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Wang, Z., Melles, M., Deng, R., Albayrak, A., Wang, Z., Xiao, D., & Lu, J. (2026). Research on the usage intention of aging-friendly smart mobility services based on behavioral reasoning theory: a case study of smart bus services. *Transportation*. https://doi.org/10.1007/s11116-026-10781-3

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Transportation
https://doi.org/10.1007/s11116-026-10781-3

Research on the usage intention of aging-friendly smart mobility services based on behavioral reasoning theory: a case study of smart bus services

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Received: 19 March 2025 / Accepted: 12 May 2026
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Abstract
Smart bus services, as a typical example of smart mobility solutions, play an irreplaceable and crucial role in urban development, green and sustainable growth, and enhancing personal travel convenience. However, in the context of an increasingly aging population, how to help older adults better benefit from technological advancements remains an underexplored but critical issue. Therefore, this study adopts Behavioral Reasoning Theory as the research framework and employs factor analysis and structural equation modeling to construct a comprehensive user experience evaluation scale for elderly smart bus users, alongside a user behavior model. Additionally, age-based group modeling was conducted to compare different elderly age groups and explore their behavioral logic. The study finds that older adults' values positively influence all user experience factors. Specifically, Usefulness and Social Equity positively affect both user attitudes and usage intentions; Social Interaction, Service Quality Deficiencies, and Low Information Accessibility influence usage intentions indirectly through user attitudes; while Management and Operational Chaos and Poor Environmental Atmosphere have a direct effect on usage intentions. Moreover, the behaviors of elderly individuals aged 50–59 are relatively more malleable, making this age range a prime stage for "active aging" interventions. This study provides theoretical support and practical guidance for age-friendly design in related industries and partially fills a gap in prior research.

Keywords Age-friendly · Smart bus service systems · Behavioral reasoning theory · Structural equation modeling · Factor analysis

Introduction

Population aging is a global issue. Studies predict that by 2050, approximately 23% of the world's population will be aged 50 or older (Zhang and Yang 2024). Meanwhile, as a populous country with a declining birth rate, China is facing severe challenges related to

Extended author information available on the last page of the article

Published online: 20 May 2026

population aging (Dou et al. 2023). With improvements in quality of life, elderly individuals are increasingly willing to travel (Dou et al. 2023), with shopping, recreational activities, and childcare responsibilities being their primary travel purposes (Guo et al. 2023). However, due to the decline in physical fitness, the mobility needs of elderly individuals are significantly restricted (Hidayati et al. 2021). Research indicates that at least one-third of the mobility demands of elderly individuals remain unmet (Zhang and Yang 2024). Access to reliable transportation is crucial for the physical and mental well-being of the elderly, as it facilitates participation in community activities, expands social interactions, and fosters a sense of community (Zhang and Yang 2024), thereby reducing social isolation (Zhang and Yang 2024) and indirectly preventing mortality and functional decline caused by social isolation (Brandt et al. 2022). Therefore, the United Nations' 2030 Agenda for Sustainable Development further emphasizes the need to improve the quality and inclusiveness of public transportation, particularly by addressing the specific needs of vulnerable populations such as older adults. It also underscores that establishing inclusive, age-friendly transportation systems is essential for enhancing older adults' mobility and overall well-being (Baig et al. 2022; He et al. 2020). Similarly, the World Health Organization (Organization 2007) has highlighted age-friendly transport services as a key focus area in the development of "age-friendly cities and communities."

Against this backdrop, smart mobility services—particularly smart bus services—have emerged as a critical avenue for enhancing individual travel efficiency and accessibility, offering a promising solution to the mobility challenges faced by older adults. Within the context of smart cities, smart mobility typically involves the innovative deployment of data and communication technologies to optimize the use of existing infrastructure, such as traffic signals and ticketing systems (Bazzan and Klügl 2022). It facilitates cross-sector development in urban transportation—including route planning, digital transformation systems, and traffic forecasting—thereby supporting evidence-based and efficient transportation decision-making and policy formulation (Tomaszewska and Florea 2018), while minimizing economic, environmental, and temporal costs (Aletà et al. 2017). Ultimately, smart mobility enhances the efficiency, safety, and sustainability of urban transport systems (Pigni et al. 2016), enabling individuals to engage with the urban environment in a more convenient, user-friendly, and contemporary manner (Allam and Newman 2018).

Smart bus services are one of the most representative types of smart mobility services. They rely on an integrated three-tier system layout consisting of smart infrastructure at the physical level (e.g., intelligent bus stops, smart buses, and other mobile terminals), an intelligent operations management platform at the management level (based on real-time data analysis and management), and user-end interactive service systems (e.g., mobile applications). This integrated system enables dynamic scheduling, adaptive operational management, information interconnectivity, and refined service delivery in actual operations (Rashvand et al. 2024).

At the same time, smart bus services possess irreplaceable advantages compared with other mobility services. First, as a form of public transportation, they are more energy-efficient and environmentally friendly than private cars and ride-hailing services equipped with smart systems, and they are more effective in alleviating urban traffic congestion (Elassy et al. 2024; Henke et al. 2020; Khalid et al. 2019; Mohammed and Oke 2023). Moreover, compared with other public transport modes such as subways and urban light rail, bus services are more flexible, involve lower construction costs, and are widely distributed across

urban streets. This allows them not only to satisfy the utilitarian demands of social mobility but also to promote social equity in urban development (Zhang and Yang 2024; Zhou et al. 2019). Furthermore, compared with traditional bus services, smart bus services—characterized by their advanced capabilities in perception (Watkins et al. 2011; Zhou et al. 2012), decision-making (Li et al. 2017; Yu et al. 2011), and service ability (Li et al. 2017; Yu et al. 2011)—can significantly improve operational efficiency and service quality, thereby enhancing the overall passenger experience. As a result, smart bus services have become a backbone of daily transportation in many countries (e.g., China and Vietnam) (Quy Nguyen-Phuoc et al. 2022a, b) and a key component in the development of modern smart cities (Massobrio et al. 2022).

Moreover, smart bus services are highly compatible with the mobility needs of older adults. In real-world contexts, older adults rely heavily on public transportation, particularly in many developing countries such as China, where public transport is the primary mode of travel beyond walking (Szeto et al. 2017), with bus travel being the most prevalent option (Zhang and Yang 2024). As people age, their travel distances gradually decrease, and the locations and times of their outings tend to become more fixed (Guo et al. 2023; Szeto et al. 2017). This regularity in travel patterns aligns closely with the operational characteristics of bus services. Moreover, buses are relatively affordable, and in China, older adults enjoy specific benefits such as half-price or free fares, making bus travel the preferred choice for many seniors. Therefore, examining smart bus services as a representative case of smart mobility in this study is both highly reasonable and meets an actual societal need.

Nevertheless, the age-friendly development of smart bus services remains severely underdeveloped, in both practical operations and academic research. Practically, the design and adaptation of smart bus services for older adults are are markedly insufficient, as these systems are often tailored to younger, healthier populations, with limited attention to the specific needs of elderly users (Lei et al. 2026).

At the theoretical level, although research on smart bus services has been expanding rapidly, it has predominantly concentrated on institutional development and technological innovation (Lai et al. 2022; Sung et al. 2022; Vismara et al. 2021; Zhang et al. 2024a, b), with comparatively few studies addressing user experience. Moreover, existing research largely emphasize positive experiential factors such as safety (Y. L. Chen et al. 2024a, b, c; Cheng and Lai 2024; Quy Nguyen-Phuoc et al. 2022a, b), usefulness (Y. L. Chen et al. 2024a, b, c; Jiang et al. 2021; Wu et al. 2021), ease of use (Cai et al. 2023; Jiang et al. 2021; Wu et al. 2021), and trust (Cai et al. 2023; W. Y. Chen et al. 2024a, b, c; Wu et al. 2021). By contrast, negative factors and their influence on actual user behavior and experience have been largely overlooked, rendering the research findings somewhat one-sided (Wang et al. 2024).

Furthermore, regarding research methodology, prior studies have predominantly followed a "hypothesis–testing" approach. That is, key influencing factors are typically identified through literature review within specific contexts, followed by hypothesis formulation and empirical validation via data analysis. While this approach can establish linear relationships between individual factors and user behavior, it is limited in its capacity to comprehensively and objectively capture the full spectrum of determinants influencing users' adoption of smart bus services. Moreover, most existing studies focus primarily on younger populations, with insufficient attention paid to older adults.

Simultaneously, existing research on aging-friendly design has predominantly focused on medical treatment and health promotion related to older adults' physiological conditions (Alsswey and Al-Samarraie 2020; Shie et al. 2024; X. Y. Wang et al. 2023a, b). Studies examining older adults' engagement in public transportation remain relatively limited, and the existing literature largely limited to basic behavioral insights (Lei et al. 2026) or design-focused discussions based on case studies and literature reviews (Ngeoywijit et al. 2022; Wu et al. 2026). Consequently, considerable opportunities remain for advancing in research on the user experience of smart mobility among older adults.

Therefore, this study employs a mixed-methods approach, combining qualitative and quantitative techniques to systematically identify user experience factors of age-friendly smart bus services from both positive and negative perspectives. Based on these findings, provide targeted recommendations for service enhancement. While ensuring that the normal use of other passenger groups is not compromised, the study aims to better meet the mobility needs of older adults and enhance their travel experience, enabling them to fully reap the benefits from technological advancements while promoting social equity and sustainable development. These contributions not only hold substantial practical and societal significance but also effectively address the limitations of previous research.

Guided by this research objective, Sect. 2 ("2 Literature Review and Theoretical Hypotheses") provides a systematic review of the key concepts underpinning this study, including "older adults" and Behavioral Reasoning Theory. It clarifies the age characteristics of the target population, explicates the theoretical framework and its applicability, and formulates the corresponding research hypotheses, thereby establishing a robust theoretical foundation for subsequent analysis. Section 3 (Material and methods) then details the research design and procedures, enhancing methodological transparency. Section 4 (Results) presents the empirical findings and data analyses, providing solid evidence to support the study's arguments. Building upon these results, Sect. 5 (Discussion) interprets the findings to uncover the underlying behavioral logic of older adults and offers targeted managerial and design-oriented recommendations. Finally, Sect. 6 (Conclusion) synthesizes the core insights of the study and delineates its limitations, aiming to inform and guide future research directions.

Literature review and theoretical hypotheses

Older adults

What defines an "older adult" is a fundamental issue in conducting age-friendly design research. Across fields such as the social sciences, medicine, and public policy, the classification of "older adults" is generally based on age as the primary criterion, with 60 years old being the most commonly adopted threshold (Organization 2025). However, with the advancement of gerontology and aging studies, the conceptual scope of "older adults" has broadened, gradually forming a more integrated and multidimensional understanding. Generally, the concept is situated within the broader framework of "aging," such that older adulthood essentially reflects the human aging process—a continuous and dynamic phenomenon (Bing 2018).

