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Factors Influencing Middle-Aged and Older Adults' Intention to Use Mobile Banking Applications from an Age-Friendly Perspective: An Empirical Analysis based on the Technology Acceptance Model

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Abstract

As banking services increasingly shift from physical branches to mobile applications, users are expected to manage routine financial tasks through self-operated digital interfaces, while population aging has increased the need to examine whether mobile banking applications are accessible to older user groups. For many middle-aged and older adults, mobile banking use remains difficult because transaction procedures, security warnings, authentication steps, and unfamiliar interface designs may create both operational burden and psychological uncertainty. This study investigates how middle-aged and older adults form intentions to use mobile banking by adapting the Technology Acceptance Model to an age-friendly service context and incorporating perceived risk, digital literacy, intergenerational support, age group, and education level. The empirical analysis was based on 552 valid questionnaire responses. The survey data were analyzed using a staged approach that assessed measurement quality, explored latent factor patterns, tested variable associations, built regression models, and examined mediation and moderation mechanisms. Exploratory factor analysis revealed an overlap between several perceived usefulness items and behavioral intention items. Accordingly, the later empirical analysis used perceived efficiency benefits as the main observable dimension of the usefulness-related construct. Respondents reported a generally strong willingness to use mobile banking, particularly when the applications were perceived as helpful in shortening waiting time, reducing visits to offline branches, and completing routine financial tasks more efficiently. The empirical findings show that ease of operation and efficiency-related value are important drivers of mobile banking use intention. Middle-aged and older adults are more inclined to adopt such services when the interface is understandable, the procedures are easy to follow, and the application offers observable improvements in service efficiency. Digital literacy and intergenerational support also play supportive roles by increasing users' confidence and providing help with registration, operation, and problem-solving. The correlation results show that higher risk concerns correspond to lower willingness to use mobile banking; however, this effect becomes less consistent once the model controls for other predictors. The mediation tests further suggest two mechanisms: perceived efficiency benefits may increase intention partly by lowering perceived risk, and digital literacy serves as an important pathway through which ease of use is translated into stronger usage intention. No significant moderating role was found for intergenerational support, digital literacy, age group, or education level in the link between perceived risk and usage intention. These findings imply that banks should combine product-level optimization with service-level support, such as clearer interface layouts, simplified transaction processes, stronger guidance on frequently used functions, digital-literacy assistance, and cooperative support involving both family members and banking staff.

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Keywords

Age-friendly Design; Middle-aged and Older Adults; Mobile Banking Applications; Technology Acceptance Model.

1. Introduction

The development of mobile Internet, smartphone-based services, and financial technology has reshaped the way commercial banks deliver services, moving many routine banking activities from physical branches to digital and mobile channels. Mobile banking applications now serve as a frequent entry point for daily financial activities, including balance inquiries, transfers, payments, wealth-management services, appointment booking, and customer support. Unlike branch-based services, mobile banking allows users to complete many tasks without visiting a counter, thereby reducing waiting time, lowering service costs, and supporting banks' broader digital transformation.

These changes are occurring alongside a rapidly aging population, which makes the accessibility of digital financial services an increasingly important issue. For middle-aged and older adults, banking services are closely connected with everyday life, including pension-related transactions, balance inquiries, money transfers, utility and bill payments, savings-related services, and routine consumer payments. However, mobile banking can be challenging for this group because financial operations often require accurate input, identity verification, password management, and careful reading of risk reminders. Interface complexity, small font sizes, multi-step procedures, and fear of mistakes may therefore discourage independent use. Understanding why older users are willing or unwilling to use mobile banking is therefore essential for evaluating whether digital financial services are genuinely age-friendly.

The TAM provides a useful theoretical basis for explaining why individuals accept or reject information technologies, especially through users' evaluations of usefulness and ease of use [1]. In the mobile banking applications context, these two constructs can be understood as whether users believe the application improves financial-service efficiency and whether they feel capable of completing transactions with limited effort [1]. Prior mobile-banking research further suggests that adoption is shaped not only by convenience and ease of operation, but also by trust in the service suppliers, perceived security, and concerns about potential risk [2–9]. For middle-aged and older users, mobile banking differs from many daily-life applications because each operation may involve personal assets, identity verification, privacy protection, and transaction safety. Their intention to use mobile banking applications is therefore likely to depend on multiple factors, including perceived functional value, ease of operation, risk perception, digital literacy, and support from family members or service providers.

Existing studies on older adults' digital inclusion and age-friendly financial services have paid attention to interface accessibility, service convenience, digital skills, and inequalities in digital access and benefits [10–14]. Other studies have emphasized that older adults' technology use is influenced by their digital skills, learning confidence, and support from younger family members [15–19]. Nevertheless, mobile banking has not been sufficiently examined as a distinct financial scenario for middle-aged and older users, even though it combines digital-operation difficulty with direct financial-risk perception.

Several gaps can still be identified. First, many mobile-banking studies focus on general consumers and give limited attention to older users' physical conditions, cognitive characteristics, risk sensitivity, and uneven digital experience. Second, research on age-friendly design and the digital divide often discusses usability, access, or skills separately, rather than combining TAM variables with perceived risk, digital literacy, and intergenerational support in a unified model. Third, mobile banking creates a practical tension for older users: they may

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recognize its necessity for daily financial management while remaining concerned about operational mistakes, fraud, privacy leakage, or financial loss. For this reason, explaining adoption only through technical convenience may overlook the roles of risk perception, user capability, and family-based assistance.

To fill these gaps, this study situates TAM in the context of age-friendly mobile banking and expands the model by adding perceived risk, digital literacy, intergenerational support, age group, and education level. Using questionnaire-based evidence, it investigates the factors that shape middle-aged and older adults' intention to use mobile banking and further examines possible mediation and moderation effects. The study is intended to inform the design of mobile banking services that are easier to understand, safer to operate, and more supportive of older users' everyday financial needs.

2. Literature Review and Theoretical Foundation

2.1. Theoretical Analysis and Research Hypotheses

According to the TAM, users' adoption of an information system is closely related to how they evaluate the system's functional value and operational effort [1]. In this study, perceived usefulness refers to older users' judgment that mobile banking can help them complete everyday financial tasks more efficiently, including account inquiries, money transfers, bill settlement, and fewer visits to physical bank branches. For middle-aged and older adults, the usefulness of mobile banking applications is not only reflected in the availability of financial functions, but also in whether these functions save time, reduce queuing, and make routine services easier to access. When users recognize these practical benefits, their willingness to adopt the application is likely to increase.

H1: Perceived usefulness has a positive effect on middle-aged and older adults' intention to use mobile banking applications.

For middle-aged and older users, ease of use is especially important because mobile banking often involves multiple steps, passwords, verification codes, and risk reminders. Difficult navigation, unclear function entrances, small text, or complicated transaction procedures may increase users' perceived burden and reduce their confidence. By contrast, an application that provides clear guidance, simple steps, and easily identifiable functions can lower learning costs and make users feel more capable of completing banking tasks independently.

H2: Perceived ease of use has a positive effect on middle-aged and older adults' intention to use mobile banking applications.

From the perspective of TAM, an application that requires less operational effort may strengthen users' perception of its usefulness, as simpler interaction makes its practical benefits easier to identify [1,20]. In the case of mobile banking applications, rich functions alone may not be sufficient for older users if they cannot complete transactions smoothly. When users can quickly find key services, understand the operation sequence, and complete tasks with fewer errors, the efficiency value of mobile banking becomes more visible to them.

H3: Perceived ease of use has a positive effect on perceived usefulness.

