online and offline promotion forms the main marketing strategy. Online channels include Douyin, Xiaohongshu, and Bilibili, supplemented by collaborations with key opinion leaders specializing in cultural tourism, targeted advertising on comparable travel platforms, and original travel-guide content. Offline promotion would involve promotional stations at pilot attractions, outreach events at universities, and cross-sector partnerships with service points at high-speed rail stations and airports. The product also includes an older-adult mode, featuring larger text and simplified functions to accommodate the usage habits of middle-aged and older users. This design addresses practical user needs and reduces the burden of navigating a complex product independently.

Financial projections envisage a transition toward profitability. According to the project's estimates, revenue is expected to reach RMB 400,000 and net profit RMB 100,000 in 2026; revenue is projected at RMB 800,000 and net profit at RMB 700,000 in 2027; and revenue is projected at RMB 1.2 million and net profit at RMB 1.05 million in 2028. Based on these figures, the implied net profit margins are 25.0% in 2026, 87.5% in 2027, and 87.5% in 2028. These projections indicate positive growth, but they remain forecasts and actual performance is uncertain. In particular, the projected net profit margins for 2027 and 2028 are unusually high for a cultural-tourism service business and require detailed validation against operating costs, customer-acquisition expenses, technology maintenance, and merchant commission arrangements.

4. Challenges and Risks

4.1. Technical Risks

Algorithmic performance depends heavily on the quality, coverage, and timeliness of its data sources, which are important considerations in tourism recommendation systems (Chen et al., 2020; Jiang & Han, 2025; Esper et al., 2025). Outdated or inaccurate information about cultural-tourism resources can directly undermine itinerary reliability. For example, if a business closure is not reflected in the database, the system may continue recommending that business and thereby create a negative user experience. The project proposes a data-maintenance mechanism combining manual review with automated validation. Nevertheless, continuously maintaining accurate information for more than 8,000 providers will be difficult in practice. In addition, growth in the user base will increase server demand. The project plans to rely on Alibaba Cloud's elastic cloud services, but short-term traffic surges during peak periods such as the National Day holiday will test the system's ability to handle concurrent requests under real-world conditions.

4.2. Market Competition

Although intelligent cultural tourism is an emerging field, major platforms have already entered the market. Leading travel and local-service platforms such as Ctrip, Meituan, and Dianping have established large user bases, extensive merchant networks, or both. If comparable AI itinerary-planning functions are introduced by these established platforms, the sustainability of the project's differentiation based on its proprietary knowledge graph will remain uncertain. Research on smart tourism highlights the importance of interconnected platform ecosystems, data integration, and collaboration among destination stakeholders (Gretzel et al., 2015; Sigala et al., 2024). The project has adopted a localization strategy focused on Beijing's cultural-tourism resources and is exploring exclusive partnerships with major attractions and distinctive businesses to build resource-based barriers to entry. This approach may help a smaller team differentiate its offering. However, exclusive partnership opportunities with high-quality attractions and merchants are limited. The project's ability to secure a stable niche alongside major platforms will depend on the quality of subsequent execution.

4.3. Constraints Arising from the Team's Practical Experience

The core team members are second-year finance undergraduates at Beijing City University. They have foundational knowledge of AI and software development, as well as some related practical experience, but their hands-on experience in commercial operations is relatively limited. Cultural tourism is closely tied to offline settings. If the operating team cannot accurately understand merchants' business needs and visitors' actual expectations, product design may become self-referential and fail to meet market demand. At the same time, the team's entry into AI-enabled cultural tourism from a finance background offers a distinctive interdisciplinary perspective. Although this may appear unconventional, it may provide advantages: technology professionals may lack sector-specific knowledge of cultural tourism, while cultural-tourism practitioners may have limited familiarity with digital business models. A finance background may help the team develop distinctive approaches to business-model design and resource coordination. The priority is

to address talent gaps through external collaboration and complementary expertise rather than attempting to manage the entire development and operation process independently.

4.4. Data Compliance and Information Security

A cultural-tourism service platform may collect and store personal information about users' identities, travel activities, and consumption patterns. Under China's Data Security Law and Personal Information Protection Law, data security and the lawful processing of personal information are critical compliance requirements (National People's Congress of the People's Republic of China, 2021a, 2021b). Research on smart-tourism destinations has also identified privacy concerns, perceived risk, and users' control over personal information as important factors in the use of digital tourism services (Afolabi et al., 2021). A data breach could expose the project operator to legal liability and cause lasting damage to its reputation. The project plans to establish data-security controls, but it remains to be demonstrated whether a student-led venture can mobilize the expertise and resources needed to implement a comprehensive security architecture.

5. Conclusion and Outlook

The foregoing analysis supports an overall assessment of the "Mapping Beijing with Data" project. Although it is not yet a fully mature solution, it addresses identifiable pain points in Beijing's cultural-tourism market: fragmented information, static itineraries, and insufficient personalization of service provision. Its use of a knowledge graph and dynamic-planning engine provides a plausible technical foundation, while its diversified revenue streams offer a clear business-model framework. The team's relatively young composition is partly offset by its interdisciplinary background and substantial field research. Nevertheless, several challenges remain: the algorithmic system requires continuous iteration, competition is likely to intensify, commercial operating experience must be developed, and data security and compliance must be implemented effectively. These risks are not insurmountable, but their management will ultimately depend on execution and resource coordination.

Looking ahead, as AI continues to advance and the cultural-tourism sector deepens its digital transformation, "AI + cultural tourism" service models may be replicated in other regions, using major destinations such as Beijing as initial cases. Travel planning may become increasingly streamlined, allowing users to submit preferences and receive integrated itineraries. "Mapping Beijing with Data" remains at an early stage and requires further product refinement. If the project maintains a consistent strategic direction and continues iterating, it may be able to establish a viable position in the expanding intelligent cultural-tourism market.

Author Contributions:

Conceptualization, Y.F and H.P; methodology, Y.F and H.P; formal analysis, Y.F and Z.Y; investigation, Y.F, Z.Y ang and Y.L; data curation, Z.Y and Y.L; writing—original draft preparation, Y.F; writing—review and editing, Y.F, H.P, Z.Y and Y.L; visualization, Y.L; project administration, Y.F. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement:

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Data Availability Statement:

Summary findings are presented in this article. Requests concerning access to the underlying questionnaire, interview and project data should be directed to the corresponding author, Hai Pan (3622039991@qq.com). Any disclosure must comply with participant consent, privacy requirements and applicable third-party restrictions.

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