Based on the dynamic and evolving characteristics of "aging," using 60 years as a rigid threshold to define "older adults" is increasingly seen as inadequate. Moreover, the Continu-

ity Theory posits that, once individuals enter old age, their established lifestyle, values, and behavioral patterns do not experience a complete rupture but are rather maintained to some degree (Atchley 1989). Therefore, to systematically and deeply explore the behavioral traits and logic of older adults, it is essential to extend the age range beyond the conventional 60-year threshold. Addressing this issue, Sabharwal et al. (2015) suggest using the onset of bone density decline as a criterion for defining older adults, with 50 years as a critical milestone. Similarly, the World Health Organization's "Study on Global AGEing and Adult Health (SAGE)" project (Organization 2024) also uses 50 years as the age threshold for categorizing older adults in international datasets. This indicates that 50 years is widely accepted as the standard for defining older adults in large-scale, international aging studies. Furthermore, in research related to the development and promotion of smart digital services/products for older adults, individuals aged 50 to 69 are often the primary focus, as they tend to exhibit relatively higher digital literacy and more inclusive attitudes compared to older age groups (Sun et al. 2024).

Meanwhile, the World Health Organization (WHO), in promoting "active aging" among older adults, also emphasizes the need for early interventions for this population (Organization 2002). Therefore, this study defines its target population as individuals aged 50 and above, which aligns with the natural age-related decline in bone density and facilitates a smoother transition for individuals in the later stages of middle age into older adulthood.

Behavioral reasoning theory

Given the current limitations in research on user experience in smart bus services—where studies have predominantly examined the effects of positive factors on user behavior while largely overlooking the impact of negative factors—Behavioral Reasoning Theory (BRT) provides a robust theoretical framework for this study. BRT posits that "reasons" are critical determinants of individual attitudes and behavioral decisions, which can be classified as either supporting or hindering reasons. Moreover, the theory highlights that personal values directly influence individuals' perceptions of both attitudes and reasons, thereby enabling a more comprehensive and systematic exploration of the behavioral logic of the target population (Chatterjee et al. 2022; Claudy and Peterson 2014; Huang and Qian 2021a, b; Westaby 2005; Ying et al. 2023).

Currently, BRT finds wide application in individual behavioral decision-making (Bhatt and Ghuman 2022; Sahu et al. 2020; Westaby et al. 2010), promoting green sustainable behaviors (Ahmad and Harun 2023; Claudy and Peterson 2014; Dhir et al. 2021), and fostering acceptance of new technologies by users (Claudy et al. 2015; Y. L. Huang & L. X. Qian, 2021; Lee et al. 2023). The theory's applicability aligns closely with the research focus of this study, which aims to explore the intention of elderly users to adopt smart bus service systems—a new and unfamiliar low-carbon environmental service for the elderly.

Thus, this study employs the BRT as the theoretical framework to construct a comprehensive evaluation scale for age-friendly smart bus services, identifying the positive and negative factors influencing elderly users' engagement with these services. In this context, factors positively affecting user intention are termed "positive reasons," while those negatively affecting it are termed "negative reasons." By integrating these factors within the BRT framework, the study further explores the relationships among elderly users' values, attitudes, usage intentions, and various elements influencing their experience. This exploration

seeks to clarify the behavioral logic of elderly users, providing a more practical theoretical basis for upgrading and optimizing age-friendly smart bus service systems.

Based on the foundational framework of BRT and extensive research on user behavior, an individual's values are found to positively influence positive factors (Wang et al. 2025) and user attitudes (Kocak et al. 2026), while negatively affecting negative factors (Wang et al. 2025). Meanwhile, positive factors have a positive impact on both attitudes and behavioral intentions (Sun et al. 2025), whereas negative factors negatively influence user attitudes and behavioral intentions (Sun et al. 2025). Accordingly, this study further proposes the following hypotheses:

H1 *Values of the elderly will lead them to support the positive factors of the smart bus service system.*

H2 *Values of the elderly will lead them to oppose the negative factors of the smart bus service system.*

H3 *Values of the elderly positively influence their attitudes towards smart bus service systems.*

H4 *Positive factors positively influence elderly individuals' attitudes toward smart bus service systems.*

H5 *Negative factors negatively influence elderly individuals' attitudes toward smart bus service systems.*

H6 *Positive factors positively influence elderly individuals' intention to use smart bus service systems.*

H7 *Negative factors negatively influence elderly individuals' intention to use smart bus service systems.*

H8 *Attitudes of the elderly positively influence their intention to use smart bus service systems.*

The hypothesized model is illustrated in Fig. 1.

Materials and methods

Research design

This study is composed of seven steps. The first step involves conducting user and literature research, where evaluations of smart bus service systems' positive and negative aspects will be gathered through literature reviews and user interviews. The second step is the evaluation scale summary, where the summarized evaluations would be compiled and reviewed by industry experts to form a comprehensive evaluation scale. The third step involves user

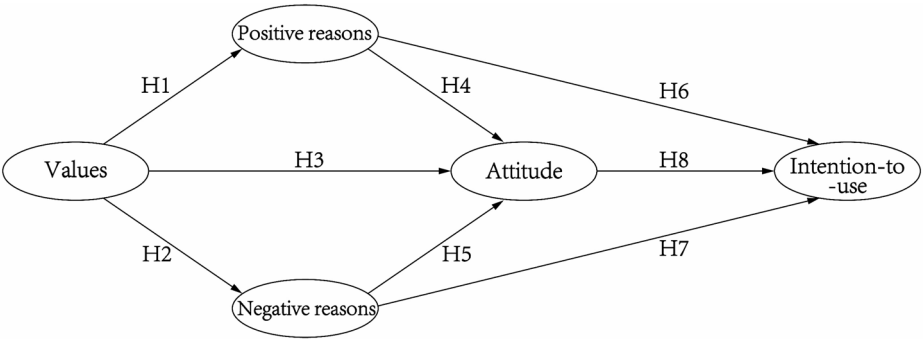


Fig. 1 Hypothetical model based on behavioral reasoning theory

testing of the evaluation scale, where the scale, along with established scales for values, attitudes, and intention to use, will be widely distributed through questionnaires to gather elderly users' evaluations. The fourth step is data analysis of the user experience evaluation scale, where user experience data will be analyzed. This includes reliability analysis to assess the quality of the questionnaire data, exploratory factor analysis (EFA) to cluster factors, and confirmatory factor analysis (CFA) to verify the discriminant validity between factors and the relationships between each factor and its observed variables. The fifth step involves naming the factors, where each factor will be named based on the literature. This method will construct a user evaluation scale, comprehensively identifying the factors affecting the intention to use, including positive and negative factors. The sixth step is hypothesis expansion, where the hypotheses proposed in Sect. 2.2 will be further developed based on the identified influencing factors. The seventh step involves constructing the user behavior model through data analysis. Structural equation modeling (SEM) is utilized to validate the theoretical hypotheses and ultimately develop the behavior model, identifying the relationships among influencing factors. Additionally, age is treated as a key variable, and separate models are constructed for different age groups of elderly respondents, facilitating a more in-depth analysis of their psychological and behavioral patterns.

Data analysis methods

The primary data analysis methods employed in this study to construct the user experience evaluation scale and behavioral model for age-friendly smart bus services include factor analysis and structural equation modeling (SEM). Factor analysis, a multivariate statistical technique, is used to identify underlying structures and reduce the dimensionality of variables. Its core objective is to extract latent factors, which demonstrate internal correlations, from multiple observed variables, thereby uncovering the structural features underlying complex phenomena (Hair et al. 2011). In the context of user experience research, individuals' perceptions of service systems are typically composed of multidimensional psychological and behavioral elements that are difficult to observe directly. Exploratory Factor Analysis (EFA) allows for the exploration of the underlying structure of initial measurement items, identification of latent experiential dimensions, and elimination of redundant indicators. Confirmatory Factor Analysis (CFA) is then applied to assess psychometric properties such as convergent and discriminant validity of the measurement scale (Watkins

2018). Consequently, factor analysis not only enhances the structural clarity and theoretical consistency of measurement instruments but also provides a statistical basis for developing scientifically grounded, stable, and interpretable user experience evaluation scales. This methodology enables the extraction of theoretically significant latent constructs from fragmented perceptual indicators.

Structural Equation Modeling (SEM), an extension of factor analysis, constitutes a comprehensive statistical framework that simultaneously models relationships among latent variables and their associated measurement structures, thereby enabling a holistic examination of complex behavioral mechanisms (Abd-El-Fattah 2010). In the study of user behavior—particularly when examining abstract psychological constructs such as attitudes, perceived value, and intention to use—SEM allows for the precise estimation of both direct and indirect effects among variables through path analysis, supporting the development of systematic models of behavioral mechanisms.

Both methods have been widely employed in user experience and user behavior research (Wang et al. 2018, 2025; Zheng et al. 2022), establishing them as mature and widely accepted analytical frameworks. Therefore, the use of these two methods in this study to construct the user experience evaluation scale and behavioral model for age-friendly smart bus services is theoretically well-founded and methodologically sound.

In developing the user experience evaluation scale and behavioral model for smart bus services, this study strictly adhered to the experimental research framework and procedures proposed by Zheng et al. (2023), whose work similarly focused on developing user experience evaluation scales and behavioral models for product-service systems. Consequently, their approach provides valuable methodological guidance for the design and execution of the present study.

Participants

Before conducting the formal user study, China was chosen as a representative country for investigating smart bus services. This choice is based on three main reasons. First, as the world's second-most populous nation and a typical developing country, China's bus transportation system is a fundamental component of its daily mobility infrastructure (Szeto et al. 2017). Second, China is facing a significant trend of population aging, with the elderly population expected to exceed 300 million by the end of 2024, making up 22% of the total population (Ministry of Civil Affairs of the People's Republic of China, 2025). In response to this demographic shift, the Chinese Ministry of Transport has issued directives to promote accessible, age-friendly transportation services, accelerate the digitalization and intelligence of transportation systems, and expand age-friendly bus services, aiming to enhance the mobility, safety, and quality of life of older adults (China 2024). Therefore, conducting this study in China provides a solid empirical foundation and aligns with significant market demand.