Unlike many daily-use applications, mobile banking is directly connected with users' assets, identity information, passwords, and transaction records. For middle-aged and older adults, perceived risk may arise from worries about mistaken transfers, account theft, privacy leakage, system malfunction, or online fraud. Prior e-service and digital-finance studies suggest that perceived uncertainty and potential loss can weaken users' willingness to adopt online services [7–9]. Thus, when older users feel that mobile banking is risky or difficult to control, their intention to use it may decline.

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H4: Perceived risk has a negative effect on middle-aged and older adults' intention to use mobile banking applications.

Perceived usefulness may influence usage intention not only directly, but also by changing users' risk assessment. If older users believe that mobile banking provides clear efficiency benefits, such as saving time and reducing branch visits, they may feel that the value of using the application outweighs potential uncertainty. In contrast, when the usefulness of mobile banking is unclear, risk concerns related to financial loss or operational errors may become more salient. Therefore, perceived risk is expected to function as a psychological mechanism linking usefulness-related evaluations and usage intention.

H5: Perceived risk mediates the relationship between perceived usefulness and middle-aged and older adults' intention to use mobile banking applications.

Ease of use may also reduce perceived risk by increasing users' sense of control. For older users, complicated interfaces and lengthy procedures can create concerns about mis-clicking, entering incorrect information, failing to complete transactions, or being unable to respond to abnormal situations. Clear prompts, simplified steps, and user-friendly interaction design can make the transaction process more predictable and controllable, thereby weakening risk-related anxiety. On this basis, perceived risk may transmit the effect of ease of use to usage intention.

H6: Perceived risk mediates the relationship between perceived ease of use and middle-aged and older adults' intention to use mobile banking applications.

The above relationships further imply a possible serial path. When the learning burden and operational complexity of mobile banking are reduced, its functional value becomes more apparent to users in middle and later adulthood. Once the application is seen as efficient and helpful, concerns about operational failure, financial loss, or information disclosure may be reduced. In this way, ease of use may first strengthen usefulness-related perceptions and then lower perceived risk, ultimately improving usage intention.

H7: Perceived ease of use affects intention through the serial mediation of perceived usefulness and perceived risk.

Digital-divide research emphasizes that inequality in digital participation is reflected not only in access to devices, but also in skills, usage patterns, and the benefits obtained from digital services [10–12]. In mobile banking, digital literacy includes the ability to operate smartphones, understand application interfaces, read security prompts, identify potential fraud, and solve basic technical problems. Older users with stronger digital literacy are more likely to understand transaction procedures and security mechanisms, which may increase their confidence in using mobile banking independently.

H8: Digital literacy has a positive effect on middle-aged and older adults' intention to use mobile banking applications.

Perceived ease of use may also shape users' digital literacy experience. When older users can complete mobile-banking tasks through simple steps and understandable instructions, they are more likely to accumulate successful digital experiences. These experiences may strengthen their perceived competence and reduce dependence on others. Therefore, an easy-to-use application may increase usage intention partly by improving users' digital-literacy-related confidence.

H9: Digital literacy mediates the relationship between perceived ease of use and intention.

Older adults' ability to engage with digital services is often shaped by the support they receive from family members. Previous studies on digital feedback and intergenerational support suggest that younger family members can provide technical instruction, emotional reassurance, and problem-solving assistance for older users [15–18]. In mobile banking, such support may include helping with app installation, account registration, password setting, function learning,

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transaction confirmation, and fraud prevention. These forms of assistance can reduce learning costs and increase users' sense of security.

H10: Intergenerational support has a positive effect on middle-aged and older adults' intention to use mobile banking applications.

Intergenerational support may further buffer the negative influence of perceived risk. When older users can consult children or younger relatives before making transactions, they may feel more confident in verifying information and responding to risk reminders. Conversely, users with limited family support may experience stronger uncertainty when dealing with authentication, password problems, or abnormal transaction alerts. Thus, intergenerational support may change how risk perception influences users' willingness to use mobile banking.

H11: Intergenerational support moderates the relationship between perceived risk and use intention.

Digital literacy may change how perceived risk influences usage intention. Older users who are familiar with smartphone operations, security verification procedures, and online transaction rules may be better able to interpret risk warnings and identify potential problems. As a result, perceived risk may have a weaker negative influence among users with higher digital literacy than among those with limited digital skills.

H12: Digital literacy moderates the relationship between perceived risk and use intention.

Differences may also exist within the broad group of middle-aged and older adults. As age increases, users may experience greater challenges related to vision, memory, learning speed, and confidence in digital operations. When facing verification codes, identity authentication, transaction confirmation, or risk alerts, older age groups may perceive higher uncertainty. Thus, users of different ages may respond differently to risk concerns when forming their intention to adopt mobile banking.

H13: Age group moderates the relationship between perceived risk and use intention.

Education level may also shape users' responses to perceived risk. Older users with higher educational attainment may have stronger information-processing ability and may find it easier to understand privacy statements, security reminders, and transaction procedures. This may help them make more informed judgments about potential risks, making such concerns less likely to discourage mobile banking adoption.

H14: Education level moderates the relationship between perceived risk and use intention.

Taken together, the proposed model extends the basic TAM logic by incorporating the financial-risk characteristics of mobile banking and the specific conditions of middle-aged and older users. By including perceived risk, digital literacy, intergenerational support, age group, and education level, the model aims to explain mobile-banking usage intention from the combined perspectives of technology cognition, risk perception, user capability, family support, and demographic differences.

2.2. Review of Domestic and International Studies

Research relevant to this topic can be organized around several connected streams. The first stream examines mobile-banking adoption and identifies the technological, functional, and trust-related factors that shape users' acceptance. The second focuses on older adults' technology use and highlights the importance of physical conditions, cognitive ability, learning confidence, and usage experience. A third body of work discusses perceived risk in online financial services, while another group of studies addresses digital literacy, the digital divide, and intergenerational support. In addition, research on age-friendly financial services provides practical insights into how banking services can become more accessible and safer for older users.

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Existing research shows that decisions to use mobile banking depend on multiple factors rather than convenience alone. Functional value, compatibility with users' needs, trust in the provider, perceived security, and perceived risk are repeatedly identified as important factors in adoption decisions [2–6]. Earlier mobile-banking research also shows that users' initial trust, knowledge about the service provider, perceptions of reliability, and overall service experience can influence whether they are willing to adopt or continue using mobile banking [2,4,6]. At the same time, resistance to mobile banking may arise when users perceive insufficient value, strong uncertainty, habitual preference for offline services, or concerns about risk [5]. These findings indicate that mobile banking should be understood as both a technological service and a financial-risk-related service.

TAM has been widely used to explain how users form adoption decisions toward information systems. The model emphasizes two core judgments: whether a technology offers practical benefits and whether it can be used without excessive effort [1]. Subsequent developments of TAM, together with UTAUT, broadened the explanation of technology adoption by adding factors related to social pressure, available support conditions, cognitive evaluation, expected performance gains, required effort, habitual use, and other contextual influences [20–22]. In the present study, the basic TAM logic is retained but adapted to mobile banking: perceived usefulness is reflected in whether the application improves the efficiency of routine financial services, while perceived ease of use is reflected in whether older users can understand, learn, and complete banking operations without excessive effort.

Research on older adults' technology acceptance shows that older users should not simply be regarded as resistant to digital technology. Their acceptance is influenced by whether the technology meets practical needs, whether it is learnable, and whether the surrounding environment provides sufficient support [23,24]. Compared with younger users, older adults may face additional barriers related to vision, memory, operational confidence, technology anxiety, and self-efficacy [23,25]. Empirical studies in the Chinese context also suggest that Internet and smartphone use are associated with older adults' active aging, life satisfaction, subjective well-being, and participation in digital life [19,26–28]. These findings imply that age-friendly mobile banking should not only provide functions, but also reduce learning difficulty and strengthen users' confidence.

