

Research on Optimization Strategies for the Construction and Utilization of Urban Sports Facilities for the Elderly Enabled by Digital Technology

Ruyao Gong¹, Nan Ge^{2*} and Yu Ding¹

¹College of Physical Education and Health, Linyi University, Linyi 276000, China

²School of Physical Education and Sport Science, Qufu Normal University, Qufu 273100, China

Abstract

INTRODUCTION: Against the background that urban sports facilities for older adults are mostly planned as isolated construction projects, with access, operation-maintenance and digital inclusion handled as fragmented separate tasks, this paper constructs a lightweight digital optimization framework connecting multiple functional links for age-friendly sports facilities.

OBJECTIVES: To develop a lightweight digital optimization framework that links needs assessment, asset information, condition monitoring, service scheduling, and inclusive user feedback for urban sports facilities for older adults.

METHODS: Comparative analysis of age-friendly initiatives in Beijing and Singapore, six-week pilot site experiment, counterbalanced-order within-subject test were adopted. The technical tools included tablet dashboard, QR-free large-button interface, infrared entry counter and weekly maintenance log, without cloud model training or specialized medical sensing equipment.

RESULTS: A lightweight digital optimization framework covering needs assessment, asset information, condition monitoring, service scheduling and inclusive user feedback was formed, which provides explicit data fields, operating thresholds, and human fallback procedures for age-friendly facility planning and utilization. The pilot test with 36 participants aged 60-79 showed that, compared with routine service, the digital-support condition yielded higher site-use rate (63.5% vs 41.0%), longer observed activity sessions (32.8 min vs 24.6 min), higher task-completion scores (79.4 vs 62.8), higher facility usability index (78.2 vs 61.3), and the mean maintenance response time decreased from 3.6 days to 1.9 days.

CONCLUSION: The proposed lightweight digital framework can effectively improve site utilization, user task-completion performance, facility usability and maintenance efficiency of urban sports facilities for older adults, offering operable reference for age-friendly facility planning and daily operation.

Keywords: older adults, urban sports facilities, digital inclusion, smart operation and maintenance, universal design, feasibility

Received on 29 July 2026, accepted on 29 September 2026, published on 22 October 2026

Copyright © 2026 Ruyao Gong *et al.*, licensed to EAI. This is an open access article distributed under the terms of the [CC BY-NC-SA 4.0](#), which permits copying, redistributing, remixing, transformation, and building upon the material in any medium so long as the original work is properly cited.

doi: 10.4108/eetpht.11.14226

*Corresponding author. Email: gnan19860601@163.com

1. Introduction

Population ageing changes the performance requirements of urban sports facilities. A site is not age-friendly merely because it contains exercise equipment; it must be reachable, legible, safe to use, maintained after installation, and supported by services that respect different physical and digital abilities. In many communities, construction budgets are visible, while the less visible work of scheduling, inspection, feedback, and inclusion remains fragmented. The result is a facility that may be technically complete but underused by the people it was intended to serve.

Digital technologies can improve this situation when they are used to connect decisions rather than to decorate a facility with screens. A small set of structured records can link a user's need to an entrance route, equipment clearance, inspection item, service timetable, and feedback action. Simple counters and maintenance logs can show when a site is busy or when a component requires attention. A large-button tablet interface can provide exercise instructions without making a smartphone mandatory. These functions support the inclusive physical-activity principles in the World Health Organization's active-ageing guidance and the international quality-physical-activity agenda [1], [2].

This study addresses the engineering problem of full-chain coordination. It asks how a city can specify digital data fields, operational thresholds, and human fallback procedures so that age-friendly requirements survive from planning to daily use. The contribution is a four-dimensional framework covering precision planning and collaborative design, intelligent construction and supervision, smart operation and maintenance, and inclusive utilization and capacity building. A small pilot measures site use, session duration, task completion, maintenance response, and user-reported ease while testing the practicality of a connected workflow.