During the user interview phase, this study first selected Wuxi City in Jiangsu Province, China, as a representative city and invited elderly individuals aged 50 and above with experience using smart bus services to participate in the interviews. Wuxi was chosen because it is a typical second-tier city in China, with economic and population development levels roughly at the national average. By the end of 2024, Wuxi's elderly population exceeded 1.54 million, accounting for 29.46% of the total population—7.46% higher than the national

average (Conference 2025). This indicates that the city not only reflects the average conditions of Chinese cities but also demonstrates a relatively high demand for age-friendly service development, making it nationally representative. A total of 58 elderly participants aged 50 and above, all with experience using smart bus services, were recruited—28 males and 30 females, with an approximately equal gender distribution. This indicates that the study sample has a certain level of representativeness, and the sample size meets the general requirements for user interviews (Wen et al. 2023; Zhao et al. 2021). Structured interviews were conducted to gather the participants' descriptions of the advantages and shortcomings of smart bus services.

In the subsequent phase of obtaining user survey evaluations, this study utilized "Wenjuanxing," a widely recognized Chinese online survey platform, to collect questionnaires nationwide. This approach ensured that the data analysis results were not biased by a single data source. A total of 456 valid responses were collected, with a roughly equal distribution of male and female elderly participants, as well as a diverse range of occupational backgrounds. This suggests that the sample is reasonably representative. All respondents were aged 50 and above, and the sample size met the necessary requirements for factor analysis and SEM (Comrey and Lee 1992; Dai et al. 2020; Hair et al. Jr 2021; Price, 1993). However, despite the extended data collection period, the majority of respondents were aged between 50 and 69 years. Although, as noted earlier, individuals in this age range generally possess relatively strong digital literacy and represent a key target group for "active aging" interventions, the study inevitably underrepresents the needs of adults aged 70 and above. This constitutes one of the study's limitations and highlights an important direction for further refinement and targeted investigation in future research. The demographic information of the respondents is presented in Table 1.

Measure

This study mainly refers to the experimental methodology of Zheng et al. (2023) to ensure that the research process is grounded in rationality and based on solid foundations.

First, during the user interview phase, participants were recruited through announcements posted on the researchers' personal social networks, as well as via on-site invitations to older adults at bus stops and on buses. All participants were over 50 years old and had prior experience using smart bus services, which in this study was defined as using the corresponding smart bus service app while traveling by bus. Interviews were conducted in a

Table 1 Respondents' basic information

	Basic information	Number of participants	Percentage (%)
Gender	Female	245	53.73
	Male	211	46.27
Age	50–59	236	51.75
	60–69	220	48.25
Currently/previously held occupations	Public institution	96	21.05
	Government officer	83	18.20
	State-owned enterprise	99	21.71
	Foreign-funded enterprises	66	14.47
	Private enterprise	112	24.56
Total		456	100.00

semi-structured format, either offline in person or online via video conferencing platforms. Each interview was conducted by two graduate researchers: one was primarily responsible for asking questions, while the other focused on recording responses and asking follow-up questions based on participants' answers. Before each interview, participants were provided with a detailed explanation of the study's purpose and the informed consent form was read to them. The interview would only commence after obtaining their verbal consent. The core interview questions included: "What advantages do you think smart bus services offer?", "What shortcomings do you think exist in smart bus services?", and "What aspects of smart bus services do you believe need improvement?" Participants were free to terminate the interview at any time, ensuring that their personal rights and interests were fully protected.

To avoid potential omissions in the user experience characteristics obtained solely through user interviews, this study also conducted a literature review to supplement the interview findings. During the literature review phase, the study used "Web of Science" as the journal database. This resource library comprehensively includes major SCIE, SSCI, A&HCI, and ESCI journal databases, allowing for a thorough search of authoritative journals regarding smart bus user experience characteristics. Considering that technological advancements can have varying impacts on user experiences, the study focused on academic papers from the last 5 years (2020–2024), published in English. In the formal retrieval phase, the study used keywords such as "smart bus" or "bus" and "user experience" for the search. The search ultimately yielded 196 papers. After manually filtering out those irrelevant to the study, 41 papers related to the user experience of smart bus services were retained as fully relevant to the research. Finally, the study extracted and summarized the evaluations of smart bus characteristics from these selected papers.

In the phase of summarizing the observed variables, this study invited three graduate students, who had no conflicts of interest with the research, to compile the results from the interviews and the literature review. After the initial compilation, three industry experts specializing in human-computer interaction or product design reviewed the results. The review ensured that each statement was easy to understand, unambiguous, and clearly distinct from others in meaning. The aggregated negative evaluations are presented in Table 2, while the aggregated positive evaluations are shown in Table 3. To facilitate subsequent analysis and discussion, all evaluation content is represented as "items," with each item coded in the format "Q + number" (as indicated in the "ID" column of the tables). To enhance research transparency, the tables also include a "Frequency" column, reporting the total number of times each item was mentioned during the user interviews and literature review.

Additionally, a literature search was conducted to identify well-established scales for measuring values, attitudes, and usage intentions to support the development of a user behavior model in the second phase of the study. Given that smart bus services are an emerging service for older adults, their willingness to adopt such services is likely influenced by their openness to change. Therefore, this study adopted the "Openness to Change" value scale proposed by Gupta and Arora (2017) to measure older adults' openness and its impact on various factors. Ultimately, the compiled user evaluations and validated scales on values, attitudes, and usage intentions formed the core content of the questionnaire. A 7-point Likert scale was used for data collection to assess user perceptions.

Meanwhile, as previously noted, although smart bus services inherently constitute a systematic framework encompassing management, infrastructure, and user-facing mobile services, the mobile application (APP) on the user side integrates most intelligent func-

Table 2 Summary of negative evaluation items

ID	Items	Frequency
Q1	Passengers not queuing, chaotic and disorderly	25
Q2	During peak hours, the interior space of the vehicle is crowded	19
Q3	Real-time arrival information of buses is inaccurate	14
Q4	Waiting time for buses is excessively long	12
Q5	Arrival notification sound is low	11
Q6	Bus stopping time is too short	9
Q7	Waiting experience at bus stops is greatly affected by the weather	8
Q8	Seating comfort of buses is low	8
Q9	Difficulties in boarding and alighting from buses via accessible pathways	6
Q10	Text on bus station platforms is too small	6
Q11	Bus door access control system is imperfect, posing safety risks	5
Q12	The payment speed is slow	4
Q13	Few arrival notifications	4
Q14	Irregular scheduling of bus services	3
Q15	Unstable speed during bus operation	2
Q16	Interior environment of the vehicle is noisy	2
Q17	There is an odor inside the bus	1
Q18	There are few seats inside the bus	1
Q19	Complex system operation	1

Table 3 Summary of positive evaluation items

ID	Items	Frequency
Q20	Low bus fare	26
Q21	Efficient route planning to reduce time wastage	25
Q22	Real-time bus location tracking	17
Q23	Effective and rapid feedback and complaint handling for issues in the service	7
Q24	Bus routes cover various areas	6
Q25	Anyone can take the bus	2
Q26	Provision of real-time operational updates (e.g., congestion, incidents, and service disruptions)	2
Q27	Promote urban planning	2
Q28	Effectively prevent traffic accidents	2
Q29	Alleviate traffic congestion	2
Q30	Staff have a good attitude	1
Q31	Maintain and expand personal social networks	1

tionalities. It serves as the primary interface through which users access features such as trip booking, real-time route information, and other smart travel services. From the user's perspective, the key distinction between smart bus services and conventional bus services lies in whether the mobile application is actively used during the journey.

To prevent the confusion between incomplete bus travel experiences (simply riding the bus) and the complete smart bus experience (riding the bus while simultaneously using the

corresponding mobile app) when measuring user "attitudes" and "intention to use," and to enhance the accuracy of the study, the term "smart bus service" in the questionnaire items for the "attitude" and "intention to use" dimensions was replaced with the more specific and explicit phrasing: "use the smart bus service system app during bus travel." The detailed questionnaire items are provided in Table 4.

The formally administered questionnaire consisted of four sections. The first section presented the informed consent form, which provided a detailed explanation of the research objectives, procedures, and participation considerations. Respondents were required to select "I acknowledge and agree to participate in this research study" before proceeding to subsequent questions; otherwise, the questionnaire would automatically close.

The second section comprised screening questions, which included two items: "Are you aged 50 or older?" and "Do you have the habit of traveling by bus and have you used a smart bus service system application during this process?" Respondents could proceed only if they answered "Yes" to both questions; otherwise, the questionnaire would be automatically terminated. This design ensured that all participants had the physical capacity and technological literacy required to use smart bus services and had sufficient prior experience to provide informed evaluations, thus enhancing the reliability and validity of the collected data.

The third section collected demographic information, including gender, age, and occupation.

The fourth section consisted of the user evaluation scale, with detailed questionnaire items presented in Tables 2 and 3, and 4.

All questionnaires were completed anonymously to protect participants' personal privacy. Respondents were free to withdraw from the survey at any time, safeguarding their individual rights. However, incomplete questionnaires were deemed invalid and excluded

Table 4 Scale for assessing value, attitude, and intention to use

Latent variable	ID	Items	Source
Attitude, AT	AT1	I am interested in using the smart bus service system app during bus travel.	(Huang and Qian 2021a, b)
	AT2	I think using the smart bus service system app during bus travel is a good approach.	
	AT3	I would consider using the smart bus service system app during bus travel as an option in the future.	
Intention to Use, ITU	ITU1	I plan to use the smart bus service system app during bus travel in the near future.	(Huang and Qian 2021a, b)
	ITU2	I am willing to use the smart bus service system app during bus travel.	
	ITU3	I would recommend others to use the smart bus service system app during bus travel.	
Value, V	V1	I enjoy experiencing new things	(Anayat et al. 2023; Gupta and Arora 2017)
	V2	I am open to new experiences	
	V3	I actively look for new technologies to adopt	

"ID" denotes the abbreviated code for each item, and "Source" indicates the origin of the evaluation scale

from analysis. Participants who submitted valid questionnaires received a monetary incentive of 3 RMB. The finalized questionnaire can be found in Appendix II.

After distributing the questionnaire on a large scale, a total of 530 responses were collected. Following data cleaning, questionnaires with incomplete answers, incorrect responses to screening questions, identical answers, or logically inconsistent responses were removed. This process resulted in 456 valid responses, yielding an effective response rate of 86%. The final sample size fully meets the requirements for factor analysis and SEM (Comrey and Lee 1992; Dai et al. 2020; Hair et al. Jr 2021; Price, 1993).

Results

Evaluation scale analysis results

Exploratory factor analysis (EFA)

In this study, EFA was first conducted to identify the factors influencing older adults' intention to use smart bus services. The analysis focused on user evaluation data from Q1–Q31 in Tables 2 and 3. Typically, EFA requires that each item load on only one factor with a coefficient greater than 0.4, and that each item's communality exceeds 0.4, ensuring clear distinctions between factors and strong correlations among variables within a factor (Kaiser 1958).

During analysis, items Q7, Q22, Q27, Q28, Q29, and Q31 exhibited factor overlap, showing loadings above 0.4 on multiple factors. Following the approach of Wang et al. (2022, 2023a, b), these items were sequentially removed using an iterative enumeration method: after deleting each item, EFA was rerun until all remaining items loaded above 0.4 on only one factor.