Perceived risk is particularly relevant in digital financial services because such services involve money, personal information, identity verification, and transaction security. Prior studies on e-services, online shopping, and mobile payment have shown that uncertainty, privacy concerns, financial loss, and lack of trust may reduce users' willingness to adopt online services [7–9]. For mobile banking, perceived risk can include fear of mistaken operations, account theft, privacy leakage, system failure, transaction failure, and online fraud. These risks may be especially salient for middle-aged and older adults who have limited experience with digital finance or lower confidence in identifying online fraud. Therefore, perceived risk should be included when explaining older adults' intention to use mobile banking.

Digital literacy and intergenerational support offer two important perspectives for understanding older adults' digital inclusion. Digital-divide research emphasizes that inequality is not limited to device access; it also appears in digital skills, usage opportunities, and the benefits users can obtain from online services [10–12]. For older adults, digital literacy affects whether they can understand application logic, interpret security prompts, solve basic operational problems, and use digital services independently [18,19,29]. At the same time, family support can compensate for individual capability limitations. Studies on digital feedback and intergenerational support show that younger family members often assist older adults by teaching smartphone skills, explaining application functions, solving technical problems, and providing emotional reassurance [15–17]. In the mobile-banking context, such support may

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reduce learning costs and improve psychological security during registration, login, password setting, transaction confirmation, and fraud prevention.

Research on age-friendly financial services further emphasizes that digital transformation should not exclude older users. Existing discussions have noted the importance of service accessibility, simplified procedures, understandable risk reminders, human-service entrances, and coordination between online and offline channels [13,14,30]. For banking applications, age-friendly design may involve larger fonts, simplified pages, prominent access to frequently used functions, clearer transaction reminders, easier access to manual assistance, and stronger protection against abnormal transactions or fraud. These studies provide useful practical directions, but several gaps remain. First, many mobile-banking studies focus on general users and pay insufficient attention to older users' physical, cognitive, and digital-capability differences. Second, research on older adults' digital inclusion often examines smartphone use, Internet use, or general digital services, while mobile banking has stronger financial-risk attributes. Third, perceived usefulness, ease of use, perceived risk, digital literacy, intergenerational support, and age-friendly financial services are often discussed separately. Therefore, this study integrates these factors into an extended TAM framework to examine middle-aged and older adults' intention to use mobile banking applications.

3. Research Design and Method

3.1. Research Model

The research model extends the basic Technology Acceptance Model by incorporating perceived risk, digital literacy, intergenerational support, age group, and education level into the explanation of middle-aged and older adults' mobile-banking usage intention. As shown in Figure 1, the proposed relationships are organized into three conceptually related groups: direct effects, mediation mechanisms, and moderation effects.

The direct-effect hypotheses include the relationships between perceived usefulness, perceived ease of use, perceived risk, digital literacy, intergenerational support, and usage intention. Specifically, H1–H4 represent the principal TAM and risk-related relationships, while H8 and H10 examine the direct roles of digital literacy and intergenerational support.

The mediation hypotheses include H5–H7 and H9. H5 examines whether perceived risk mediates the relationship between perceived usefulness and usage intention. H6 examines whether perceived risk mediates the relationship between perceived ease of use and usage intention. H7 examines the serial pathway through perceived usefulness and perceived risk, while H9 examines the mediating role of digital literacy. Although H5–H7 are theoretically connected through risk-related mechanisms, they are retained as separately numbered hypotheses because they represent distinct indirect pathways and are tested through different indirect-effect estimates. Retaining separate labels also allows the empirical results of the three pathways to be reported and compared more precisely.

The moderation hypotheses include H11–H14. These hypotheses examine whether intergenerational support, digital literacy, age group, and education level change the strength of the relationship between perceived risk and usage intention.

In Figure 1, solid arrows represent hypothesized direct effects, dashed arrows represent mediation pathways, and dotted arrows represent moderation effects on the perceived-risk-to-usage-intention relationship. This organization improves the conceptual clarity of the model while retaining the separate hypothesis labels needed to distinguish the tested pathways.

In the empirical analyses reported below, hypotheses involving perceived usefulness are interpreted through the perceived efficiency benefits dimension because the exploratory factor analysis showed that the original perceived-usefulness items did not remain as a single

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independent factor. Usage intention is empirically represented by the overall usage intention composite identified through the exploratory factor analysis.

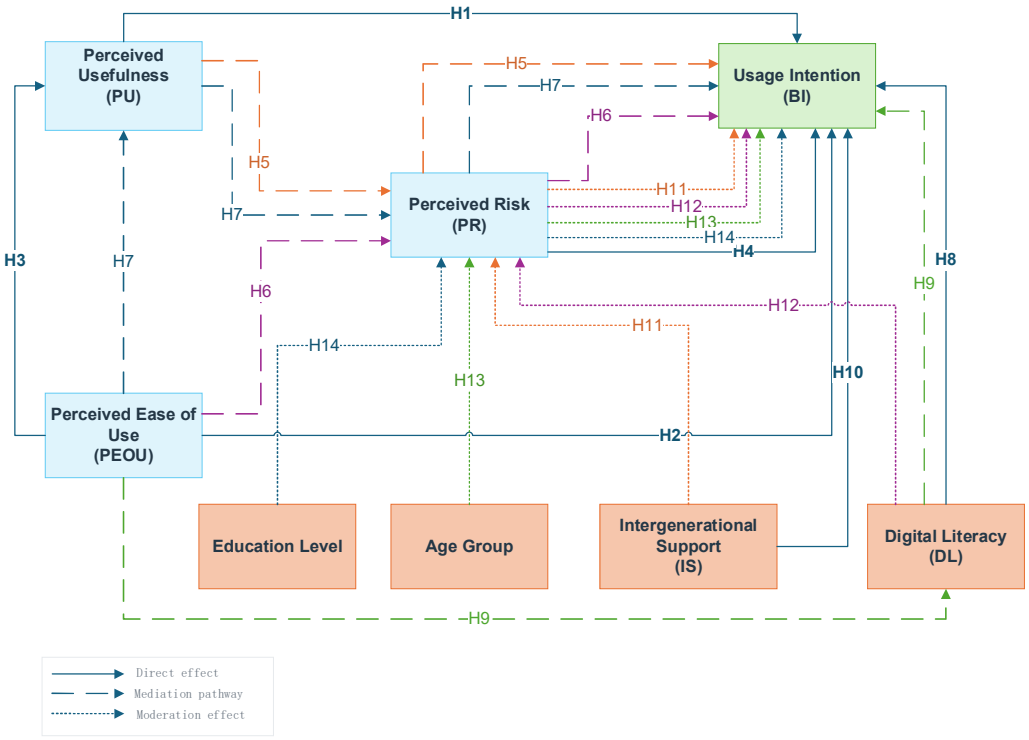

Figure 1. Proposed Research Model

3.2. Questionnaire Design

This study employed a structured questionnaire to measure respondents' perceptions of mobile banking, behavioral intention, digital capabilities, and intergenerational support. The questionnaire items were developed with reference to the Technology Acceptance Model and related studies on perceived risk, the digital divide, older adults' digital inclusion, and family-based support. The wording was adapted to the context of age-friendly mobile banking and simplified to improve its comprehensibility for middle-aged and older respondents.

The questionnaire included two initial screening questions concerning respondents' age and prior mobile-banking use. Respondents younger than 45 years and those who reported that they had never used mobile banking were directed to the end of the questionnaire and were not included in the statistical analyses. Questions 3 to 10 collected demographic and usage-related information, including gender, education, income, years of smartphone use, mobile operating system, frequently used mobile-banking functions, self-rated vision, and self-rated health.