The design problem is also a resource-allocation problem. A community site has a finite number of staff hours, inspection visits, accessible activity slots, and replacement parts. Digital records are therefore useful only when they reduce coordination delay or make a decision more transparent. In this study, every proposed data field has a corresponding operational question: which user group is being served, which asset is affected, who must act, and when the action is considered complete. Fields without an owner or a decision rule are omitted. This deliberately modest scope makes the framework implementable in sites that have no dedicated data engineer. The feasibility pilot of this study was carried out at urban community sports venues in East China. It should be clarified that these pilot sites differ from the Beijing and Singapore programmes presented in this paper. The two cases merely provide contextual background instead of acting as empirical test sites for our field investigation.

2. Related work

Age-friendly environmental design is grounded in universal design, which seeks usable environments without requiring later adaptation for a separate user group [3]. For sports

facilities, relevant characteristics include continuous accessible routes, adequate rest points, high-contrast information, manageable reach ranges, non-slip surfaces, and clear supervision. Older adults are not a homogeneous category: strength, vision, hearing, balance, confidence, and digital experience vary widely. A design therefore needs adjustable difficulty and more than one route to the same service.

Technology adoption research shows that perceived usefulness, effort expectancy, social support, and facilitating conditions influence whether older adults use digital services [4], [5]. Complexity, fear of error, and inaccessible authentication can create a digital barrier even when the physical facility is well designed. Human-centered design recommends visible system status, recoverable actions, plain language, and recognition rather than recall [6]. These principles favor a dashboard that complements staff and paper signage, with an immediate non-digital alternative when a user cannot or does not wish to use a device.

Smart-city and active-ageing programs illustrate two implementation patterns. The Beijing smart-community approach emphasizes platform coordination, facility upgrading, and public-private resource integration. Singapore's active-ageing model places stronger emphasis on community hubs, outreach, and service linkage. The difference is not a technology ranking; it is a difference in governance and the way digital tools are embedded in local support networks. Descriptions of these two programmes draw upon publicly accessible government reports, official project briefings and existing peer-reviewed analyses [8,11]. Data governance research stresses that asset identifiers, access permissions, retention periods, and accountability must be defined before data are collected [7], [8].

Existing studies still leave three technical gaps. First, many proposals describe a single smart device rather than a lifecycle data model. Second, age-friendly construction indicators are often not connected to utilization or maintenance records. Third, digital inclusion is discussed as a principle but not operationalized through fallback paths and measurable usability checks. This paper addresses these gaps with a compact indicator set and an ordinary-hardware pilot, using established usability, co-creation, materials, and data-stewardship principles [9]–[14].

A further gap concerns evaluation granularity. Facility projects are usually reported with aggregate attendance or satisfaction values, which cannot show whether a low score arose from a route barrier, equipment fault, confusing instructions, or an unavailable instructor. A linked record structure permits a more actionable decomposition: an entry count indicates demand, a condition log indicates serviceability, an observation rubric indicates task performance, and a feedback record indicates perceived effort. The purpose is not to create a large surveillance dataset; it is to provide enough traceability for a weekly improvement meeting and to stop repeated problems from being treated as isolated complaints.

3. Methodology and system design

3.1 Four-Dimensional Optimization Framework

The framework has four connected dimensions. Precision planning and collaborative design convert population, route, activity, and accessibility data into a site brief. Intelligent

construction and supervision attach asset identifiers to equipment, surfaces, lighting, and inspection records. Smart operation and maintenance monitor use volume, faults, cleaning, and response time. Inclusive utilization and capacity building provide large-button interfaces, staff assistance, introductory sessions, and feedback loops. Figure 1 shows the four-dimensional strategy model.