Ultimately, seven factors were retained, fully meeting the analysis criteria, as shown in Table 5. Factors 1, 2, 4, and 7 were classified as negative factors, while factors 3, 5, and 6 were classified as positive factors. Reliability was strong, with Cronbach's α for all factors exceeding 0.6, and validity metrics also met requirements (Bartlett's Test of Sphericity: $p = 0.000 < 0.05$; KMO $= 0.973 > 0.6$). These results indicate that the dataset is both reliable and valid, and that the factor analysis outcomes are robust and credible (Nunnally 1994).

Based on these clustering results, this study preliminarily developed an age-friendly user experience evaluation scale for smart bus services. Each factor was subsequently named according to the content of its observed variables and insights from relevant literature. The final structure of the evaluation scale—including specific items, dimensional composition, and the definitions of each dimension—is presented in Tables 6 and 7. The negative factors comprise Service Quality Deficiencies (SEQ), Management and Operational Chaos (MOC), Low Information Accessibility (LIA), and Poor Environmental Atmosphere (PEA), while the positive factors consist of Social Equity (SE), Usefulness (U), and Social Interaction (SI).

Meanwhile, as this study plans to use SEM to explore the relationships among influencing factors, values, attitudes, and behavioral intentions, and to construct the corresponding behavioral model, an additional EFA was conducted. Specifically, the scale data for values, attitudes, and behavioral intention were jointly analyzed with the age-friendly smart bus service experience scale. The results also met the established statistical criteria, indicating

Table 5 Exploratory factor analysis of evaluation scale

ID	Mean user rating score	Factor loading coefficients							Commonality
		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	
Q8	2.779	**0.653**	0.295	− 0.149	0.241	− 0.231	− 0.233	0.131	0.719
Q18	2.842	**0.653**	0.257	− 0.223	0.311	− 0.105	− 0.181	0.181	0.716
Q11	2.855	**0.669**	0.286	− 0.216	0.222	− 0.153	− 0.176	0.198	0.718
Q9	2.901	**0.657**	0.283	− 0.201	0.233	− 0.185	− 0.158	0.185	0.700
Q12	2.909	**0.707**	0.274	− 0.147	0.188	− 0.23	− 0.176	0.198	0.755
Q19	2.833	**0.740**	0.259	− 0.093	0.216	− 0.154	− 0.169	0.166	0.749
Q1	2.893	0.270	**0.711**	− 0.165	0.242	− 0.191	− 0.190	0.180	0.769
Q6	2.954	0.296	**0.681**	− 0.185	0.189	− 0.17	− 0.146	0.268	0.744
Q15	2.833	0.290	**0.740**	− 0.180	0.262	− 0.153	− 0.163	0.053	0.786
Q14	2.875	0.375	**0.636**	− 0.126	0.268	− 0.040	− 0.133	0.270	0.725
Q4	2.901	0.334	**0.656**	− 0.174	0.261	− 0.194	− 0.115	0.242	0.749
Q20	4.531	− 0.199	− 0.178	**0.806**	-0.150	0.224	0.213	− 0.135	0.856
Q25	4.485	− 0.134	-0.154	**0.831**	− 0.126	0.211	0.261	− 0.106	0.871
Q24	4.447	− 0.224	− 0.192	**0.802**	− 0.14	0.221	0.194	− 0.124	0.851
Q3	2.873	0.38	0.304	− 0.142	**0.609**	− 0.115	− 0.14	0.293	0.747
Q10	2.886	0.331	0.305	− 0.165	**0.672**	− 0.159	− 0.154	0.179	0.762
Q5	2.860	0.333	0.380	− 0.133	**0.584**	− 0.211	− 0.152	0.243	0.741
Q13	2.862	0.312	0.316	-0.18	**0.708**	-0.141	-0.097	0.169	0.788
Q21	4.511	− 0.245	− 0.203	0.285	− 0.171	**0.729**	0.3	− 0.169	0.862
Q22	4.518	− 0.233	− 0.172	0.272	− 0.15	**0.787**	0.276	− 0.124	0.891
Q26	4.502	− 0.194	− 0.165	0.228	− 0.131	**0.801**	0.303	−0.113	0.880
Q23	4.436	− 0.220	− 0.158	0.282	− 0.152	0.313	**0.762**	− 0.122	0.870
Q30	4.441	− 0.223	− 0.188	0.243	− 0.129	0.272	**0.792**	− 0.100	0.872
Q31	4.478	− 0.253	− 0.183	0.264	− 0.108	0.291	**0.751**	− 0.174	0.858
Q16	2.741	0.286	0.334	− 0.2	0.224	− 0.204	− 0.23	**0.644**	0.793
Q17	2.846	0.354	0.285	− 0.171	0.306	− 0.16	− 0.096	**0.685**	0.833
Q2	2.846	0.336	0.345	− 0.162	0.317	− 0.152	− 0.205	**0.579**	0.759
Reliability analysis									
Cronbach α		0.922	0.913	0.917	0.891	0.930	0.923	0.872	
KMO and Bartlett's test									
KMO		0.973							
Bartlett's Sphericity test		$p=0.000$							

Values highlighted in bold and shaded represent factor loadings exceeding 0.40 for each observed variable on its respective factor

Table 6 Negative user experience evaluation scale for age-friendly smart bus services

Factor	ID	Item	Name	Definition	Naming rationale
Factor 1	Q8	Seating comfort of buses is low	Service quality deficiencies (SQD)	The extent to which the service level of the smart bus service system fails to meet user demands.	(Watthanaklang et al. 2024; Y. Zhang et al. 2024a, b)
	Q18	There are few seats inside the bus			
	Q11	Bus door access control system is imperfect, posing safety risks			
	Q9	Difficulties in boarding and alighting from buses via accessible pathways			
	Q12	The payment speed is slow			
	Q19	Complex system operation			
Factor 2	Q1	Passengers not queuing, chaotic and disorderly	Management and operational chaos (MOC)	Due to the lack of adequate planning, coordination, supervision, and management in the operation of smart bus service systems, passenger behavior is often uncoordinated with the bus service system's operation, resulting in inefficiency and disorder.	(Wamba et al. 2024)
	Q6	Bus stopping time is too short			
	Q15	Unstable speed during bus operation			
	Q14	Irregular scheduling of bus services			
	Q4	Waiting time for buses is excessively long			
Factor 4	Q3	Real-time arrival information of buses is inaccurate	Low information accessibility (LIA)	The smart bus service system cannot ensure that all passengers can conveniently and accurately access and use information related to bus service.	(Ababshait et al. 2022)
	Q10	Text on bus station platforms is too small			
	Q5	Arrival notification sound is low			
	Q13	Few arrival notifications			
Factor 7	Q16	Interior environment of the vehicle is noisy	Poor environmental atmosphere (PEA)	The extent to which passengers feel discomfort and dislike due to various environmental factors inside the smart bus.	(McConnell 1942)
	Q17	There is an odor inside the bus			
	Q2	During peak hours, the interior space of the vehicle is crowded			

that the integrated dataset is suitable for subsequent analyses (detailed analysis results can be found in Tables 12 and 13 of Appendix I).

Confirmatory factor analysis (CFA)

To further validate the stability of the results from the EFA, this study conducted CFA on the data corresponding to the seven factors identified in the age-friendly smart bus service experience scale. The results demonstrated a good fit and fully met the required standards, indicating that the evaluation scale developed in this study shows excellent stability (the detailed analysis results can be found in Tables 14 and 15 of Appendix I).

Next, in order to further examine the discriminant validity of the seven user experience factors and their relationships with the dimensions of values, attitudes, and behavioral intention, and to prepare for subsequent SEM analysis, the study performed a CFA for all 10 factors collectively. The results, shown in Table 8, reveal that the standardized factor loadings for each observed variable were greater than 0.5 (Muilenburg and Berge 2005; Shevlin and Miles 1998), the average variance extracted (AVE) values exceeded 0.5, and

Table 7 Positive user experience evaluation scale for age-friendly smart bus services

Factor	ID	Item	Name	Definition	Naming rationale
Factor 3	Q20	Low bus fare	Social equity (SE)	The smart bus service system has a low entry barrier, ensuring equal rights for everyone to use	(Elassy et al. 2024)
	Q25	Anyone can take the bus			
	Q24	Bus routes cover various areas			
Factor 5	Q21	Efficient route planning to reduce time wastage	Usefulness (U)	The smart bus service system can effectively assist users in achieving their travel objectives.	(Davis 1989)
	Q22	Real-time bus location tracking			
	Q26	Provision of real-time operational updates (e.g., congestion, incidents, and service disruptions)			
Factor 6	Q23	Effective and rapid feedback and complaint handling for issues in the service	Social interaction (SI)	The smart bus service system can effectively improve the efficiency of communication and interaction among passengers.	(Y. V. Chen et al. 2024a, b, c)
	Q30	Staff have a good attitude			
	Q31	Maintain and expand personal social networks			

the composite reliability (CR) values were greater than 0.6 (Ahmad et al. 2016; Fornell and Larcker 1981). These findings indicate strong correspondence between the factors and their respective observed variables, and good convergent validity among the observed variables within each factor.

To test the discriminant validity between different factors, the study used the square root of the AVE values for verification, as shown in Table 9. The values on the diagonal, bolded and shaded, represent the square roots of the AVE for each factor. The square root of the AVE for each factor was greater than the correlation between that factor and any other factor, indicating strong discriminant validity between the 10 factors.

In conclusion, the questionnaire data associated with these 10 factors fully meets the criteria for conducting SEM analysis.