The questionnaire contained 34 seven-point Likert-type measurement items covering six core constructs: five perceived-usefulness items (PU1–PU5), six perceived-ease-of-use items (PEOU1–PEOU6), ten perceived-risk items (PR1–PR10), three behavioral-intention items (BI1–BI3), five digital-literacy items (DL1–DL5), and five intergenerational-support items (IS2–IS6). However, the final intergenerational-support composite used in the statistical analyses was calculated as the mean of four items, IS2–IS5. IS6 was administered as a negatively worded item but was excluded from the final composite because it reflected reduced or avoided mobile-banking use in the absence of family assistance rather than the actual receipt of intergenerational support.

Question 40, coded as IS1, was a categorical eligibility and routing question concerning the availability and form of intergenerational support. Respondents who reported receiving

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neither in-person nor remote support from their children or younger family members were directed past the subsequent intergenerational-support items and were not included in the SPSS analyses. Among the respondents retained for analysis, IS1 distinguished between in-person and remote support. Because it was a categorical routing item rather than a Likert-type measurement item, it was not included in the intergenerational-support composite score, reliability analysis, or exploratory factor analysis.

Question 46 was an instructional attention-check item requiring respondents to select "agree." Respondents who failed this attention check were excluded from the analytical sample. The attention-check item was used solely for data-quality screening and was not included in construct scoring, reliability analysis, exploratory factor analysis, or any subsequent statistical model.

All core measurement items were assessed using a seven-point agreement scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). PEOU6, PR10, and IS6 were negatively worded in the administered questionnaire. PEOU6 and PR10 were retained in the statistical analyses and were reverse-coded using the formula: reversed score = 8 − original score. IS6 was not included in the final intergenerational-support composite and was therefore not reverse-coded for the reported analyses. The complete wording, original questionnaire number, construct classification, response format, and analytical status of the measurement items are presented in Appendix A.

Table 1. Measurement Structure of the Administered Questionnaire

Construct	Code	Administered Likert items	Question Nos.	Reverse-worded item	Final analytical treatment
Perceived usefulness	PU	5	11–15	None	PU1, PU2, PU3, and PU5 entered the reported EFA; PU4 was excluded.
Perceived ease of use	PEOU	6	16–21	PEOU6	All six items entered the reported EFA; PEOU6 was reverse-coded.
Perceived risk	PR	10	22–31	PR10	PR1–PR8 and reverse-coded PR10 entered the reported EFA; PR9 was excluded.
Behavioral intention	BI	3	32–34	None	All three items entered the reported EFA.
Digital literacy	DL	5	35–39	None	DL1–DL5 were used to calculate M_DL.
Intergenerational support	IS	5	41–45	IS6	IS2–IS5 were used to calculate M_IS; IS6 was excluded.
Total		**34**			

Note. All core measurement items were assessed on a seven-point scale ranging from 1 = strongly disagree to 7 = strongly agree. Question 40 (IS1) was a categorical eligibility and routing question and was not included in the count of 34 Likert-type items. Question 46 was an instructional attention-check item used exclusively for data-quality screening. The distinction between administered items and analytically retained items is reported in Appendix A.

3.3. Data Collection and Processing

Data were collected using an online questionnaire with programmed routing rules. Before the statistical analyses, the responses were screened according to predetermined eligibility and data-quality criteria. The analytical sample excluded respondents who: (1) were younger than 45 years; (2) reported that they had never used mobile banking; (3) reported receiving neither

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in-person nor remote intergenerational support; (4) failed the instructional attention-check item; or (5) submitted substantially incomplete or clearly abnormal responses.

Question 2 was used as an eligibility screening item and, among eligible respondents, as an ordinal indicator of prior mobile-banking usage frequency. Question 40 was used as an eligibility and routing question concerning the availability and form of intergenerational support. Neither Question 2 nor Question 40 was included in construct scoring, reliability analysis, or exploratory factor analysis. The attention-check item was also excluded from all substantive analyses. After applying the eligibility and data-quality criteria, 552 valid responses were retained for the statistical analyses.

Among the eligible respondents, prior mobile-banking usage frequency was coded ordinally as 1 = occasional use of less than once per month, 2 = use one to three times per month, and 3 = frequent use of four or more times per month.

4. Data Analysis and Results

4.1. Sample Characteristics and Descriptive Statistics

Table 2 presents the demographic and usage characteristics of the 552 respondents included in the analytical sample. The sample covered all eligible age groups from 45 years onward. Respondents aged 51–55 years constituted the largest age group, accounting for 32.4% of the sample, followed by those aged 45–50 years at 28.3% and those aged 61 years or older at 27.4%. The gender distribution was relatively balanced, with women accounting for 50.5% and men accounting for 49.3% of the sample.

In terms of education, 40.0% of the respondents had completed senior high school or technical secondary school, 26.6% had completed junior college, and 21.6% held a bachelor's degree. The largest monthly income category was RMB 5,000–7,999, representing 34.2% of the sample. Regarding smartphone experience, 47.6% of the respondents had used a smartphone for ten years or more, while only 6.4% had used one for fewer than four years. In addition, 43.5% reported using mobile banking four or more times per month, and 40.6% used it one to three times per month. These distributions suggest that the analytical sample generally had substantial experience with smartphones and mobile banking.

Although the sample included respondents across all eligible age groups and had a relatively balanced gender distribution, it should not be considered statistically representative of the entire middle-aged and older population. First, the questionnaire was administered online, which may have favored respondents with greater Internet access, stronger smartphone skills, and more experience with digital services. Second, nearly half of the respondents had used smartphones for ten years or more, and more than four-fifths used mobile banking at least once per month. The sample may therefore overrepresent relatively experienced digital users. Third, respondents who had never used mobile banking were excluded, meaning that the study primarily captures continued-use or expanded-use intention among existing users rather than initial adoption among non-users. Respondents who reported receiving neither in-person nor remote support from children or younger family members were also excluded. Consequently, the sample does not represent middle-aged and older adults without access to family-based digital support. Finally, residential location was not collected in the administered questionnaire, so the urban–rural composition of the sample could not be assessed. The demographic findings should therefore be interpreted as a description of the analytical sample rather than as evidence of population-level representativeness.

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Table 2. Demographic and Usage Characteristics of the Respondents

Characteristic	Category	Frequency	Percentage (%)
Age group	45–50 years	156	28.3
	51–55 years	179	32.4
	56–60 years	66	12.0
	61 years or older	151	27.4
Gender	Male	272	49.3
	Female	279	50.5
	Prefer not to say	1	0.2
Education level	Primary school or below	4	0.7
	Junior high school	47	8.5
	Senior high school/technical secondary school	221	40.0
	Junior college	147	26.6
	Bachelor's degree	119	21.6
	Postgraduate degree or above	14	2.5
Monthly income/pension before tax	Below RMB 3,000	29	5.3
	RMB 3,000–4,999	133	24.1
	RMB 5,000–7,999	189	34.2
	RMB 8,000–11,999	136	24.6
	RMB 12,000 or above	62	11.2
	Prefer not to say	3	0.5
Years of smartphone use	Less than 1 year	2	0.4
	2–3 years	33	6.0
	4–5 years	72	13.0
	6–7 years	114	20.7
	8–9 years	68	12.3
	10 years or more	263	47.6
Mobile operating system	Android	496	89.9
	iOS	54	9.8
	Other	2	0.4
Prior mobile-banking usage frequency	Occasional use, less than once per month	88	15.9
	Moderate use, 1–3 times per month	224	40.6
	Frequent use, 4 or more times per month	240	43.5
Self-rated vision	Very good	60	10.9
	Good	296	53.6
	Average	167	30.3
	Poor	27	4.9
	Very poor	2	0.4
Self-rated health	Very good	95	17.2
	Good	327	59.2
	Average	115	20.8
	Poor	13	2.4
	Very poor	2	0.4
Form of intergenerational support	In-person support	432	78.3
	Remote support	120	21.7

Note. N = 552. Percentages may not sum to 100.0 because of rounding. Residential location was not collected in the administered questionnaire; therefore, an urban–rural distribution could not be reported. The analytical sample included respondents aged 45 years or older who had prior mobile-banking experience and reported access to either in-person or remote intergenerational support. Respondents who had never used mobile banking and those who reported receiving neither form of intergenerational support were not included in the analytical sample.

