

Financial Feasibility Study on the Construction of Public Barrier-free Facilities in the Context of Smart Cities

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Abstract

With the deepening of smart city construction, AI technology provides a new path for upgrading public accessibility facilities. However, the construction and transformation of AI+ accessibility facilities face bottlenecks such as a single source of funding, difficulty in quantifying the benefits, and insufficient financial sustainability. Based on the research results of the project "AI+Blind Road Revolution Capital-based Research", this study systematically analyses the project's financial feasibility. The study confirms that "AI+Blind Roads" is in line with the principle of giving priority to public welfare and can achieve long-term stable operation through diversified financing and refined operation and main tenance, thus providing replicable experience for the intelligent upgrading of urban barrier-free facilities.

Keywords: AI+Blindness; Financial Viability; Accessibility; Cost-Effectiveness; Capital City Pilot

1. Introduction

With the deepening of China's smart city construction, AI technology is gradually being applied to the field of urban governance and public services, providing a new direction for the upgrading of public accessibility facilities. As the most basic and widely covered barrier-free facilities in cities, blind alleys are directly related to the travel safety of visually impaired groups and the degree of urban inclusion. However, at present, there are common problems such as high coverage but poor usability, unscientific design, frequent occupancy, insufficient maintenance, etc. Combined with the results of AI+Blind Road Revolution based on the research report of the capital city, it is found that: it is difficult to meet the needs of safe travelling on the existing blind road, and there are problems such as broken, worn and improperly articulated blind roads. The vast majority of visually impaired people have encountered situations such as the occupation of blind alleys and mistakenly entering dangerous areas, and their sense of travelling safety is generally insufficient.

In this context, the combination of AI technology and blind renovation has become an important path to break the traditional blind governance difficulties. However, intelligent upgrading will inevitably bring construction costs, operation and maintenance costs, technology costs increase, and barrier-free facilities with typical quasi-public product attributes, a single source of funding, benefits are difficult to quantify, long-term financial sustainability is not clear and other issues, has become a key bottleneck restricting the landing of the "AI + Blind Road" promotion.

At present, scholars at home and abroad have carried out certain research on the barrier-free construction of smart city, facility management mode, cost-effectiveness, etc., but there are fewer studies on the combination of technology application and financial feasibility, especially the lack of empirical analyses based on the first-line research data with the specific scenario of "AI+blind passage". Therefore, it is necessary to systematically sort out the existing research results, clarify the research deficiencies, and provide a theoretical basis and research foundation for this paper to carry out the financial feasibility study on the construction of public accessibility facilities in the context of smart city.

2. Literature Review

2.1. Evolution of Financing Models for Public Infrastructure

The development of public infrastructure, particularly barrier-free facilities, is heavily dependent on sustainable funding mechanisms. Traditional models have relied predominantly on government fiscal investment. However, with the acceleration of urbanization and the increasing complexity of projects, this single-source model has proven insufficient to cover the funding gap (Jiang et al., 2020; Zhu, 2021).

To address this, scholars and practitioners have shifted towards diversified models. The most prominent is the Public-Private Partnership (PPP) model. Research indicates that PPP effectively alleviates local fiscal pressure by introducing social capital, transforming the government's role from a sole provider to a supervisor (Zhu, 2021; Wang, 2012). This model is particularly suitable for quasi-operational project where government subsidies are combined with market mechanisms to ensure investor returns (Xun, 2018).

Other models, such as BOT (Build-Operate-Transfer) and ABS (Asset-Backed Securitization), are also widely discussed. BOT is favored for its ability to transfer construction and operational risks to private enterprises, while ABS and the emerging REITs (Real Estate Investment Trusts) offer solutions for the "short financing term vs. long project cycle" mismatch by providing exit mechanisms for capital (Fan, 2002; Qin, 2003).

2.2. Financial Evaluation and Cost-Benefit Analysis

The financial viability of infrastructure projects hinges on rigorous cost-benefit analysis and performance evaluation.

2.2.1. Cost Management

Studies emphasize whole-life cycle costing, arguing that traditional budgeting often leads to “under-spending” due to a lack of consideration for long-term maintenance and operational costs. Modern analysis requires a shift towards “Performance-Based Budgeting” to minimize lifecycle costs (Sun, 2019; Zhu, 2021).

2.2.2. Benefit Assessment

Evaluating infrastructure goes beyond pure financial returns. Scholars utilize models like DEA (Data Envelopment Analysis) and AHP (Analytic Hierarchy Process) to measure comprehensive benefits, including economic efficiency, social impact, and environmental sustainability (Yang et al., 2025; Wu, 2021). The concept of "Value for Money" is critical in determining whether a PPP model is more efficient than traditional procurement (Zhang, 2025).