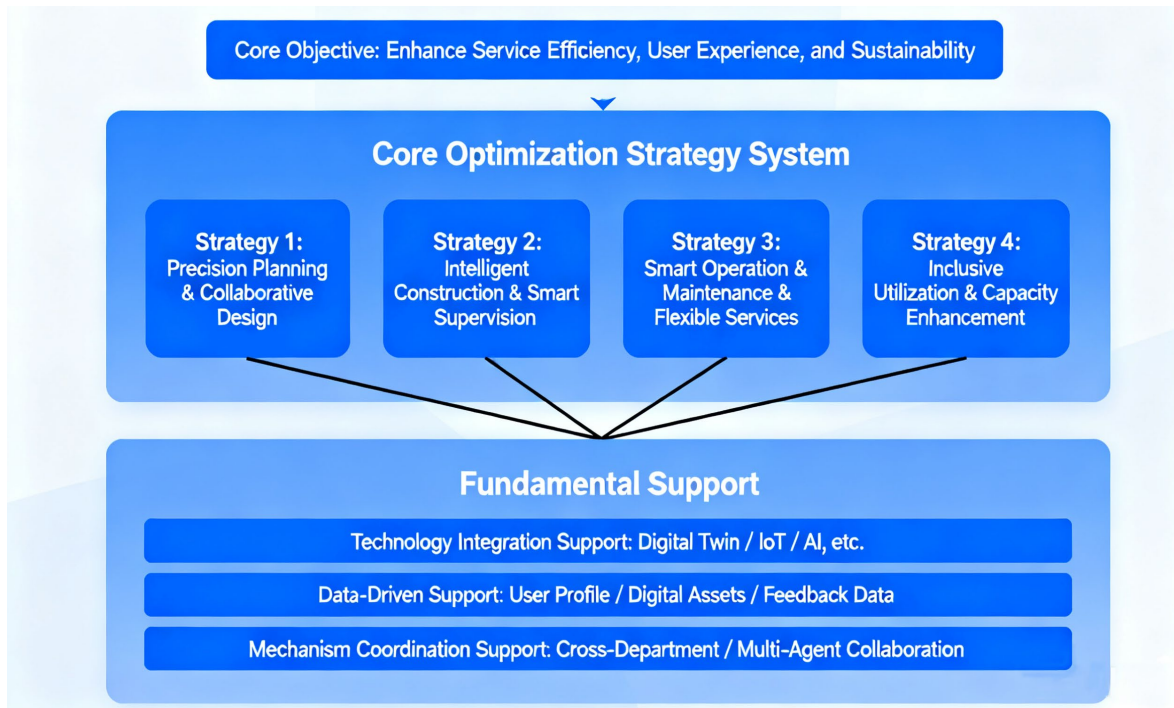


Figure 1. Four-dimensional optimization strategy system for digitally enabled age-friendly urban sports facilities

The minimum data model uses five linked records. A user-needs record stores age band, preferred activity, mobility support, route barrier, and preferred instruction channel. A facility records stores asset identifier, activity type, clear zone, surface, capacity, and inspection interval. A service record stores opening hours, class schedule, instructor, and fallback contact. A condition record stores fault type, severity, photo reference, and response status. A feedback record stores a rating, free-text or voice note, consent flag, and closure action. Each record uses a date, responsible role, and retention rule. Health data are not required for the pilot and are excluded from the dashboard. (See Table 1.)

The records are linked by a site identifier and asset identifier rather than by a personal identifier. At the end of each operating day, staff reconcile the entry counter with the manual sign-in sheet, review unresolved urgent faults, and export a read-only weekly summary. The summary contains counts and response intervals, not individual trajectories. A supervisor can reopen a closed work order when a follow-up inspection fails. This simple state transition prevents the common failure mode in which a ticket is marked complete when a contractor has merely

acknowledged it. It also makes the workflow auditable with ordinary spreadsheet tools.

Table 1. Core data fields and operating thresholds

Dimension	Minimum data	Operational check
Planning	route, activity, clear zone, rest point	route barrier closed before opening
Construction	asset ID, drawing, surface, capacity	handover record complete
O&M	fault, severity, owner, due date	urgent fault acknowledged <24 h
Utilization	session, instruction channel, feedback	weekly use and access review

3.2 Low-Cost Digital Configuration

The pilot configuration was selected for a community center rather than a high-budget smart-city laboratory. A tablet with a 10.1 in screen displayed four large actions: start exercise, view picture instructions, call staff, and leave feedback. A low-cost infrared counter recorded entries at the main gate in one-minute intervals. Staff used a spreadsheet template to register inspections, and a shared folder stored photographs and repair records. The dashboard refreshed once per day; it did not make automated health recommendations. A printed instruction board and a staff telephone were retained as fallback channels.