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Descriptive statistics were subsequently calculated for the core analytical variables. As shown in Table 3, the mean perceived-risk score was 3.3637 (SD = 1.49982), indicating a moderate-to-low overall level of risk perception but considerable individual variation. The mean perceived-ease-of-use score was 5.6522 (SD = 0.77610), showing that respondents generally considered mobile banking relatively easy to use. The mean overall usage intention score was 5.9649 (SD = 0.58125), suggesting a generally strong intention to continue or expand mobile-banking use. Perceived efficiency benefits had the highest mean score at 6.2418, indicating strong agreement that mobile banking saves time and improves service efficiency.

Table 3. Descriptive Statistics of the Main Variables

	N	Minimum	Maximum	Mean	Std. Deviation
Perceived risk (M_PR)	552	1.00	6.78	3.3637	1.49982
Perceived ease of use (M_PEOU)	552	2.67	7.00	5.6522	.77610
Overall usage intention (M_BI_Mix)	552	3.60	7.00	5.9649	.58125
Perceived efficiency benefits (M_PU_Eff)	552	3.50	7.00	6.2418	.68357
Digital literacy (M_DL)	552	2.80	7.00	5.6192	.70620
Intergenerational support (M_IS)	552	2.25	7.00	5.6264	.76118
Valid N (listwise)	552				

4.2. Reliability Analysis

Internal consistency was assessed for the 22 items entered into the exploratory factor analysis. These items comprised four perceived-usefulness items, six perceived-ease-of-use items, nine perceived-risk items, and three behavioral-intention items. The reported Cronbach's alpha coefficients therefore apply to the reduced EFA item set rather than to all 34 Likert-type items in the administered questionnaire. Digital literacy and intergenerational support were constructed separately and were not included in the reported reliability analysis or the four-factor exploratory factor analysis. The perceived-risk scale had a Cronbach's alpha of 0.963 across nine items, indicating very high internal consistency. The perceived ease of use scale had an alpha of 0.858 across six items, indicating good reliability. The perceived usefulness scale had an alpha of 0.679 across four items, close to the commonly accepted threshold. The behavioral intention scale had an alpha of 0.706 across three items, reaching an acceptable level.

Table 4. Reliability Analysis of the Measurement Scales

Variable	Cronbach's Alpha	Number of items	Valid N
Perceived risk (PR)	.963	9	552
Perceived ease of use (PEOU)	.858	6	552
Perceived usefulness (PU)	.679	4	552
Behavioral intention (BI)	.706	3	552

The four item sets included in the reported reliability analysis showed acceptable to very high internal consistency, although the coefficient for perceived usefulness was slightly below 0.70. Because separate reliability coefficients were not calculated for digital literacy and intergenerational support in the reported analysis, the reliability conclusion should be interpreted as applying specifically to the 22-item EFA set.

4.3. Validity Analysis and Exploratory Factor Analysis

The exploratory factor analysis was conducted using a reduced set of 22 items rather than all 34 Likert-type items in the administered questionnaire. The analytical set consisted of PU1, PU2, PU3, PU5, PEOU1–PEOU5, reverse-coded PEOU6, PR1–PR8, reverse-coded PR10, and BI1–BI3.

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PU4 and PR9 were not entered into the reported EFA. The DL and IS items were used to construct separate composite variables and were not included in this four-factor analysis. Principal component analysis was applied, four factors were specified in advance, and Promax oblique rotation was used.

The construct validity of the measurement items was examined through exploratory factor analysis. The KMO value was 0.943, showing strong suitability for factor analysis. A significant Bartlett's test of sphericity further confirmed that the data met the correlation requirement for factor extraction, $\chi^2 = 8243.317$, df = 231, $p < 0.001$, showing that the dataset was appropriate for extracting underlying factors.

Table 5. KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.943
Bartlett's Test of Sphericity	Approx. Chi-Square	8243.317
	df	231
	Sig.	.000

The first four factors explained 67.039% of the total variance, indicating that the extracted factors provided strong explanatory coverage of the measurement items. The rotated pattern matrix showed that PR1, PR2, PR3, PR4, PR5, PR6, PR7, PR8, and PR10_r mainly loaded on the first factor; PEOU1, PEOU2, PEOU3, PEOU4, PEOU5, and PEOU6_r mainly loaded on the second factor; PU1, PU3, BI1, BI2, and BI3 showed relatively high loadings on the third factor; and PU2 and PU5 mainly loaded on the fourth factor. Therefore, the study treated PU2 and PU5 as the "perceived efficiency benefits" dimension (M_PU_Eff) and integrated PU1, PU3, BI1, BI2, and BI3 into the "overall usage intention" variable (M_BI_Mix), consistent with the SPSS variable computation based on the pattern matrix. Because the empirical factor structure differed from the original theoretical scale structure, subsequent analyses used perceived efficiency benefits as the empirical representation of the usefulness-related construct. Therefore, hypotheses involving perceived usefulness were interpreted and tested in terms of perceived efficiency benefits.

Table 6. Summary of the Exploratory Factor Structure

Factor	Main items	Naming
1	PR1, PR2, PR3, PR4, PR5, PR6, PR7, PR8, PR10_r	Perceived risk
2	PEOU1, PEOU2, PEOU3, PEOU4, PEOU5, PEOU6_r	Perceived ease of use
3	PU1, PU3, BI1, BI2, BI3	Overall usage intention
4	PU2, PU5	Perceived efficiency benefits

Based on the retained item set and the rotated pattern matrix, six composite variables were calculated. M_PR was calculated as the mean of PR1–PR8 and reverse-coded PR10. M_PEOU was calculated as the mean of PEOU1–PEOU5 and reverse-coded PEOU6. M_BI_Mix was calculated as the mean of PU1, PU3, BI1, BI2, and BI3. M_PU_Eff was calculated as the mean of PU2 and PU5. M_DL was calculated as the mean of DL1–DL5. M_IS was calculated as the mean of IS2–IS5. All composite variables were calculated using the SPSS MEAN function.

4.4. Correlation Analysis

Initial relationships among the main variables were assessed using Pearson correlation coefficients. Perceived ease of use was significantly positively correlated with overall usage

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intention ($r = 0.584$, $p < 0.01$). The results also indicated that higher perceived efficiency benefits corresponded to stronger overall usage intention ($r = 0.471$, $p < 0.01$). Digital literacy was significantly positively correlated with overall usage intention ($r = 0.633$, $p < 0.01$), and intergenerational support was also positively correlated with overall usage intention ($r = 0.314$, $p < 0.01$).