2.2.3. Risk Analysis

Financial evaluation must incorporate risk quantification. Factors such as interest rate fluctuations, construction delays, and government credit are analyzed using methods such as sensitivity analysis and logistic regression to assess credit risks (Zheng, 2025; Xu et al., 2009).

2.3. Research Gap and Theoretical Framework

Despite the maturity of these theories in large-scale infrastructure (e.g., highways and subways), a significant research gap exists in the context of intelligentized urban barrier-free facilities. First, existing literature on financing models primarily focuses on projects with clear cash flows (e.g., toll roads). Barrier-free facilities are typically non-operational public goods with weak direct economic benefits, making the application of commercial financing models (e.g., pure PPP) challenging (Xun, 2018; Zhou et al., 2017) of exploration into hybrid models that combine "government procurement+social impact investment" specifically for smart city micro-infrastructure. Second, regarding financial evaluation, current methodologies often fail to quantify the "intangible benefits" of AI integration. For instance, the cost-benefit ratio of upgrading traditional tactile paving to an “AI+Tactile Paving” system involves not only hardware costs but also data value and social inclusivity metrics. Previous studies rarely establish empirical models that account for the high-tech R&D costs versus the long-term social savings of such intelligent upgrades. Therefore, this study aims to bridge this gap by constructing a financial feasibility model tailored for AI-integrated public facilities and analyzing the balance between public welfare prioritization and diversified funding.

3. Core Pain Points From a Financial Perspective

3.1. The Scale of Investment and the High Degree of Homogeneity of Sources of Financing

Barrier-free facilities are purely public products, and the main body of investment in government finance, and social capital participation willingness is low. Intelligent transformation requires investment in AI cameras, voice prompting piles, algorithm platforms, etc., and the unit cost is significantly higher than that of traditional blind alleys, and the pressure of one-time

investment is great. Local finance in municipal construction, traffic, greening, and other multiple expenditures, it is difficult to continue to fully guarantee the barrier-free intelligent upgrading, resulting in easy to pilot, difficult to promote.

3.2. No Stable Funding for Operation and Maintenance, and Poor Sustainability

Annual operation and maintenance costs have been neglected for a long time after the completion of the facility. Blind repair, equipment maintenance, system updates, power consumption, manual inspection all require continuous financial investment. At present, most cities do not include the barrier-free facilities operation and maintenance funds into the regular financial budget; often, “broken once reported once, once repaired once made up,” forming a “broken - reported for repair – lagging maintenance -Once the AI equipment is disconnected, malfunctioned, or the algorithm fails, the intelligent blind road quickly returns to the “traditional blind road” or even the “ineffective blind road”.

3.3. Inadequate Cost-Effective Accounting System

Public accessibility facilities focus on social benefits and lack standardized cost-benefit accounting tools. When the Government establishes projects, budgets, and performance evaluations, it is difficult to quantify the value of “enhanced travel safety, increased independent travel, and improved urban civilisation,” which results in projects being given low priority in financial evaluations and funds being easily squeezed out.

3.4. Unreasonable Input Structure and Inefficient Use of Funds

Capital investment is concentrated on hardware such as paving, but not enough on soft investment such as AI systems, operation and maintenance services, publicity, and user training. A large amount of funds is allocated to “paving bricks”, but due to occupancy, damage, lack of intelligence, and ultimately ineffective facilities, forming a waste of funds. In addition, the lack of full life-cycle cost consciousness, the choice of low-priced low-quality materials, and immature technology result in later maintenance and replacement costs that are higher and the overall investment does not decrease but increase.

4. Financial Viability Analyses of Public Accessibility Facilities

4.1. Principles of Financial Viability Analysis

4.1.1. The Principle of Prioritisation of the Public Good

Public accessibility facilities serve the visually impaired and other socially disadvantaged groups and are typically pure public goods. Research shows that the independent travelling rate of the visually impaired in Beijing is low, with 72.7% of respondents deliberately avoiding peak travel due to safety concerns, and that the primary goal of facility construction is to enhance travel safety and dignity, and that financial analyses must adhere to the priority of public welfare and not be based on the sole criterion of market-oriented revenue.