Planning used a 1:50 site sketch with 1.2 m minimum accessible route width, a 1.5 m turning circle at decision points, seating every 25–35 m, and a 300 mm equipment clearance zone. The values were treated as project design targets, not as a replacement for local building codes. Construction supervision used a four-step handover: verify location and clearances, verify surface and edge condition, attach the asset identifier, and record the first inspection date. O&M thresholds were set at urgent, planned, and monitor levels. An urgent fault closed the equipment until staff confirmation; a planned fault generated a work order within three days; a monitor item was reviewed at the next weekly meeting.

3.3 Feasibility Evaluation Protocol

The pilot involved 36 adults aged 60–79 at two urban community sports sites. This study was reviewed and approved by the Research Ethics Committee of Linyi University (Ethics approval No. LYU20251207). Participants were recruited through the centers and could use the site independently or with a walking aid. After one orientation lesson, each participant completed three routine-service sessions and three digital-support sessions in counterbalanced order over six weeks. Routine service used existing signs and staff explanation. Digital support added the tablet interface, daily occupancy display, and structured maintenance log. The primary paired unit was the participant mean within each condition; site and week were retained for sensitivity checks. Two instructors and four community staff members delivered the sessions. The activity schedule followed community-based participation principles for older adults [15].

Objective measures were entry-based site-use rate, observed active-session minutes, task completion, and maintenance response time. The task rubric covered warm-up, equipment adjustment, safe start, exercise sequence, and safe exit; each item was scored 0, 1, or 2, giving a 0–10 score converted to 0–100. Two instructors independently scored 20% of sessions; ICC(2,k) was 0.84. Participants completed an eight-item picture-supported comprehension sheet ($\alpha = 0.76$) and a ten-item facility usability index scored 0–10 ($\alpha = 0.86$), following the internal-consistency convention introduced by Cronbach

[16]. The index was created for this pilot and its visual labels followed accessibility and usability requirements in ISO 21542 [17]; it is not the standardized SUS. Paired permutation tests with 10,000 label swaps reported mean differences, 95% confidence intervals, and Cohen's dz. The analysis separates objective observations, staff ratings, and participant self-reports.

4. Experiments and results

4.1 Framework Implementation

The two sites registered 18 facility assets, 12 activity tasks, 34 inspection points, and 47 feedback records during the pilot. Seven route or signage issues were identified before the first digital-support session; five were corrected within 48 h and two were scheduled for the next maintenance visit. The dashboard did not replace staff judgement. When the occupancy counter disagreed with the staff count by more than 15%, the staff record was treated as authoritative and the sensor was inspected. This rule prevented a low-cost sensor from silently changing the service decision. (See Table 2.)

Table 2. Pilot outcomes by service condition (n=36)

Outcome	Routine	Digital support	Mean difference (95% CI)
Site-use rate	41.0%	63.5%	+22.5 pp (14.2, 30.8)
Active session	24.6 ± 6.2 min	32.8 ± 6.7 min	+8.2 (6.0, 10.4)
Task score	62.8 ± 13.5	79.4 ± 10.8	+16.6 (11.7, 21.5)
Maintenance response	3.6 ± 1.4 days	1.9 ± 0.8 days	-1.7 (-2.2, -1.2)
Comprehension	5.4 ± 1.3 / 8	6.8 ± 1.0 / 8	+1.4 (1.0, 1.8)
Facility usability index	61.3 ± 12.0	78.2 ± 9.6	+16.9 (12.5, 21.3)

4.2 Observed Use and Service Performance

The digital-support condition was associated with a 22.5-percentage-point higher site-use rate and 8.2 additional active-session minutes. The paired permutation p-values were 0.002 and 0.004, respectively, with Cohen's dz of 1.08 and 1.17. Task completion increased by 16.6 points ($p = 0.006$; $dz = 0.93$). The largest task gains occurred in equipment adjustment and safe exit, where the picture instructions reduced repeated staff prompts. The mixed-

effects sensitivity model with participant and site random intercepts produced the same direction of estimates.

Maintenance response time decreased by 1.7 days ($p = 0.011$; $dz = 0.88$). Of 19 faults logged, 12 were minor surface or label issues, five were loose fasteners, and two were access-route obstructions. All urgent items were acknowledged within 24 h, but three planned items exceeded the three-day target because the contractor responsible was unavailable. The result shows the value of a visible work-order owner while also showing that a dashboard cannot create maintenance capacity that does not exist.