Perceived risk was significantly negatively correlated with overall usage intention ($r = -0.247$, $p < 0.01$), perceived ease of use ($r = -0.450$, $p < 0.01$), digital literacy ($r = -0.434$, $p < 0.01$), and intergenerational support ($r = -0.321$, $p < 0.01$). These results indicate that older users' perceived operational convenience, digital capability, and family support are associated with lower risk concerns, whereas stronger perceived risk corresponded to a lower level of overall usage intention. Although some variable pairs were highly correlated, such as perceived ease of use and digital literacy ($r = 0.715$), collinearity diagnostics showed VIF values between 1.310 and 2.416 and tolerance values between 0.414 and 0.763, indicating no serious multicollinearity.

Table 7. Correlations among the Main Variables

Variable pair	Correlation	Significance
M_PEOU – M_BI_Mix	.584**	p < 0.01
M_PU_Eff – M_BI_Mix	.471**	p < 0.01
M_DL – M_BI_Mix	.633**	p < 0.01
M_IS – M_BI_Mix	.314**	p < 0.01
M_PR – M_BI_Mix	–.247**	p < 0.01
M_PR – M_PEOU	–.450**	p < 0.01
M_PR – M_DL	–.434**	p < 0.01
M_PR – M_IS	–.321**	p < 0.01

**. Correlation is significant at the 0.01 level (2-tailed).

4.5. Regression Analysis of the Main TAM Path

For the basic TAM path, overall usage intention (M_BI_Mix) was used as the dependent variable, and perceived efficiency benefits (M_PU_Eff) and perceived ease of use (M_PEOU) were entered as independent variables in a multiple linear regression.

The model results were $R = 0.655$, $R^2 = 0.430$, adjusted $R^2 = 0.428$, showing that perceived efficiency benefits and perceived ease of use explained 43.0% of the variance in overall usage intention. The regression model reached statistical significance, $F = 206.754$, $p < 0.001$.

The regression result supported a positive link between perceived efficiency benefits and overall usage intention ($B = 0.268$, $\beta = 0.315$, $t = 9.234$, $p < 0.001$). The regression results also confirmed a positive relationship between perceived ease of use and overall usage intention ($B = 0.361$, $\beta = 0.482$, $t = 14.145$, $p < 0.001$). The larger standardized coefficient for perceived ease of use suggests that operational simplicity explained overall usage intention more strongly than perceived efficiency benefits in this sample.

Table 8. Regression Results for the Main TAM Model

Predictor	B	Std. Error	β	t	p
Constant	2.255	.192		11.730	.000
Perceived efficiency benefits (M_PU_Eff)	.268	.029	.315	9.234	.000
Perceived ease of use (M_PEOU)	.361	.026	.482	14.145	.000

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4.6. Extended Regression Analysis

To further test model robustness, perceived risk, digital literacy, intergenerational support, age group, education level, income level, and prior-use experience were added to the regression model. The model results were R = 0.729, R^2 = 0.532, and adjusted R^2 = 0.524, indicating that the extended model explained 53.2% of the variance in overall usage intention. The model was significant, F = 68.427, p < 0.001. No substantial multicollinearity problem was detected, since the VIF statistics were all less than 2.5 and the tolerance statistics were all greater than 0.4.

Perceived efficiency benefits continued to positively predict overall usage intention in the extended model (B = 0.180, β = 0.211, p < 0.001). Perceived ease of use continued to make a significant positive contribution in the extended model (B = 0.149, β = 0.199, p < 0.001). Digital literacy had a significant positive effect (B = 0.269, β = 0.327, p < 0.001), as did intergenerational support (B = 0.097, β = 0.127, p < 0.001). Prior-use experience also significantly increased overall usage intention (B = 0.151, β = 0.188, p < 0.001). However, once perceived ease of use, digital literacy, and intergenerational support were included, perceived risk did not independently explain overall usage intention (B = 0.008, β = 0.020, p = 0.577), and age, education, and income were also not significant predictors.

Table 9. Extended Regression Results

Predictor	B	Std. Error	β	t	p	Tolerance	VIF
Perceived efficiency benefits (M_PU_Eff)	.180	.029	.211	6.224	.000	.748	1.337
Perceived risk (M_PR)	.008	.014	.020	.559	.577	.672	1.489
Perceived ease of use (M_PEOU)	.149	.033	.199	4.467	.000	.435	2.297
Digital literacy (M_DL)	.269	.038	.327	7.161	.000	.414	2.416
Intergenerational support (M_IS)	.097	.026	.127	3.781	.000	.763	1.310
Age group (AgeGroup)	.012	.017	.024	.711	.477	.741	1.350
Education (Edu)	.011	.024	.018	.449	.654	.513	1.949
Income (Income)	.002	.020	.004	.111	.912	.647	1.545
Prior mobile-banking usage frequency (PriorUse)	.151	.028	.188	5.340	.000	.698	1.432

4.7. Mediation-Effect Tests

4.7.1. Mediating Role of Perceived Risk between Perceived Efficiency Benefits and Overall Usage Intention

Table 10. Mediation Effect of Perceived Risk

Effect	B/Effect	SE/BootSE	t	p	95% CI
M_PU_Eff → M_PR	−.3385	.0972	−3.4824	.0005	[−.5294, −.1476]
M_PU_Eff → M_BI_Mix (direct in mediator model)	.3180	.0317	10.0461	.0000	[.2558, .3802]
M_PR → M_BI_Mix	−.0930	.0138	−6.7489	.0000	[−.1201, −.0659]
Indirect effect via M_PR	.0315	.0106			[.0123, .0539]

PROCESS Model 4 was applied to determine whether perceived efficiency benefits influenced overall usage intention indirectly through perceived risk. Perceived efficiency benefits were negatively associated with perceived risk (B = −0.3385, p < 0.001), indicating that the more older users believed mobile banking saved time and improved efficiency, the lower their risk concerns. In the outcome model, perceived efficiency benefits were positively associated with

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overall usage intention (B = 0.3180, p < 0.001), while perceived risk had a significant negative effect (B = −0.0930, p < 0.001). Bootstrap testing showed that the indirect effect through perceived risk was 0.0315 (BootSE = 0.0106), with a 95% confidence interval of [0.0123, 0.0539], excluding zero. These results support a partial mediating role of perceived risk in the link between perceived efficiency benefits and overall usage intention.

4.7.2. Serial Mediation among Perceived Ease of Use, Perceived Efficiency Benefits, and Perceived Risk

PROCESS Model 6 was applied to examine whether perceived ease of use influenced overall usage intention through the sequential roles of perceived efficiency benefits and perceived risk. Perceived ease of use significantly and positively affected perceived efficiency benefits (B = 0.2450, p < 0.001) and significantly negatively affected perceived risk (B = −0.9895, p < 0.001), but perceived efficiency benefits did not significantly affect perceived risk in this model (B = −0.0163, p = 0.8543). In the overall usage intention model, perceived ease of use (B = 0.3040, p < 0.001) and perceived efficiency benefits (B = 0.2432, p < 0.001) had significant positive effects, while perceived risk was not significant (B = −0.0217, p = 0.1323).

Bootstrap results showed that the total indirect effect was 0.0811, with a 95% confidence interval of [0.0447, 0.1220]. The indirect effect of "perceived ease of use → perceived efficiency benefits → overall usage intention" was significant (effect = 0.0596, 95% CI [0.0364, 0.0865]). The indirect effect of "perceived ease of use → perceived risk → overall usage intention" was not significant (effect = 0.0215, 95% CI [−0.0056, 0.0513]), and the serial indirect path was also not significant (effect = 0.0001, 95% CI [−0.0011, 0.0014]). These findings suggest that ease of use contributes to overall usage intention primarily by strengthening users' perceived efficiency benefits, rather than by triggering a sequential process of risk reduction.