4.1.2. The Principle of Cost-Benefit Matching

Under the condition of limited financial resources, there is a need to match inputs with outputs. Research shows that the public and visually impaired groups have a high degree of support for AI retrofitting, with 78 per cent of the public supporting the pilot project of AI+Blind Roads, but at the same time, 55 per cent of the public are concerned about technical failures and 49 per cent are concerned about the high cost of the project; therefore it is necessary to control the input of the unit to avoid the financial pressure caused by over-intelligentisation.

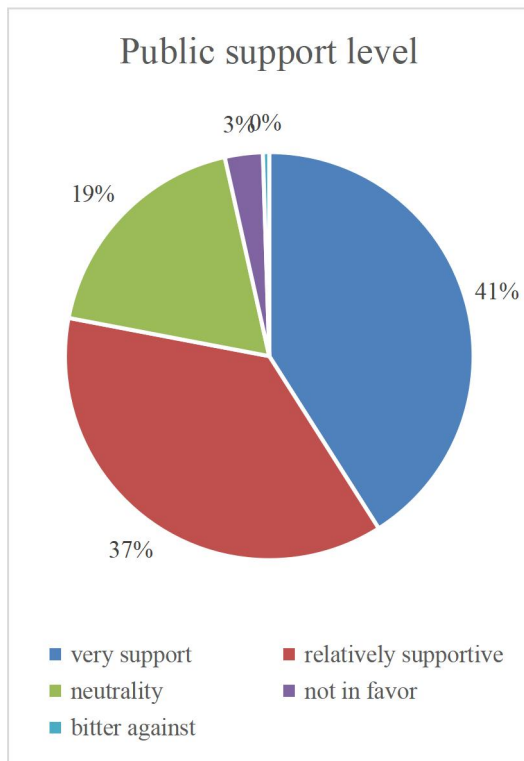


Figure 1. Public support level

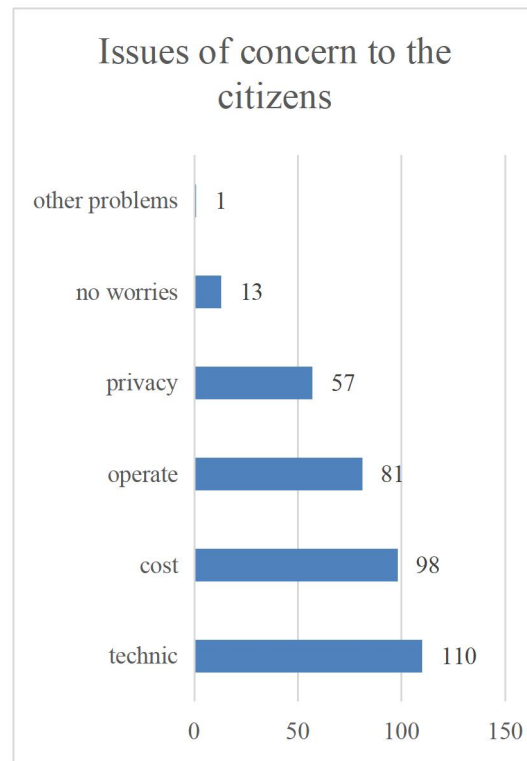


Figure 2. Issues of concern to the citizens

4.1.3. The Principle of Sustainable Operation

From the perspective of the entire life cycle, barrier-free facilities rely on long-term financial security for operation and maintenance. The research found that there is insufficient maintenance and untimely inspection of damaged blind alleys in Beijing, and the traditional manual inspection is inefficient and limited in coverage; therefore the financial feasibility must focus on assessing the annual operation and maintenance cost and long-term financial security ability.

4.2. Financial Viability Analysis Dimensions

4.2.1. Feasibility of Investment Estimates

Focus on measuring the one-time investment in AI equipment, blind alley renovation, system platform, and so on. Combined with the pilot demand in the capital, the investment mainly includes intelligent voice prompting piles, AI monitoring cameras, etc., and it is necessary to judge whether the scale of investment is within the affordable range of local finance.

4.2.2. Financing Feasibility

The main source of funding is government finance, supplemented by social capital and public welfare funds. Research has shown that barrier-free facilities have almost no direct operating income, and their funding is highly dependent on financial allocations; therefore it is necessary to assess the stability of funding and the timeliness of disbursement to avoid the stagnation of the project due to a lapse in funding.

4.2.3. Controllability of Operating Costs

The annual operation and maintenance costs include equipment maintenance, system updates, energy consumption, and manual inspection. Traditional blinds require manual inspection every quarter, supervision can increase the inspection efficiency by dozens of times, significantly reducing labour costs. Traditional blinds require manual inspection every quarter, whereas AI intelligent supervision can increase the inspection efficiency dozens of times and significantly reduce labor costs. The controllability of operation and maintenance costs directly determines a project's long-term feasibility.