Table 8 Confirmatory factor analysis of the behavioral model

Factor	Observed variable	Coef.	Std. error	z	*p*	Std. estimate	AVE	CR
Service quality deficiencies	Q8	1.000	–	–	–	0.816	0.663	0.922
	Q18	0.973	0.048	20.321	0.000	0.811		
	Q11	1.006	0.049	20.515	0.000	0.817		
	Q9	0.973	0.049	20.054	0.000	0.804		
	Q12	1.055	0.050	21.082	0.000	0.832		
	Q19	1.004	0.050	20.111	0.000	0.806		
Management and operational chaos	Q1	1.000	–	–	–	0.829	0.677	0.913
	Q6	0.958	0.046	20.994	0.000	0.819		
	Q15	0.962	0.047	20.605	0.000	0.809		
	Q14	0.971	0.047	20.784	0.000	0.814		
	Q4	1.024	0.047	21.865	0.000	0.841		
Social equity	Q20	1.000	–	–	–	0.898	0.788	0.917
	Q25	0.950	0.035	27.363	0.000	0.888		
	Q24	0.950	0.036	26.631	0.000	0.876		
Low information accessibility	Q13	1.000	–	–	–	0.810	0.673	0.891
	Q3	1.079	0.053	20.435	0.000	0.826		
	Q10	1.055	0.053	19.862	0.000	0.81		
	Q5	1.128	0.054	20.704	0.000	0.834		
Usefulness	Q21	1.000	–	–	–	0.906	0.817	0.931
	Q22	0.968	0.031	30.833	0.000	0.914		
	Q26	0.982	0.034	29.116	0.000	0.892		
Social Interaction	Q23	1.000	–	–	–	0.900	0.799	0.923
	Q30	0.964	0.034	28.025	0.000	0.887		
	Q31	1.016	0.036	28.603	0.000	0.895		
Poor environmental atmosphere	Q16	1.000	–	–	–	0.822	0.694	0.872
	Q17	1.058	0.05	21.042	0.000	0.838		
	Q2	1.031	0.049	21.078	0.000	0.839		
Attitude	AT1	1.000	–	–	–	0.971	0.921	0.972
	AT2	0.985	0.018	53.782	0.000	0.96		
	AT3	0.966	0.020	49.527	0.000	0.947		
Intention to use	ITU1	1.000	–	–	–	0.930	0.872	0.953
	ITU2	0.996	0.026	37.764	0.000	0.940		
	ITU3	0.969	0.026	36.606	0.000	0.931		
Value	V1	1.000	–	–	–	0.904	0.794	0.920
	V2	0.983	0.035	27.942	0.000	0.889		
	V3	0.969	0.035	27.420	0.000	0.881		

Analysis results of the behavioral model

Extension of the research model hypotheses

Before formally constructing the behavioral model of older adults' intention to use age-friendly smart bus service systems through SEM, this study further extends the hypothesis framework proposed in Sect. 2.2 based on the positive and negative factors identified in Sect. 4.1.

Table 9 Discriminant validity analysis of the behavioral model

	SQD	MOC	SE	LIA	U	SI	PEA	AT	ITU	V
SQD	**0.814**									
MOC	0.789	**0.823**								
SE	− 0.568	− 0.548	**0.887**							
LIA	0.799	0.803	− 0.531	**0.82**						
U	− 0.623	− 0.572	0.641	− 0.567	**0.904**					
SI	− 0.629	− 0.568	0.645	− 0.545	0.734	**0.894**				
PEA	0.770	0.779	− 0.550	0.790	− 0.585	-0.582	**0.833**			
AT	− 0.737	− 0.694	0.687	− 0.695	0.756	0.763	− 0.673	**0.959**		
ITU	− 0.668	− 0.676	0.648	− 0.641	0.704	0.662	− 0.679	0.781	**0.934**	
V	− 0.562	− 0.532	0.673	− 0.502	0.654	0.679	− 0.519	0.666	0.618	**0.891**

The numbers with hatched diagonal lines are the square roots of AVE

The extended hypotheses are as follows:

H1a *Values of the elderly will lead them to support the social equity of smart bus service systems.*

H1b *Values of the elderly will lead them to support the usefulness of smart bus service systems.*

H1c *Values of the elderly will lead them to support the social interaction of smart bus service systems.*

H2a *Values of the elderly will lead them to oppose the service quality deficiencies of smart bus service systems.*

H2b *Values of the elderly will lead them to oppose the management and operational chaos of smart bus service systems.*

H2c *Values of the elderly will lead them to oppose the low information accessibility of smart bus service systems.*

H2d *Values of the elderly will lead them to oppose the poor environmental atmosphere of smart bus service systems.*

H3 *Values of the elderly positively influence their attitudes towards smart bus service systems.*

H4a *Social equity positively influences elderly individuals' attitudes toward smart bus service systems.*

H4b *Usefulness positively influences elderly individuals' attitudes toward smart bus service systems.*

H4c *Social interaction positively influences elderly individuals' attitudes toward smart bus service systems.*

H5a *Service quality deficiencies negatively influences elderly individuals' attitudes toward smart bus service systems.*

H5b *Management and operational chaos negatively influences elderly individuals' attitudes toward smart bus service systems.*

H5c *Low information accessibility negatively influences elderly individuals' attitudes toward smart bus service systems.*

H5d *Poor environmental atmosphere negatively influences elderly individuals' attitudes toward smart bus service systems.*

H6a *Social equity positively influences elderly individuals' intention to use smart bus service systems.*

H6b *Usefulness positively influences elderly individuals' intention to use smart bus service systems.*

H6c *Social interaction positively influences elderly individuals' intention to use smart bus service systems.*

H7a *Service quality deficiencies negatively influences elderly individuals' intention to use smart bus service systems.*

H7b *Management and operational chaos negatively influences elderly individuals' intention to use smart bus service systems.*

H7c *Low information accessibility negatively influences elderly individuals' intention to use smart bus service systems.*

H7d *Poor environmental atmosphere negatively influences elderly individuals' intention to use smart bus service systems.*

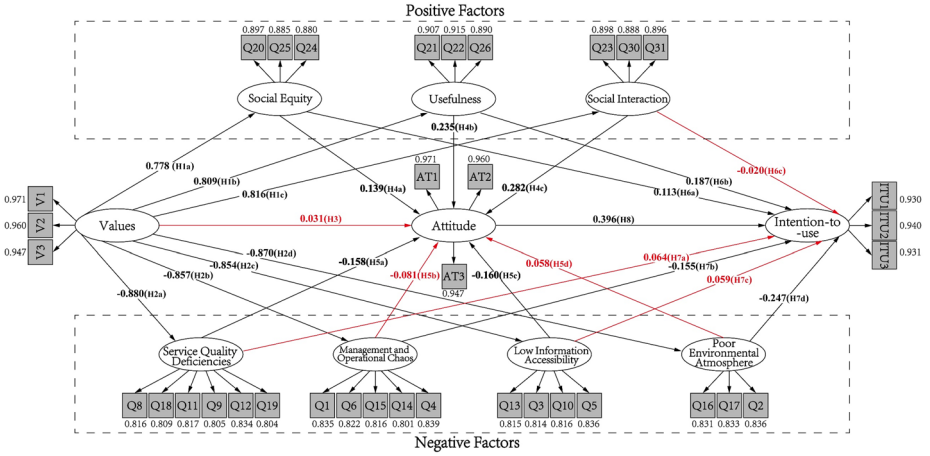
H8 *Attitudes of the elderly positively influences their intention to use smart bus service systems.*

Structural equation model analysis

Based on the theoretical hypotheses in Sect. 4.2.1, this study utilized AMOS software for model path analysis. The analysis results are shown in Table 10, where the *p*-values of H3, H5b, H5d, H6c, H7a, and H7c are greater than 0.05, indicating that these hypotheses are not supported. The remaining hypotheses are supported as their *p*-values are less than 0.05. The linear model is illustrated in Fig. 2.

Table 10 Structural equation model analysis results

Hypothesis	X	→	Y	Unstandardized regression coefficients	SE	z	*p*	Standardized regression coefficients	Result
H1a	V	→	SE	0.900	0.059	15.284	0.000	0.778	Supported
H1b	V	→	U	0.961	0.06	16.077	0.000	0.809	Supported
H1c	V	→	SI	0.971	0.06	16.065	0.000	0.816	Supported
H2a	V	→	SQD	− 0.724	0.046	− 15.904	0.000	− 0.880	Supported
H2b	V	→	MOC	− 0.732	0.046	− 15.829	0.000	− 0.857	Supported
H2c	V	→	LIA	− 0.681	0.044	− 15.363	0.000	− 0.854	Supported
H2d	V	→	PEA	− 0.696	0.044	− 15.79	0.000	− 0.870	Supported
H3	V	→	AT	0.044	0.357	0.123	0.902	0.031	Rejected
H4a	SE	→	AT	0.167	0.058	2.909	0.004	0.139	Supported
H4b	U	→	AT	0.276	0.062	4.472	0.000	0.235	Supported
H4c	SI	→	AT	0.331	0.064	5.164	0.000	0.282	Supported
H5a	SQD	→	AT	− 0.268	0.127	− 2.107	0.035	− 0.158	Supported
H5b	MOC	→	AT	− 0.132	0.108	− 1.229	0.219	− 0.081	Rejected
H5c	LIA	→	AT	− 0.279	0.117	− 2.391	0.017	− 0.160	Supported
H5d	PEA	→	AT	0.101	0.13	0.777	0.437	0.058	Rejected
H6a	SE	→	ITU	0.115	0.047	2.441	0.015	0.113	Supported
H6b	U	→	ITU	0.184	0.05	3.662	0.000	0.187	Supported
H6c	SI	→	ITU	− 0.019	0.053	− 0.367	0.714	− 0.020	Rejected
H7a	SQD	→	ITU	0.091	0.086	1.054	0.292	0.064	Rejected
H7b	MOC	→	ITU	− 0.213	0.077	− 2.764	0.006	− 0.155	Supported
H7c	LIA	→	ITU	0.087	0.086	1.017	0.309	0.059	Rejected
H7d	PEA	→	ITU	− 0.363	0.093	− 3.920	0.000	− 0.247	Supported
H8	AT	→	ITU	0.334	0.056	5.924	0.000	0.396	Supported



Note: Paths shown in red indicate hypotheses that were not supported.

Fig. 2 Behavioral model of intention to use age-friendly smart bus service systems

Comparative analysis of age-based group modeling

The elderly participants in this study were primarily concentrated in the 50–59 and 60–69 age groups. The 50–59 age group represents a critical transitional period from middle age to older adulthood and is an important intervention stage for promoting "active aging." On the other hand, the 60–69 age group falls within the officially defined elderly population in many countries. To gain deeper insights into the differences in attitudes and usage intentions toward smart bus services between these two groups, this study conducted separate modeling for each age group, allowing for a comparison of their evaluations and behavioral patterns regarding age-friendly smart bus services. The analysis results are shown in Table 11, where differences between the two groups are highlighted with a grey background. Overall, most of the path relationships in both models are consistent with the model shown in Fig. 2. However, there are differences between the two groups in the following path relationships: "Social Equity → Attitude," "Service Quality Deficiencies → Attitude," "Low Information Accessibility → Attitude," "Social Interaction → Intention to Use," "Service Quality Deficiencies → Intention to Use," and "Management and Operational Chaos → Intention to Use."