Table 11. Serial Mediation Analysis

Indirect path	Effect	BootSE	BootLLCI	BootULCI	Conclusion
Total indirect effect	.0811	.0200	.0447	.1220	Significant
M_PEOU → M_PU_Eff → M_BI_Mix	.0596	.0128	.0364	.0865	Significant
M_PEOU → M_PR → M_BI_Mix	.0215	.0146	−.0056	.0513	Not significant
M_PEOU → M_PU_Eff → M_PR → M_BI_Mix	.0001	.0006	−.0011	.0014	Not significant

4.7.3. Mediating Role of Digital Literacy between Perceived Ease of Use and Overall Usage Intention

The mediating role of digital literacy was examined in the path from perceived ease of use to overall usage intention. Perceived ease of use was found to be a positive predictor of digital literacy (B = 0.6242, p < 0.001). Digital literacy significantly and positively affected overall usage intention (B = 0.3483, p < 0.001), and the direct effect of perceived ease of use on overall usage intention remained significant (B = 0.1677, p < 0.001). Bootstrap results showed that the indirect effect of digital literacy was 0.2174 (BootSE = 0.0267), with a 95% confidence interval of [0.1668, 0.2734], excluding zero. These results support the mediating role of digital literacy in the link between perceived ease of use and overall usage intention.

Table 12. Mediation Effect of Digital Literacy

Path / Effect	Effect	SE/BootSE	p / CI
M_PEOU → M_DL	.6242	.0284	p < .001
M_DL → M_BI_Mix	.3483	.0369	p < .001
Direct effect of M_PEOU on M_BI_Mix	.1677	.0336	p < .001
Indirect effect via M_DL	.2174	.0267	95% CI [.1668, .2734]

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4.8. Moderation and Moderated-Mediation Tests

PROCESS Model 14 was applied to assess whether the risk–intention relationship varied across different levels of individual characteristics and external support. Intergenerational support, digital literacy, age group, and education level were separately used as moderators of the "perceived risk → overall usage intention" path. The results showed that none of the interaction terms reached significance: intergenerational support interaction B = 0.0076, p = 0.6435; digital literacy interaction B = 0.0172, p = 0.3422; age-group interaction B = −0.0024, p = 0.8006; and education interaction B = 0.0058, p = 0.6197. The bootstrap confidence intervals for all moderated-mediation indices included zero. Therefore, these variables neither significantly moderated the perceived-risk path nor formed significant moderated mediation.

This suggests that although intergenerational support, digital literacy, age group, and education may directly affect older users' acceptance of mobile banking, they did not significantly change the strength of the relationship between perceived risk and overall usage intention in this sample.

4.9. Summary of Hypothesis Testing

The hypothesis-testing results suggest that older adults' willingness to use mobile banking applications is mainly shaped by usability, perceived efficiency, and digital capability. Perceived ease of use and perceived efficiency benefits both helped explain stronger overall usage intention, confirming the relevance of the TAM framework in this study. Perceived risk did not operate as a simple direct barrier in all models. Instead, it partly explained how perceived efficiency benefits were translated into stronger intention, while its direct effect became unstable after other explanatory variables were included. Digital literacy played a notable mediating role, showing that easier operation may increase intention by strengthening users' digital competence. However, the data did not support the assumption that intergenerational support, digital literacy, age group, or education level would change the strength of the relationship between perceived risk and usage intention.

Table 13 summarizes the hypothesis-testing results. To avoid repeating the full hypothesis statements already presented in the theoretical section, the table reports the core relationship tested and the corresponding empirical conclusion.

Table 13. Summary of Hypothesis Testing

Hypothesis	Core relationship tested	Result
H1	Service efficiency and adoption willingness	Supported
H2	Ease of operation and adoption willingness	Supported
H3	Ease of operation and perceived service efficiency	Supported
H4	Risk-related hesitation and adoption willingness	Partially supported / unstable
H5	Indirect pathway through risk concerns	Supported
H6	Risk pathway from ease of operation to willingness	Not supported
H7	Serial pathway through efficiency and risk	Not supported
H8	Digital capability and adoption willingness	Supported
H9	Digital capability as an indirect pathway	Supported
H10	Family-based support and adoption willingness	Supported
H11	Support-based moderation of the risk pathway	Not supported
H12	Digital-literacy moderation of the risk pathway	Not supported
H13	Age-based moderation of the risk pathway	Not supported
H14	Education-based moderation of the risk pathway	Not supported

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5. Conclusion

This study examined mobile-banking usage intention among middle-aged and older adults by extending the TAM within an age-friendly service context. Using 552 valid questionnaire responses, the analysis considered not only perceived usefulness and perceived ease of use, but also perceived risk, digital literacy, intergenerational support, age group, and education level. The empirical tests provided evidence on both the direct determinants of usage intention and the possible mediation and moderation mechanisms among these variables.

One important empirical finding concerns the measurement structure. The exploratory factor analysis showed that several perceived-usefulness items were closely associated with behavioral-intention items. As a result, PU1, PU3, BI1, BI2, and BI3 were combined into the overall usage intention variable, M_BI_Mix, while PU2 and PU5 formed the perceived efficiency benefits variable, M_PU_Eff. This result suggests that, for the respondents in this study, the perceived value of mobile banking was closely connected with their willingness to use it. Therefore, the usefulness-related hypotheses were interpreted mainly through the perceived efficiency benefits dimension.

Three main findings can be drawn from the empirical analysis. First, perceived ease of use and perceived efficiency benefits are central predictors of usage intention. This indicates that older users are more willing to use mobile banking when they find the application easy to operate and when they recognize its value in saving time and improving service efficiency. Second, digital literacy and intergenerational support also increase usage intention, showing that personal digital capability and family-based assistance are important conditions for mobile-banking acceptance. Third, perceived risk plays a more complicated role. Although it is negatively associated with usage intention in the correlation analysis and functions as a mediator in the path from perceived efficiency benefits to usage intention, its direct effect becomes unstable after other variables are controlled. The moderation tests further show that intergenerational support, digital literacy, age group, and education level do not significantly change the perceived-risk-to-intention relationship.

The findings also provide practical implications for banks' age-friendly digital transformation. At the product level, mobile banking applications should offer clearer layouts, larger and more readable text, simplified home pages, and prominent entrances to frequently used functions. At the process level, high-risk or high-frequency services such as transfers, payments, authentication, password recovery, and abnormal-transaction handling should be redesigned with clearer prompts, fewer unnecessary steps, and stronger confirmation mechanisms. At the support level, banks should provide accessible guidance through demonstration videos, in-branch assistance, telephone support, community training, and step-by-step tutorials. In addition, family–bank cooperation can be strengthened by encouraging younger family members and bank staff to help older users learn key functions, identify fraud risks, and build confidence in safe mobile-banking use.

Some limitations of the present research should be considered when interpreting the results. First, the empirical data were gathered through a web-based survey, which may have excluded some middle-aged and older adults with limited Internet access or very weak digital skills. As a result, the sample may overrepresent users who already have experience with digital devices and online services.

Second, the cross-sectional design can identify associations among the variables but cannot establish their temporal order or determine the direction of causality. Although the theoretical model assumes that perceived ease of use, perceived efficiency benefits, and digital literacy influence usage intention, reverse or reciprocal relationships are also possible. For example, respondents who are already more willing to use mobile banking may evaluate the application as easier to use and more useful, rather than favorable perceptions necessarily preceding usage

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intention. Similarly, the positive relationship between digital literacy and usage intention may partly reflect the possibility that more frequent mobile-banking use strengthens users' digital skills and confidence over time. Therefore, the directional paths in the present model should be interpreted as theory-based associations rather than definitive causal effects.