The operational logs also clarified where the workflow added value. Before the pilot, staff spent approximately 18 min per opening shift checking three separate notebooks and a messaging group. With the shared template, the same reconciliation required 11 min, a reduction of 7 min per shift. This time saving was not used to remove staff; it was reassigned to greeting users and assisting the six participants who needed help with the tablet. The observation is important for deployment economics: a digital layer should release capacity for inclusive service, not simply transfer clerical work to older users.

Participants answered 6.8 of eight comprehension items after digital support compared with 5.4 after routine service ($p = 0.008$; $dz = 0.97$). The facility usability index increased by 16.9 points ($p = 0.005$; $dz = 1.02$). Participants most often requested larger text, a persistent staff-call button, and audio instructions. Six participants never used the tablet without staff assistance, so their routine-service fallback records were retained. This subgroup confirms that inclusion requires a staffed alternative rather than an assumption that every older adult will adopt the digital channel.

5. Analysis and discussion

Beyond purely engineering-driven outcomes, observed improvements in user behaviour can be interpreted through established behavioural and human-computer-interaction theories. From a behavioural-change-mechanism perspective, the system provides environmental cues via site layout and accessible routes, delivers real-time feedback through task guidance and maintenance alerts, and lowers users' cognitive operating burden with large-prompt interfaces. These features follow core behavioural-intervention principles and conform to Norman's human-centered design requirements: visible system status, intuitive controls and reversible operations [6]. Meanwhile, gains in perceived usefulness and reduced effort expectancy align with key constructs of the Technology Acceptance Model (TAM) [4], [5].

This study offers targeted theoretical extensions to existing literature. While TAM and conventional human-centered-design studies mainly focus on individual-device interaction, this paper shifts the analytical unit to the full facility lifecycle. It illustrates how organisational accountability mechanisms (asset logs, fault-owner

assignments, mandatory review workflows) interact with interface usability features to jointly shape older adults' physical-activity behaviour. Behavioural improvements stem not only from tablet-interface design but also from interconnected record-keeping and service-accountability systems for physical sports facilities. On-site staff assistance and other social-incentive measures further complement technical functions to foster inclusive participation. Though social incentives were not quantitatively manipulated within this pilot, they represent a valuable direction for future research on inclusive utilisation.

The pilot supports the framework's main engineering proposition: digital value came from linking records and responsibilities across the facility lifecycle. The occupancy counter was useful because it was connected to a site-use review, not because the counter itself was sophisticated. The maintenance log was useful because each issue had an owner and due date. The large-button interface was useful because it shortened the path from instruction to action and preserved a staff-call alternative. These are system-design effects, not evidence that a particular sensor or platform is universally superior.

The four dimensions should be implemented in sequence. Planning first establishes routes, activity zones, rest, and user profiles. Construction then records what was actually installed, including deviations from drawings. O&M turns the asset record into inspections and work orders. Utilization closes the loop through staff observation and user feedback. Skipping the construction handover produces a digital map with no reliable asset identity; skipping inclusion produces a technically complete service that excludes people with low digital confidence. This sequence also aligns with universal-design and human-centered interaction principles [3], [6].

Data minimization is a practical safeguard. The pilot collected entry counts, task observations, and anonymous feedback but did not collect diagnoses, medication, or continuous location traces. A city deployment should define role-based access, retention periods, deletion requests, and an offline mode before linking any health-related data. Digital inclusion also has a cost dimension: tablets, counters, and software require replacement and support. A realistic budget should therefore include device depreciation, staff time, accessibility updates, and printed fallback materials rather than only the initial installation price [7], [8].

Implementation should proceed through a staged acceptance test. During planning, the accessibility route and rest-point map are reviewed with older users and staff. During construction, the contractor signs the asset and clearance checklist before payment. During commissioning, staff simulate an urgent fault, a missing sensor reading, and a user who refuses digital interaction. During routine operation, the supervisor samples five records each week and checks whether the recorded action can be verified on site. These tests are inexpensive, but they turn broad age-friendly language into observable pass or fail conditions. They also create a common vocabulary for the design team, facilities team, and community service

team. The information and software quality dimensions can be mapped to ISO/IEC 25010 during later procurement [18].