Table 11 Results of the age-based group modeling comparative analysis

X	→	Y	Older adults aged 50–59			Older adults aged 60–69		
			p	Standardized regression coefficients	Result	*p*	Standardized regression coefficients	Result
V	→	SE	0.000	0.731	Supported	0.000	0.823	Supported
V	→	U	0.000	0.773	Supported	0.000	0.836	Supported
V	→	SI	0.000	0.819	Supported	0.000	0.798	Supported
V	→	SQD	0.000	− 0.91	Supported	0.000	− 0.846	Supported
V	→	MOC	0.000	− 0.896	Supported	0.000	− 0.818	Supported
V	→	LIA	0.000	− 0.898	Supported	0.000	− 0.807	Supported
V	→	PEA	0.000	− 0.891	Supported	0.000	− 0.846	Supported
V	→	AT	0.528	0.313	Rejected	0.640	− 0.131	Rejected
SE	→	AT	0.728	0.021	Rejected	0.001	0.254	Supported
U	→	AT	0.003	0.206	Supported	0.002	0.245	Supported
SI	→	AT	0.000	0.318	Supported	0.000	0.281	Supported
SQD	→	AT	0.705	− 0.054	Rejected	0.016	− 0.200	Supported
MOC	→	AT	0.914	− 0.014	Rejected	0.163	− 0.104	Rejected
LIA	→	AT	0.829	− 0.029	Rejected	0.001	-− 0.243	Supported
PEA	→	AT	0.795	− 0.033	Rejected	0.116	0.14	Rejected
SE	→	ITU	0.069	0.102	Rejected	0.178	0.105	Rejected
U	→	ITU	0.002	0.199	Supported	0.049	0.154	Supported
SI	→	ITU	0.047	0.148	Supported	0.053	− 0.146	Rejected
SQD	→	ITU	0.007	0.254	Supported	0.363	− 0.073	Rejected
MOC	→	ITU	0.009	− 0.231	Supported	0.38	− 0.065	Rejected
LIA	→	ITU	0.979	0.002	Rejected	0.107	0.125	Rejected
PEA	→	ITU	0.001	− 0.31	Supported	0.003	− 0.262	Supported
AT	→	ITU	0.003	0.259	Supported	0.000	0.528	Supported

Discussion

Discussion of behavioral model results

Influence of values

H1a/b/c and H2a/b/c are all supported, indicating that the openness values of elderly individuals positively influence social equity, usefulness, and social interaction while negatively impacting service quality deficiencies, operational chaos, low information accessibility, and poor environmental atmosphere. This finding further suggests that personal values lead older adults to support the positive aspects of the service while resisting its negative aspects, consistent with prior studies applying Behavioral Reasoning Theory (BRT) to predict usage intentions (Ashfaq et al. 2021; Wang et al. 2024; Westaby 2005; Yadav et al. 2022). This highlights the critical role of personal values in shaping individual behavior, suggesting that relevant organizations should prioritize value-oriented guidance and promotion. For instance, through multiple channels—such as mobile applications, bus stops, and short-video platforms—organizations can showcase the benefits of smart bus services, encouraging older adults to adopt more positive and open-minded values. This, in turn, can enhance their appraisal of advantageous features while reducing undue attention to negative aspects.

Notably, H3 was not supported, indicating that older adults' preexisting values do not directly shape their attitudes toward the service. Although values function as internal behavioral norms and evaluative standards (Jørgensen 2006), older users encountering an emerging service such as smart bus services do not rely on these inherent values to form immediate judgments. Instead, values influence attitudes indirectly through the service's specific characteristics, encompassing both positive and negative factors. This finding challenges the conventional stereotype that older adults are inherently conservative and resistant to new technologies (Glenn 1974), highlighting that the service's actual performance and attributes are the key determinants of attitudinal evaluation and subsequent behavioral intention.

Comparison between attitudes and intention to use

Attitude is regarded as an individual's overall evaluation of external services or conditions and is widely recognized as a key mediating variable influencing user intention (Indriani et al. 2019). This conclusion is also supported in this study (H8 is supported), with the path coefficient between attitude and usage intention significantly higher than that of other factors. This indicates that users' overall evaluation of the service is the primary determinant of their intention to use it. Other factors influence usage intention either directly or indirectly through attitude. Therefore, in this study, factors that directly affect usage intention can be considered necessary triggers for user behavior, whereas those that influence intention indirectly through attitude serve only as key indicators in users' comprehensive service evaluation.

In positive factors, both H4a and H6a are supported, indicating that social equity positively influences both users' attitudes and usage intentions. This suggests that social equity is not only an important indicator for evaluating the quality of smart bus services for the

elderly but also one of the necessary conditions for influencing their usage intention. The social equity attribute reflects, to some extent, the elderly's pursuit of personal dignity. This is because elderly people, with rich work and life experiences, feel a sense of superiority within the context of China's traditional culture of respecting the elderly, and place more importance on personal dignity (Po Wah 2007). Consequently, they become more averse to being treated differently (Mégret 2011). Therefore, when the social equity attribute of smart bus services allows the elderly to travel anywhere at a lower cost according to their habits and enables them to ride the bus fairly, just like the general population, it significantly enhances their evaluation of the service and increases their willingness to use it. Meanwhile, in age-based grouped modeling analyses, social equity does not significantly affect the attitudes of older adults aged 50–59 but exerts a direct influence on those aged 60 and above. This indicates that as individuals age, they place increasing importance on fairness and respect. Therefore, companies providing these services should pay increasing attention to social equity for older adults, particularly for the oldest segments of this population. This can include offering certain benefits or policy preferences for this vulnerable group, such as fare discounts and concessions, as well as improving accessibility within buses—for example, by deploying low-floor vehicles and barrier-free pathways—so that older adults can use these services on an equal footing. Additionally, service personnel on board should maintain a respectful and supportive attitude toward older passengers, avoiding any form of age-related discrimination.

Furthermore, both H4b and H6b are supported, indicating that usefulness positively influences both the elderly's overall attitude toward the service and their usage intention. This is consistent with previous research on user intention (Kasilingam 2020; Tjokrosaputro 2023). Additionally, the path coefficient between usefulness and usage intention is 0.187, which is higher than that of other factors, indicating that usefulness is a key determinant of the elderly's usage intention among positive factors. Therefore, relevant enterprises should give priority to this factor. For instance, they can leverage Geographic Information System (GIS) and Global Positioning System (GPS) data to provide real-time bus tracking, promptly disseminating this information via bus stops and mobile applications to keep users updated on bus movements. Additionally, companies can employ collaborative filtering, content-based filtering, and hybrid recommendation algorithms to understand older adults' travel needs and provide personalized route suggestions, thereby enhancing the usefulness of smart bus services.

Finally, H4c is supported but H6c is not, indicating that the social interaction attribute of the service positively influences users' overall evaluation of the service but does not directly impact their usage intention. This is because a good social interaction attribute not only helps elderly individuals use the smart bus service better but also satisfies their social needs (Luo and Waite 2014), which can enhance their overall evaluation of the service. However, the interaction with service providers is merely an auxiliary factor in helping the elderly perceive the service as useful. Despite the elderly's social needs, public transportation is not the only means for maintaining social circles, which leads to users not intentionally using the service for social interaction purposes.

In age-based grouped modeling analyses, social interaction positively influences the behavioral intentions of older adults aged 50–59 but has no significant effect on those aged

60 and above. This indicates that individuals under 60 exhibit greater behavioral plasticity and are more likely to adjust their behavior in response to social interaction needs. Accordingly, service providers should establish accessible complaint mechanisms, maintain a positive service attitude, and permit users to engage in voluntary communication. Moreover, promotional efforts emphasizing the social interaction benefits of the service should primarily target older adults under 60, thereby guiding the formation of relevant behavioral patterns in advance.

In negative factors, H5a and H5c are supported, while H7a and H7c are not, indicating that service quality deficiencies and low information availability negatively impact users' attitude evaluation but do not directly affect their usage intention. Service quality defects reflect the service's shortcomings in terms of convenience, comfort, safety, usability, etc., while low information availability reflects the service's lack of information provision. These issues significantly influence the overall evaluation of the service. However, they do not affect the elderly's core goal of using the service to reach their destination. Therefore, these two factors only influence the users' overall attitude evaluation but do not directly decrease their usage intention.

Notably, these dimensions exhibit age-specific differences. For older adults under 60, neither service quality deficiencies nor low information accessibility significantly affect attitudes. In contrast, for those aged 60 and above, both factors directly influence attitudinal evaluations, indicating that sensitivity to these issues increases with age. While low information accessibility does not reduce usage intention in either group, service quality deficiencies directly affect the usage intention of individuals under 60, suggesting that younger older adults have higher expectations and are more likely to reject services that fail to meet their experiential needs. Therefore, to foster more positive user attitudes and prevent the loss of users under 60, service providers should ensure clear, stable, and appropriately volumed onboard announcements, while providing real-time arrival reminders and traffic updates via mobile applications to help passengers avoid missing stops and stay informed about vehicle conditions. Meanwhile, existing service quality deficiencies should be addressed—for example, by replacing damaged or uncomfortable infrastructure and simplifying system operation processes. Through these measures, improvements can be achieved in both information accessibility and overall service quality.

In contrast, H5b and H5d are not supported, while H7b and H7d are supported, indicating that management disorganization and a poor environmental atmosphere will directly reduce users' usage intention but will not affect their attitude evaluation of the service. First, when service management and operations are too disorganized, elderly individuals cannot properly schedule their travel times, which affects their core goal of traveling, ultimately leading to a reduction in their willingness to use the service. However, in age-based grouped modeling, the Management and Operational Chaos dimension had no effect on the behavioral intentions of adults aged 60 and above, further indicating that this age group tends to be more conservative, less likely to alter established habits, and consequently exhibits greater tolerance for service shortcomings.

Second, a poor environmental atmosphere also directly affects usage intention because elderly individuals, due to their declining physical abilities, are at a higher risk of accidents (e.g., falls) in daily life. This increases their need for more control over the spatial envi-

ronment (Barnes 2006), and a complicated environment adds cognitive load, making the elderly reject such environments (Cassarino and Setti 2016). Therefore, when elderly passengers experience a poor environment on the bus, they are likely to feel repelled, which directly decreases their usage intention. Additionally, the path coefficient between poor environmental atmosphere and usage intention is slightly higher in absolute value than that of management disorganization, indicating that elderly individuals are more concerned with the environment on the bus. Therefore, service providers could strategically leverage these two disadvantageous conditions to effectively guide the daily travel behavior of older adults. For instance, they might inform elderly passengers of potential operational disruptions or suboptimal environmental conditions during peak hours and recommend alternative travel times, thereby alleviating traffic congestion.

Finally, by comparing the subtle behavioral differences between the two age groups, it is evident that older adults aged 50–59 exhibit greater behavioral flexibility due to their stronger capacity for action and higher sense of agency, making their responses to service advantages and shortcomings more pronounced. In contrast, adults aged 60 and above demonstrate more conservative behavioral patterns and are less likely to alter established routines. From a service promotion and operations perspective, efforts should prioritize the 50–59 age group, attracting them with high-quality services and fostering habitual usage. As they transition into the 60 + group, they are more likely to show higher loyalty and less likely to switch travel modes, thereby enhancing the service provider's resilience and reducing marketing costs. For adults over 60, the focus should be on improving the quality of services they are already familiar with, emphasizing operational efficiency and safety, while minimizing changes to established usage patterns, as introducing entirely new services to this group entails greater difficulty and expense.