Third, the empirical factor structure revealed that some usefulness-related items clustered closely with behavioral-intention items, indicating that the measurement of usefulness could be further refined. This overlap may have increased the observed relationship between perceived value and usage intention and should be examined using independently validated scales in future studies.

Fourth, the sample-selection procedure further limits the generalizability of the findings. Respondents who had never used mobile banking were excluded, meaning that the study primarily explains continued-use or expanded-use intention among existing users rather than initial adoption among non-users. Respondents who reported receiving neither in-person nor remote support from children or younger family members were also excluded from the SPSS analyses. Consequently, the analytical sample did not represent middle-aged and older adults without access to intergenerational support. This restriction may have reduced the variability of the intergenerational-support measure and may partly explain why its moderating effect was not statistically significant.

Future research may address these limitations in several ways. Offline surveys or mixed online–offline data collection could include older adults with lower levels of digital participation. Future studies should also adopt longitudinal or multi-wave research designs to establish temporal order and evaluate possible reciprocal relationships. For example, perceived ease of use, perceived efficiency benefits, digital literacy, and prior usage frequency could be measured at Time 1, while usage intention and subsequent mobile-banking behavior could be measured at Time 2. A third measurement wave could further assess whether continued mobile-banking use subsequently improves users' digital literacy, operational confidence, and perceptions of ease of use. Such a design would help distinguish whether technology-related perceptions and digital literacy shape later usage intention, whether prior willingness and usage experience influence subsequent perceptions and skills, or whether these relationships are reciprocal over time.

Future research could also retain non-users and respondents without family-based support to compare initial adoption, continued use, and different levels of support availability. More advanced model-testing techniques, including confirmatory factor analysis and structural equation modeling, could be used to verify whether the observed factor structure remains stable across different samples. Comparisons across age groups, regions, banks, and different age-friendly application designs would further support the development of more targeted optimization strategies.

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Appendix A. Measurement Items

The following tables reproduce the substantive wording of the measurement items included in the questionnaire administered to respondents. All core construct items were assessed on a seven-point agreement scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The analytical-status column distinguishes the complete administered questionnaire from the reduced item set used in the reported reliability and exploratory factor analyses.

A1. Perceived Usefulness (PU)

Table A1. Perceived Usefulness Items

Question No.	Code	Complete English wording	Analytical status
11	PU1	Using mobile banking makes it more convenient for me to handle routine banking activities, such as transferring money, paying bills, and checking account balances.	Included in EFA; included in M_BI_Mix after EFA
12	PU2	Using mobile banking saves me the time required to visit and wait at an offline bank branch.	Included in EFA; retained in M_PU_Eff
13	PU3	Using mobile banking improves the efficiency with which I conduct banking activities.	Included in EFA; included in M_BI_Mix after EFA
14	PU4	Mobile banking is useful for managing my personal or family finances.	Administered; not included in the reported EFA
15	PU5	Overall, mobile banking is helpful to me.	Included in EFA; retained in M_PU_Eff

A2. Perceived Ease of Use (PEOU)

Table A2. Perceived Ease of Use Items

Question No.	Code	Complete English wording	Analytical status
16	PEOU1	Learning to use mobile banking is easy for me.	Included in M_PEOU
17	PEOU2	The steps involved in interacting with mobile banking are clear and easy to understand.	Included in M_PEOU
18	PEOU3	I find it easy to get mobile banking to perform the tasks I want it to perform.	Included in M_PEOU
19	PEOU4	Becoming proficient in using mobile banking does not require much time.	Included in M_PEOU
20	PEOU5	When I encounter a problem, I can solve it independently or quickly learn how to handle it.	Included in M_PEOU
21	PEOU6 (R)	Learning to use mobile banking requires considerable effort from me.	Reverse-coded; included in M_PEOU

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A3. Perceived Risk (PR)

Table A3. Perceived Risk Items

Question No.	Code	Complete English wording	Analytical status
22	PR1	I am concerned that operational errors when using mobile banking may result in financial loss.	Included in M_PR
23	PR2	I am concerned that encountering fraud when using mobile banking may result in financial loss.	Included in M_PR
24	PR3	I am concerned that my account may be stolen or operated without authorization.	Included in M_PR
25	PR4	I am concerned that my personal information in mobile banking may be disclosed.	Included in M_PR
26	PR5	I am concerned that my transaction or account data may be collected or used improperly.	Included in M_PR
27	PR6	I am concerned that system failures or unstable network connections may cause transaction failure or duplicate charges.	Included in M_PR
28	PR7	I am concerned that learning or updating mobile banking may require considerable time and effort.	Included in M_PR
29	PR8	I am concerned that resolving a mobile-banking problem would be troublesome or time-consuming.	Included in M_PR
30	PR9	To avoid potential risks, I would prefer to use mobile banking less frequently or not use it at all.	Administered; not included in the reported EFA
31	PR10 (R)	I do not think there is much risk involved in using mobile banking.	Reverse-coded; included in M_PR

A4. Behavioral Intention (BI)

Table A4. Behavioral Intention Items

Question No.	Code	Complete English wording	Analytical status
32	BI1	I intend to use or continue using mobile banking in the near future.	Included in EFA and M_BI_Mix
33	BI2	When I need to conduct a banking activity, I will give priority to using mobile banking.	Included in EFA and M_BI_Mix
34	BI3	I am willing to increase the frequency with which I use mobile banking or expand the range of functions I use.	Included in EFA and M_BI_Mix

A5. Digital Literacy (DL)

Table A5. Digital Literacy Items

Question No.	Code	Complete English wording	Analytical status
35	DL1	I can install and update applications on my smartphone, including managing permissions and passwords.	Used in M_DL
36	DL2	I can change commonly used smartphone or application settings, such as notifications, permissions, and font size.	Used in M_DL
37	DL3	I can recognize security prompts on my smartphone and assess whether information is reliable.	Used in M_DL
38	DL4	I can use different mobile applications to complete daily tasks, such as transportation, payment, shopping, and government services.	Used in M_DL
39	DL5	When I encounter a new application, I can usually learn its basic functions relatively quickly.	Used in M_DL

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A6. Intergenerational Support (IS)

Table A6. Intergenerational Support Items

Question No.	Code	Complete English wording	Analytical status
41	IS2	My children or younger family members have taught me how to use or update mobile banking applications.	Included in M_IS
42	IS3	My children or younger family members accompany or assist me when I perform important or complicated operations, such as large-value transfers.	Included in M_IS
43	IS4	Encouragement from my children or younger family members and their reassurance that mobile banking is safe to use increase my trust in mobile banking.	Included in M_IS
44	IS5	When I am concerned about risk or encounter a problem, my family can promptly help me identify and resolve it.	Included in M_IS
45	IS6 (R)	When family assistance is unavailable, I reduce or avoid my use of mobile banking.	Administered as a negatively worded item but excluded from M_IS and the reported statistical analyses

Note. M_IS was calculated as the arithmetic mean of IS2, IS3, IS4, and IS5. Although IS6 was identified as a reverse-worded item in the administered questionnaire, it was not included in M_IS and was not reverse-coded in the reported statistical analyses.

A7. Eligibility, Routing, and Data-Quality Items

Table A7. Eligibility, Routing, and Data-Quality Items

Question No.	Function	Treatment
2	Prior mobile-banking use	Respondents selecting “never used” were excluded. The remaining categories were retained as an ordinal usage-frequency control variable.
40	Availability and form of intergenerational support	Respondents selecting “neither in-person nor remote support” were excluded. The item was not included in M_IS.
46	Instructional attention check	Respondents selecting “disagree” were excluded. The item was not included in any construct score or substantive analysis.