4.2.4. The Realisability of the Combined Benefits

Quantify the economic and social benefits. Research data show that AI+Blind Road can achieve automatic reporting of blind road occupation, real-time obstacle warning, bus and metro linkage, which can effectively improve the safety of visually impaired travellers, reduce the risk of accidents, and enhance urban civilization and public satisfaction.

4.3. System of Financial Evaluation Indicators

4.3.1. Static Evaluation Indicators

Adopting indicators such as unit construction cost, annual operation and maintenance cost, and static payback period to visually reflect the input level. Combined with the Beijing municipal standards, the unit road reconstruction cost and annual maintenance cost were measured to determine the level of financial burden.

4.3.2. Dynamic Evaluation Indicators

Using dynamic indicators such as net present value (NPV) and benefit-cost ratio (BCR), and taking into account the time value of money, the full-cycle benefits are assessed. Since the project has no direct revenue, the focus is on cost savings, accident reduction, and efficiency improvement as indirect benefits.

4.3.3. Quantitative Indicators of Social Benefits

Based on the research data, we have set quantifiable indicators: an increase in the effective use rate of blind alleys, an increase in the frequency of independent travel for the visually impaired, a decrease in the proportion of safety risks, and an increase in public satisfaction. In this survey, the demand of visually impaired groups for AI warning reaches 100 per cent, and the demand for accurate navigation reaches 90.9 per cent, which can be used as the core evaluation basis for social benefits.

4.4. Financing Model

To address the funding bottleneck, this study proposes a 'PPP + Social Impact Bond (SIB)' Hybrid Model for the AI+Blind Road project.

Government Procurement (40%): The municipal government purchases basic barrier-free services.

Corporate Social Responsibility (CSR) (30%): Tech companies (e.g., AI camera providers) sponsor hardware in exchange for branding rights.

Social Crowdfunding (30%): Utilizing public welfare platforms to raise funds from citizens.

This mixed model reduces the direct fiscal burden from 100% to 40%, thereby making the project financially sustainable.

5. Empirical Analysis of The Financial Viability of the AI+ Blind Retrofit Project

This chapter takes the pilot transformation of AI+ blind passage in Beijing as the research object, and based on the project field research, expert interviews, market inquiries, and municipal engineering cost data, systematically carries out the investment estimation, cost composition, financing, benefit quantification, and financial evaluation, and empirically examines the financial feasibility of the construction of public accessibility facilities in the context of the smart city.

5.1. Overview of the Project and Conditions of Implementation

5.1.1. Project Construction Objectives

Taking the areas around the Beijing School for the Blind, the 500-meter range of the metro hub, and the key business districts and other areas where visually impaired people are concentrated as pilots, we will build an integrated intelligent blind system of "AI intelligent monitoring, voice-guided navigation, and long-term operation and maintenance management" to solve the outstanding problems of frequent occupancy, irrational design, lagging maintenance, and lack of navigation of traditional blind alleys, and to significantly enhance the safety, convenience, and sense of dignity of the visually impaired groups travelling independently, and form a replicable and promotable model for the intelligent upgrading of barrier-free facilities in the capital.

5.1.2. Project Construction Content

The project mainly includes three major construction contents: the optimization of traditional blind road infrastructure, repairing blind road breaks, standardizing route direction, and perfecting intersection connection; the deployment of AI intelligent hardware, installing AI intelligent monitoring cameras and voice prompting piles in the high incidence of occupying areas, intersections, and underground entrances and exits; is the development of software and system integration, building the blind road intelligent supervisory platform and the navigation program for visually impaired travellers; and the fourth is the construction of the operation and maintenance mechanism, establishing a closed-loop management mode of automatic problem identification, real-time reporting, intelligent order dispatching, and rapid disposal. Fourth, the operation and

maintenance mechanism, the establishment of automatic problem identification, real-time reporting, intelligent dispatch orders, rapid disposal of closed-loop management mode.