Theoretical and practical significance

The evaluation scale and behavioral model for elderly smart bus adoption developed in this study have significant theoretical and practical implications. Theoretically, as population aging intensifies, the elderly—a large and growing group with physical limitations compared to younger individuals—warrant deeper academic exploration but have long been overlooked. This study addresses this gap by investigating their user experience with smart bus services. Moreover, previous studies have primarily focused on positive factors influencing smart bus adoption, neglecting negative aspects. Grounded in the BRT framework, this study not only develops a comprehensive evaluation scale covering both positive and negative dimensions but also examines how personal values shape user experience. This offers a more holistic research perspective and theoretical foundation for future studies on smart bus services.

In practice, this study provides a theoretical foundation for the design and optimization of related services. Meanwhile, the developed user experience evaluation scale serves as a crucial guide throughout service design, implementation, promotion, and refinement. In the design phase, the evaluation scale and behavioral model help enterprises define design objectives and formulate implementation plans. During implementation, the behavioral model clarifies key design focuses, enabling efficient resource allocation to maximize user

adoption. In the promotion phase, the model identifies critical factors influencing user intention, guiding targeted marketing strategies to enhance user attraction. For service refinement, the evaluation scale functions as a user research tool, facilitating feedback collection via questionnaires. This allows service providers to identify strengths and shortcomings, enabling continuous optimization. In summary, this study holds significant theoretical and practical value.

Conclusion

Research conclusions

This study integrates user interviews, literature review, factor analysis, SEM, and other quantitative and qualitative research methods to develop a user experience evaluation scale and usage intention behavior model for aging-friendly smart bus service systems. Additionally, it conducts a comparative modeling analysis for elderly individuals aged 50–59 and 60–69 to explore the psychological and behavioral differences between these two groups. Based on the research findings, the study provides design and management recommendations with significant practical implications. On one hand, this research fills gaps in previous studies and offers a more comprehensive perspective on the study of smart bus service systems. On the other hand, it provides a solid theoretical foundation and reference for the optimization and upgrading of relevant industries. This research has significant research and practical value. The main conclusions of this study are as follows:

(1) This study's user experience evaluation scale includes seven elements. The positive factors are Social Equity, Usefulness, and Social Interaction. The negative factors are Service Quality Deficiencies, Management and Operational Chaos, Low Information Accessibility, and Poor Environmental Atmosphere.
(2) The values of the elderly positively influence all positive factors and negatively influence all negative factors, but they do not affect the attitude evaluation of the elderly.
(3) Among the positive factors, Social Equity and Usefulness positively influence user attitude evaluation and intention to use. In contrast, Social Interaction can only indirectly influence the intention to use through attitude evaluation.
(4) Among the negative factors, Management and Operational Chaos, and poor Environmental Atmosphere directly negatively influence the intention to use of the elderly. Service Quality Deficiencies and Low Information Accessibility can only negatively influence the intention to use indirectly through attitude.
(5) Elderly individuals aged 50–59 are more behavior-driven and are more likely to make direct behavioral decisions based on both the positive and negative aspects of the service. This age group represents a critical opportunity for promoting new services and shaping the behavior of elderly users.
(6) Elderly individuals aged 60–69 tend to exhibit more conservative behavior, demonstrating higher loyalty and tolerance toward familiar smart transportation services. They are less likely to alter their established behavioral patterns easily.

Limitations and future directions

Although this study has comprehensively developed a user experience evaluation scale for older adults and constructed a behavioral model of usage intention—substantially addressing the limitations of previous research—certain shortcomings remain that could be addressed and refined in future studies. First, the target population of this study comprised individuals aged 50 and above. However, due to practical constraints during questionnaire collection, the valid sample predominantly consisted of individuals aged 50–69. While this age range falls within the general elderly population and, according to continuity theory, can partially reflect the behaviors and psychological traits of those aged 70 and above, it nonetheless overlooks the specific needs and characteristics of the 70 + age group. This limitation may lead to partial misalignment between the study's findings and the actual experiences of older seniors. Therefore, future research should place greater emphasis on this demographic to achieve a more comprehensive understanding.

Second, this study primarily focused on smart mobility services, particularly smart bus services, which possess strong public attributes and promote social equity as a core function. The study aimed to develop a generalizable age-friendly smart bus service evaluation scale. Moreover, all participants had prior experience and habitual use of smart bus services, ensuring that respondents were physically capable of using such services. Consequently, age was treated as the core variable influencing usage intention and behavioral logic, with age also serving as a proxy for retirement status to some extent. Accordingly, only basic demographic information—such as age, gender, and employment status—was collected. During data analysis, age was used as the primary variable for in-depth group modeling and comparative analysis, while other potentially influential factors, such as retirement status, physical condition, income level, and travel preferences, were not collected or controlled for. This omission may have affected the rigor and precision of the study's findings. Future research should therefore collect more detailed demographic data and perform targeted comparative analyses based on these characteristics to further refine and enhance the accuracy of the results.

Finally, the behavioral model constructed in this study mainly focuses on the user experience elements of the smart bus service system, lacking consideration of users' psychological states and social environmental factors. Therefore, future research could further supplement the existing model by referencing more established theoretical models.

Appendix I: Supplementary tables of data analysis results not reported in the main text due to space constraints

See (Tables 12, 13, 14, and 15).

Table 12 Exploratory factor analysis results for all constructs included in the behavioral model

ID	Mean user rating score	Factor loading coefficients										Communality
		SQD	MOC	V	SE	LIA	U	SI	ITU	PEA	AT	
Q8	2.779	**0.657**	0.279	− 0.115	− 0.135	− 0.228	− 0.209	0.220	− 0.194	0.096	− 0.035	0.733
Q18	2.842	**0.651**	0.251	− 0.156	− 0.198	− 0.143	− 0.090	0.268	− 0.092	0.185	− 0.151	0.717
Q11	2.855	**0.661**	0.282	− 0.143	− 0.197	− 0.145	− 0.141	0.182	− 0.092	0.204	− 0.155	0.723
Q9	2.901	**0.653**	0.262	− 0.219	− 0.151	− 0.120	− 0.148	0.217	− 0.16	0.154	− 0.086	0.707
Q12	2.909	**0.696**	0.259	− 0.138	− 0.119	− 0.140	− 0.204	0.152	− 0.118	0.190	− 0.217	0.766
Q19	2.833	**0.744**	0.238	− 0.114	− 0.074	− 0.173	− 0.127	0.225	− 0.200	0.096	0.011	0.775
Q1	2.893	0.276	**0.705**	− 0.118	− 0.151	− 0.191	− 0.177	0.242	− 0.15	0.138	− 0.04	0.779
Q6	2.954	0.291	**0.67**	− 0.150	− 0.15	− 0.11	− 0.142	0.162	− 0.147	0.255	− 0.171	0.753
Q15	2.833	0.296	**0.726**	− 0.130	− 0.162	− 0.156	− 0.133	0.253	− 0.179	0.014	− 0.018	0.796
Q14	2.875	0.376	**0.618**	− 0.128	− 0.088	− 0.091	− 0.003	0.225	− 0.205	0.262	− 0.120	0.732
Q4	2.901	0.331	**0.647**	− 0.163	− 0.139	− 0.082	− 0.167	0.237	− 0.131	0.229	− 0.149	0.756
Q20	4.531	− 0.185	− 0.155	0.309	**0.747**	0.165	0.177	− 0.136	0.195	− 0.118	0.113	0.853
Q25	4.485	− 0.125	− 0.142	0.262	**0.792**	0.231	0.183	− 0.115	0.168	− 0.092	0.067	0.873
Q24	4.447	− 0.216	− 0.181	0.191	**0.78**	0.176	0.200	− 0.126	0.156	− 0.110	0.123	0.862
Q3	2.873	0.398	0.304	− 0.049	− 0.143	− 0.149	− 0.105	**0.608**	− 0.153	0.251	− 0.030	0.764
Q10	2.886	0.338	0.302	− 0.124	− 0.145	− 0.130	− 0.143	**0.648**	− 0.102	0.177	− 0.126	0.757
Q5	2.860	0.34	0.372	− 0.163	− 0.101	− 0.123	− 0.187	**0.569**	− 0.147	0.227	− 0.078	0.743
Q13	2.862	0.316	0.303	− 0.14	− 0.143	− 0.062	− 0.102	**0.685**	− 0.169	0.144	− 0.158	0.789
Q21	4.511	− 0.234	− 0.184	0.270	0.234	0.26	**0.689**	− 0.156	0.209	− 0.150	0.110	0.862
Q22	4.518	− 0.224	− 0.157	0.207	0.239	0.249	**0.758**	− 0.132	0.197	− 0.110	0.115	0.894
Q26	4.502	− 0.18	− 0.147	0.233	0.184	0.267	**0.761**	− 0.116	0.213	− 0.093	0.131	0.878
Q23	4.436	− 0.211	− 0.143	0.27	0.239	**0.726**	0.277	− 0.134	0.181	− 0.108	0.089	0.869
Q30	4.441	− 0.212	− 0.171	0.247	0.202	**0.757**	0.236	− 0.112	0.156	− 0.088	0.144	0.869
Q31	4.478	− 0.241	− 0.166	0.26	0.219	**0.71**	0.253	− 0.089	0.174	− 0.163	0.138	0.852
Q16	2.741	0.293	0.330	− 0.113	− 0.183	− 0.227	− 0.188	0.228	− 0.177	**0.606**	-0.065	0.782
Q17	2.846	0.362	0.275	− 0.118	− 0.142	− 0.077	− 0.130	0.297	− 0.221	**0.653**	-0.05	0.83
Q2	2.846	0.340	0.336	− 0.157	− 0.128	− 0.173	− 0.126	0.297	− 0.169	**0.568**	-0.113	0.767

Table 12 (continued)