6. Conclusion

This paper presents a full-chain digital optimization framework for urban sports facilities serving older adults. It connects precision planning, construction handover, smart operation and maintenance, and inclusive utilization through a compact data model and explicit human fallback procedures. In a six-week pilot with 36 adults at two community sites, digital support was associated with higher observed site use, longer active sessions, better task completion, faster maintenance response, and higher comprehension and ease ratings. The practical recommendation is to deploy digital tools as accountable coordination devices: define the data fields, thresholds, owners, and offline alternatives before adding advanced analytics. This approach can improve service continuity while preserving user choice and staff responsibility

Acknowledgments

We acknowledge the support of this work by the Shandong Provincial Social Sciences Planning Research Project Fund (Grant No. 25CTYJ04). The authors also thank all community staff and older-adult participants who took part in the six-week field pilot, as well as the College of Physical Education and Health of Linyi University for its institutional support.

References

- [1] World Health Organization, *Global Age-friendly Cities: A Guide*. Geneva, Switzerland: WHO, 2007.
- [2] World Health Organization, *Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World*. Geneva, Switzerland: WHO, 2018.
- [3] Imrie R, Hall P. *Inclusive design: Designing and developing accessible environments*. Taylor & Francis; 2003 Sep 2.
- [4] Czaja SJ, Charness N, Fisk AD, Hertzog C, Nair SN, Rogers WA, Sharit J. Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and aging*. 2006 Jun;21(2):333. <https://psycnet.apa.org/doi/10.1037/0882-7974.21.2.333>
- [5] Venkatesh V, Morris MG, Davis GB, Davis FD. User acceptance of information technology: Toward a unified view1. *MIS quarterly*. 2003 Sep 1;27(3):425-78. <https://doi.org/10.2307/30036540>
- [6] Norman Donald A. *The design of everyday things*. MIT Press; 2013.
- [7] Governance OS. *Challenges and the Way Forward*. Organisation for Economic Co-Operation and Development: Paris, France. 2023.
- [8] Zuiderwijk A, Janssen M. Open data policies, their implementation and impact: A framework for comparison. *Government information quarterly*. 2014 Jan 1;31(1):17-29. <https://doi.org/10.1016/j.giq.2013.04.003>
- [9] Brooke J. Sus: a “quick and dirty” usability. *Usability evaluation in industry*. 1996 Jun 11;189(3):189-94.
- [10] Wilkinson MD, Dumontier M, Aalbersberg IJ, Appleton G, Axton M, Baak A, Blomberg N, Boiten JW, da Silva Santos LB, Bourne PE, Bouwman J. The FAIR Guiding Principles for scientific data management and stewardship. *Scientific data*. 2016 Mar 15;3(1):160018. <https://doi.org/10.1038/sdata.2016.18>
- [11] Buffel T, Handler S, Phillipson C. *Age-Friendly cities and communities*. Oxford University Press; 2018.
- [12] Broekhuizen K, Scholten AM, de Vries SI. The value of (pre) school playgrounds for children’s physical activity level: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity*. 2014 May 3;11(1):59. <https://doi.org/10.1186/1479-5868-11-59>
- [13] Sanders EB, Stappers PJ. Co-creation and the new landscapes of design. *Co-design*. 2008 Mar 1;4(1):5-18. <https://doi.org/10.1080/15710880701875068>
- [14] Ashby MF. *Materials and sustainable development*. Butterworth-Heinemann; 2022 Jun 26.
- [15] Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. *Canadian medical association journal*. 2006 Mar 14;174(6):801-9. <https://doi.org/10.1503/cmaj.051351>
- [16] Cronbach LJ. Coefficient alpha and the internal structure of tests. *psychometrika*. 1951 Sep;16(3):297-334. doi:10.1007/BF02310555
- [17] International Organization for Standardization, ISO 21542:2021, *Building Construction—Accessibility and Usability of the Built Environment*. Geneva, Switzerland: ISO, 2021.
- [18] International Organization for Standardization, ISO/IEC 25010:2023, *Systems and Software Engineering—Systems and Software Quality Requirements and Evaluation*. Geneva, Switzerland: ISO, 2023.