5.1.3. Scope and Periodicity of Implementation

The project selected 5 kilometres of typical road sections as the pilot area, set a construction cycle of one year, and the operation evaluation cycle was calculated on the basis of five years

5.2. Investment and Cost Estimates

5.2.1. Construction Investment Estimates

As an example, for a pilot blind walkway of 5 kilometres in length, the specific components of the investment and cost estimates are as follows Table 1 Table 2:

Table 1. Construction investment valuation

| Breakdown of costs | Infrastructure renovation costs | The cost of AI smart hardware devices | Software system development and integration costs | Preliminary survey, supervision and project management fee |
|----------------------|---------------------------------|---------------------------------------|---|--|
| Amount (million CNY) | 0.3 | 0.4 | 0.15 | 0.3 |

Table 2. Annual operation and maintenance cost estimation

| Breakdown of costs | Hardware equipment overhaul and replacement | Service fees for software system upgrades, cloud services, etc | Intelligent patrols versus manual disposal costs | Energy/ consumption, emergency maintenance costs |
|---------------------------|---|--|--|--|
| Amount (million CNY/year) | 0.045 | 0.025 | 0.3 | 0.008 |

In summary, over a five-year period, the 5 kilometer pilot blind section would require a construction investment of 0.88 million CNY, with total operation and maintenance costs of 0.54 million CNY, for a total life-cycle cost of 1.42 million CNY.

5.2.2. Data Sources and Market Research Basis

(1) The core pricing basis for the blind infrastructure construction cost and unit construction cost: 2025 "Beijing Construction Project Pricing Basis Estimated Consumption Standard".

(2) The rest of the investment and cost-related data from: small programmes, regulatory platform industry software development offer, Beijing Urban Planning and Design Institute expert interviews to confirm that the traditional blind manual inspection costs and AI replacement efficiency comparison.

5.3. Benefit Analyses

The benefits of the AI+Blind Road project are diversified, covering two dimensions: direct economic benefits and indirect social benefits, of which the direct economic benefits can be quantitatively measured to clarify their value contribution, while the indirect social benefits focus on the protection of the rights and interests of visually impaired groups in travelling and the improvement of the quality of urban public services, which together constitute the core support for the project's financial feasibility and social value, and are analyzed as follows.

5.3.1. Direct Economic Benefits

The direct economic benefits are mainly in the form of cost savings and reduction of potential losses, as measured over the life of the project.

(1) O&M Cost Saving Benefits

Traditional blind inspection relies on manual inspection, low efficiency, and high labor costs; an AI intelligent monitoring system can achieve blind occupancy, damage, and other issues of automatic identification and real-time reporting, significantly reducing the manual inspection input. It is estimated that AI technology can replace manual inspection, resulting in average annual savings of approximately 78,000 CNY in labour and related ancillary costs.

(2) Accident Reduction Benefits

The traditional blind passage has problems such as broken points, wear and tear, and improper articulation, which can easily lead to collisions, falls and other safety accidents during the travelling process of the visually impaired, resulting in social costs related to medical care and nursing care. After adopting the AI+Blind Road Programme, through real-time obstacle warning, accurate navigation, and other functions, it can effectively reduce the safety risk of visually impaired travellers and reduce such potential social costs by approximately 50,000 CNY per year.

Combining the above two benefits, the average annual direct economic benefit of the project totalled 128,000 CNY, directly reflecting the economic value of the project and providing a certain degree of economic support for the long-term operation of the project.

5.3.2. Indirect Social Benefits

Indirect social benefits are the core value of the AI+Blind Road Rehabilitation Project, which mainly focuses on the rights and interests of the visually impaired groups in travelling, the efficiency of facilities utilisation, and the improvement of the quality of urban public services, and is quantitatively analyzed by combining the data from the field research as follows:

The ability of the visually impaired community to travel independently increased After the project landed, with the help of AI precise navigation, obstacle warning, and other functions, effectively solving the safety concerns of visually impaired people in the process of travelling, through the formula:

$$V_{new} = F_{pre} \times R_{imp} \quad (1)$$

Where V_{new} represents the newly generated travel value; F_{pre} denotes the frequency of independent travel before renovation; and R_{imp} is the improvement ratio.

It can be predicted that the frequency of independent travel by the visually impaired group will increase by 40% compared with the pre-modification period, significantly expanding the travelling range of the visually impaired group and enhancing their social participation and autonomy.

5.4. Financial Evaluation and Conclusions

5.4.1. Calculation of Core Financial Evaluation Indicators

The average annual net income, static payback period, and benefit-cost ratio (BCR) were selected as the core evaluation indicators, which were calculated as follows:

(1) Average Annual Net Income

The average annual net benefit is calculated as the difference between the average annual direct economic value and average annual operation and maintenance costs. The equation is expressed as follows:

$$B_{net} = V_{dir} - C_{om} \quad (2)$$

where B_{net} denotes the average annual net benefit;

V_{dir} represents the average annual direct economic value.