ID	Mean user rating score	Factor loading coefficients									Communality
		SQD	MOC	V	SE	LIA	U	SI	ITU	PEA	AT	
AT1	4.336	− 0.311	− 0.240	0.235	0.264	0.326	0.278	− 0.236	0.334	− 0.112	**0.548**	0.944
AT2	4.349	− 0.322	− 0.254	0.235	0.249	0.336	0.329	− 0.22	0.275	− 0.144	**0.529**	0.931
AT3	4.353	− 0.295	− 0.231	0.232	0.268	0.318	0.278	− 0.244	0.284	− 0.096	**0.582**	0.932
ITU1	4.456	− 0.231	− 0.237	0.200	0.217	0.208	0.247	− 0.153	**0.713**	− 0.148	0.246	0.915
ITU2	4.482	− 0.27	− 0.254	0.197	0.226	0.202	0.267	− 0.169	**0.714**	− 0.176	0.098	0.918
ITU3	4.474	− 0.22	− 0.25	0.232	0.252	0.195	0.219	− 0.183	**0.727**	− 0.187	0.084	0.917
V1	4.322	− 0.177	− 0.124	**0.781**	0.239	0.223	0.208	− 0.092	0.20	− 0.102	0.074	0.872
V2	4.292	− 0.163	− 0.193	**0.796**	0.230	0.192	0.168	− 0.103	0.13	− 0.079	0.166	0.876
V3	4.294	− 0.192	− 0.139	**0.76**	0.263	0.240	0.215	− 0.134	0.134	− 0.088	0.032	0.852

Table 13 Reliability and validity analysis results for all constructs in the behavioral model

	SQD	MOC	V	SE	LIA	U	SI	ITU	PEA	AT
Reliability analysis (Cronbach α)	0.922	0.913	0.92	0.917	0.923	0.93	0.891	0.953	0.872	0.972
KMO and Bartlett's test										
KMO	0.977									
Bartlett's Sphericity test	$p=0.000$									

Table 14 Confirmatory factor analysis of evaluation scale

Factor	ID	Coef.	Std. error	z	*p*	Std. estimate	AVE	CR
Service quality deficiencies	Q8	1.000	–	–	–	0.817	0.663	0.922
	Q18	0.971	0.048	20.343	0.000	0.812		
	Q11	1.005	0.049	20.544	0.000	0.817		
	Q9	0.971	0.048	20.072	0.000	0.804		
	Q12	1.052	0.050	21.054	0.000	0.831		
	Q19	1.004	0.050	20.163	0.000	0.807		
Management and operational chaos	Q1	1.000	–	–	–	0.830	0.677	0.913
	Q6	0.956	0.045	21.017	0.000	0.819		
	Q15	0.96	0.046	20.646	0.000	0.809		
	Q14	0.968	0.047	20.766	0.000	0.813		
	Q4	1.023	0.047	21.928	0.000	0.842		
Social equity	Q20	1.000	–	–	–	0.891	0.788	0.918
	Q25	0.958	0.036	26.853	0.000	0.890		
	Q24	0.962	0.036	26.395	0.000	0.881		
Low information accessibility	Q13	1.000	–	–	–	0.807	0.672	0.891
	Q3	1.084	0.053	20.339	0.000	0.827		
	Q10	1.058	0.054	19.742	0.000	0.809		
	Q5	1.134	0.055	20.647	0.000	0.836		
Usefulness	Q21	1.000	–	–	–	0.905	0.817	0.931
	Q22	0.971	0.032	30.772	0.000	0.917		
	Q26	0.981	0.034	28.817	0.000	0.890		
Social interaction	Q23	1.000	–	–	–	0.902	0.799	0.923
	Q30	0.961	0.035	27.801	0.000	0.885		
	Q31	1.015	0.036	28.443	0.000	0.895		
Poor environmental atmosphere	Q16	1.000	–	–	–	0.823	0.694	0.872
	Q17	1.053	0.050	20.943	0.000	0.836		
	Q2	1.031	0.049	21.124	0.000	0.841		

Table 15 Discriminant validity analysis of the evaluation scale

	SQD	MOC	SE	LIA	U	SI	PEA
SQD	**0.814**						
MOC	0.789	**0.823**					
SE	− 0.568	− 0.548	**0.887**				
LIA	0.799	0.803	− 0.531	**0.82**			
U	− 0.623	− 0.572	0.641	− 0.567	**0.904**		
SI	− 0.629	− 0.568	0.645	− 0.545	0.734	**0.894**	
PEA	0.77	0.779	− 0.55	0.790	− 0.585	− 0.582	**0.833**

The numbers with hatched diagonal lines are the square roots of AVE

Appendix II: Survey questionnaire

Research questionnaire on the user experience and willingness to use aging-friendly smart bus services

Research Questionnaire on the User Experience and Willingness to Use Aging-Friendly Smart Bus Services

Informed Consent Form

Dear Participant,

Hello! Thank you for agreeing to participate in our research. This study aims to construct an aging-friendly smart bus user experience evaluation scale and usage willingness behavior model. Your participation will help improve the effectiveness of smart bus services for the elderly.

1. Purpose and Content of the Study:

This research primarily involves a questionnaire survey to collect data on the elderly users' experiences and willingness to use smart bus services. Your responses will help us better understand the needs of elderly individuals within the smart bus system, optimize service design, and improve user experience.

2. Eligibility:

The target participants for this study are elderly individuals who have experience and habits using smart bus services. Specifically, individuals who are accustomed to using the accompanying smart bus service app or mini-program while riding public buses. Additionally, participants must be over 50 years old.

3. Data Use and Privacy Protection:

Your personal information and responses will be kept strictly confidential and used solely for the analysis of this study. All data will be processed anonymously, and no personal identifying information will be disclosed. Participation is completely voluntary, and you may choose to withdraw at any time without any negative consequences.

4. Risks and Benefits of Participation:

There are no risks or discomforts associated with this study. You will not be under any pressure or disturbance while participating. After completing the questionnaire, you will receive a 3 RMB reward as appreciation for your time, and your valuable feedback will contribute significantly to the future development of smart bus services.

5. Results and Report:

The results of this study will be used for academic research and professional reports. The final outcomes will be published in relevant academic journals or presented at conferences. The data collected will be used for summary analysis, and no personal information will be disclosed.

6. Your Rights:

You have the right to withdraw from the survey at any time without providing any reason. If you choose to withdraw, all data you have provided will be completely deleted to ensure your personal information remains secure.

7. Participation:

Please read the above information carefully and decide whether you wish to participate in this survey. If you agree to participate, please click on the option "I acknowledge and agree to participate in this research study" before starting the questionnaire.

○ I acknowledge and agree to participate in this research study

Screening Questions

The following are screening questions. This study needs to confirm whether you meet the target demographic for the research. Please answer truthfully.

1. Are you aged 50 or older?

○ YES
○ NO

2. Do you have the habit of traveling by bus and have you used a smart bus service system application during this process?

○ YES
○ NO

Basic Information Section

1. What is your gender?

○ Male
○ Female

2. What is your age?

○ 50-59
○ 60-69
○ 70-79
○ 80 or above

3. What is your current/former occupation?

○ Public Institution
○ Civil Servant
○ State-Owned Enterprise
○ Foreign-Invested Enterprise
○ Private Enterprise

User Scale Evaluation Section

1. I would be willing to use a smart bus service system (offline bus services + smart bus application) when it provides the following features.

	Strongly Disagree	**Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Agree**	**Strongly Agree**
Passengers not queuing, chaotic and disorderly	○	○	○	○	○	○	○
During peak hours, the interior space of the vehicle is crowded	○	○	○	○	○	○	○
Real-time arrival information of buses is inaccurate	○	○	○	○	○	○	○

Waiting time for buses is excessively long	○	○	○	○	○	○	○
Arrival notification sound is low	○	○	○	○	○	○	○
Bus stopping time is too short	○	○	○	○	○	○	○
Waiting experience at bus stops is greatly affected by the weather	○	○	○	○	○	○	○
Seating comfort of buses is low	○	○	○	○	○	○	○
Difficulties in boarding and alighting from buses via accessible pathways	○	○	○	○	○	○	○
Text on bus station platforms is too small	○	○	○	○	○	○	○
Bus door access control system is imperfect, posing safety risks	○	○	○	○	○	○	○
The payment speed is slow	○	○	○	○	○	○	○
Few arrival notifications	○	○	○	○	○	○	○
Irregular scheduling of bus services	○	○	○	○	○	○	○
Unstable speed during bus operation	○	○	○	○	○	○	○
Interior environment of the vehicle is noisy	○	○	○	○	○	○	○
There is an odor inside the bus	○	○	○	○	○	○	○
There are few seats inside the bus	○	○	○	○	○	○	○

Complex system operation	○	○	○	○	○	○	○
Low bus fare	○	○	○	○	○	○	○
Efficient route planning to reduce time wastage	○	○	○	○	○	○	○
Real-time bus location tracking	○	○	○	○	○	○	○
Effective and rapid feedback and complaint handling for issues in the service	○	○	○	○	○	○	○
Bus routes cover various areas	○	○	○	○	○	○	○
Anyone can take the bus	○	○	○	○	○	○	○
Provision of real-time operational updates (e.g., congestion, incidents, and service disruptions)	○	○	○	○	○	○	○
Promote urban planning	○	○	○	○	○	○	○
Effectively prevent traffic accidents	○	○	○	○	○	○	○
Alleviate traffic congestion	○	○	○	○	○	○	○
Staff have a good attitude	○	○	○	○	○	○	○
Maintain and expand personal social networks	○	○	○	○	○	○	○

2. This section aims to understand your values characteristics.

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
I enjoy experiencing new things	○	○	○	○	○	○	○
I am open to new experiences	○	○	○	○	○	○	○
I actively look for new technologies to adopt	○	○	○	○	○	○	○

3. This section aims to understand your attitude towards the smart bus service.

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
I am interested in using the smart bus service system app during bus travel.	○	○	○	○	○	○	○
I think using the smart bus service system app during bus travel is a good approach.	○	○	○	○	○	○	○
I would consider using the smart bus service system app during bus travel as an option in the future.	○	○	○	○	○	○	○

4. This section aims to understand your intention to use the smart bus service.

	Strongly Disagree	Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Agree	Strongly Agree
I plan to use the smart bus service system app during bus travel in the near future.	○	○	○	○	○	○	○
I am willing to use the smart bus service system app during bus travel.	○	○	○	○	○	○	○
I would recommend others to use the smart bus service system app during bus travel.	○	○	○	○	○	○	○

Acknowledgements Thanks to Jiangnan University for supporting this study.

Author contributions Z. W. : Conceptualization, Methodology, Software, Validation, Investigation, Writing—Original Draft, Visualization. M. M. : Writing—Review & Editing. R. D. : Project administration, Writing—Review & Editing. A. A. : Writing—Review & Editing. Z. Y. W. : Writing—Original Draft. D. X. : Writing—Review & Editing. J. L. : Writing—Original Draft.

Funding This work was supported by the Postgraduate Research & Practice Innovation Program of Jiangsu Province [KYCX25_2626]; the China Scholarship Council [202506790034]; the General Project of National Social Science Foundation of China in Art [21BG131]; the China Foreign Experts Affairs [G2023144005]; and the General Project of Philosophy and Social Science Research in Higher Education Institutions [2024SJYB0651].

Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interests The authors declare no conflict of interests.

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