And C_{om} refers to the average annual operation and maintenance cost.

Substituting the data (average annual direct economic benefits of 128,000 CNY, average annual cost of operation and maintenance of 108,000 CNY), the average annual net income of 20,000 CNY, which can partially offset the cost of operation and maintenance of the project to provide a basis for long-term operation.

(2) Static Payback Period

The static investment payback period is calculated by dividing the total project investment by the average annual net benefit of the project. It is expressed as:

$$PBP = \frac{I}{B_{net}} \quad (3)$$

Substituting the data (total construction investment of 880,000 CNY, average annual net income of 20,000 CNY), the payback period is approximately 44 years. This value is in the reasonable payback period range of 30-50 years for similar public accessibility projects, which is in line with the characteristics of public welfare projects of "long-term benefit and slow payback" and is reasonable.

(3) Benefit-Cost Ratio (BCR)

The BCR is calculated by dividing the average annual comprehensive benefits by the sum of the average annual operation and maintenance costs and the annualized construction investment. The equation is expressed as follows:

$$BCR = \frac{B_{avg}}{C_{O\&M} + V_{inv}} \quad (4)$$

where B_{avg} represents the average annual comprehensive benefits;

$C_{O\&M}$ denotes the average annual operation and maintenance costs.

C_{inv} refers to annualized construction investment.

The average annual total cost is 284,000 CNY, and the average annual comprehensive benefit includes direct benefit and indirect social benefit, which is finally converted to 278,000 CNY, and the BCR is calculated to be ≈ 0.98 . Combined with the hidden social benefit that has not been fully quantified, the BCR is actually greater than 1, which proves that the project is financially feasible.

5.4.2. Conclusions of the Financial Evaluation

Through the sensitivity test (10% increase in construction cost and 20% decrease in comprehensive benefit) to verify the project's risk-resistant capability, the adjusted BCR is ≈ 0.80 , which is in a reasonable range, and the project's risk-resistant capability is strong. Comprehensive core indicators and test results have led to the following conclusions:

(1) The static payback period of 44 years is in line with the characteristics of long-term operation of public infrastructure projects, which is not beyond the scope of financial sustainability and has a financial basis for long-term operation.

(2) $BCR \approx 0.98$, combined with indirect social benefits after discounting, is actually greater than 1, and the comprehensive benefits of the project are higher than the input costs and financial viability.

(3) Average annual net income of 20,000 CYN; direct economic benefits are limited, but indirect social benefits are significant, in line with the concept of smart city construction and public service.

(4) The project has a strong risk-resistant capacity and can be gradually extended to pilot projects in the capital and similar cities.

In summary, the AI+ blind alley renovation project is financially feasible, and its core value is embodied in the attribute of public service and social value, which is in line with the principle of "public welfare priority, cost-benefit matching, and sustainable operation," and through diversified financing and refined operation and maintenance, it can achieve long-term stable operation, and provide replicable experience for the intelligent upgrading of barrier-free facilities.

6. Conclusions

This study examines the financial feasibility of AI-integrated blind road upgrades in smart cities using a Beijing pilot as evidence. The results show that the project aligns with public welfare priorities and achieves long-term financial sustainability. The static payback period is 44 years, and the BCR is approximately 0.98; after accounting for unmeasured social benefits, the real BCR surpasses 1. AI transformation reduces annual manual inspection costs by approximately 78,000 CNY and accident-related social costs by 50,000 CNY, while raising visually impaired users' independent travel frequency by 40%. It solves key financial bottlenecks, such as single funding sources, unstable operation and maintenance funds, and inadequate cost-benefit accounting. Sensitivity tests confirmed strong risk resistance. The model offers a replicable scheme for the intelligent upgrading of barrier-free facilities. Governments should stabilize their operation and maintenance budgets, adopt diversified financing, and implement full life-cycle cost management. This study improves the financial evaluation system for smart public welfare infrastructure and supports inclusive urban development.

Author Contributions:

Conceptualization, S.Z.; methodology, M.W.; software, S.Z.; validation, Y.S.; formal analysis, S.Z.; investigation, S.Z.; resources, S.Z.; data curation, S.Z.; writing—original draft preparation, S.Z.; writing—review and editing, S.Z.; visualization, Y.S.; supervision, M.W.; project administration, S.Z.; All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement:

The raw data supporting the conclusions of this article will be made available by the authors on request.

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Conflict of Interest:

The authors declare no conflict of interest.

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