

Article

Assessing the Effectiveness of Sustainable Strategies to Bridge the Digital Divide in the Mobility Sector: A Pilot Test in Seoul

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Abstract: The emergence of digital mobility services holds great promise for enhancing efficiency, convenience, and accessibility for passengers. However, these benefits are predominantly accessible to those proficient in utilizing these technologies, which may intensify the disparity in transportation usage. This paper presents plans to alleviate the digital divide in the mobility sector. First, two fundamental approaches were established through a literature review: (1) app usage education and (2) an AI-based Mobility Service App. To substantiate the effectiveness of these approaches, a pilot test was conducted in Seoul. The results of the pilot test showed that the AI-based Mobility Service App was effective for reducing travel time and enhancing the convenience of passage. Accordingly, the Technology Acceptance Model was adopted to derive technology acceptance factors of the AI-based Mobility Service App. Finally, a phased approach with short-term, medium-term, and long-term plans was proposed based on the analysis results to ensure sustainable policies in the mobility sector.

Keywords: digital divide; digital mobility service; pilot test; AI-based digital mobility service app; inclusive plans



Citation: Cho, A.; Seo, J.; Kim, S.; Cho, J.; Kim, Y. Assessing the Effectiveness of Sustainable Strategies to Bridge the Digital Divide in the Mobility Sector: A Pilot Test in Seoul. *Sustainability* **2024**, *16*, 4078. <https://doi.org/10.3390/su16104078>

Academic Editor: Marilisa Botte

Received: 29 March 2024

Revised: 30 April 2024

Accepted: 10 May 2024

Published: 13 May 2024



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1. Introduction

The increasing integration of digital technology into various fields has led to opportunities and challenges. In particular, the emergence of digital mobility services holds great promise for enhancing efficiency, convenience, and accessibility for passengers. Passengers can simply access information about transportation options and can purchase travel tickets regardless of time and place. For instance, various digital mobility services include multi-modal route recommendation, navigation systems, vehicle sharing/rental, ticketing, and smart parking [1]. However, these benefits will be limited to those who are proficient in utilizing them, which potentially leads to significant disadvantages for individuals who are not proficient in these technologies [2].

According to a study cited in [3], access levels of digitally disadvantaged groups related to the possession of digital devices and internet use have steadily increased to 96.0%, suggesting that the gap was not significantly different from the general population. However, there remains a wide gap in capability levels and utilization levels, at 78.0% and 64.5%, respectively. These results indicate that the digital divide persists due to disparities in capability and utilization.

This is a very important issue in the era of digital mobility services because it can lead to mobility inequality. In particular, shared mobility such as car-sharing, bike-sharing, and ride-hailing can only be used through digital devices [4]. Furthermore, further mobility services such as Mobility as a Service (MaaS), Autonomous Vehicle (AV), Demand-Responsive Transport (DRT), and Urban Air Mobility (UAM) are supposed to be provided only with the use of mobile apps [5–8]. This implies that these services are not available to people with low digital skills.

Despite the recognized need for solutions to bridge the digital divide in mobility services, there remains a scarcity of studies within this domain. Research has predominantly been limited to surveys that assess the current landscape of digital mobility services. Consequently, it is imperative to first empirically examine the impacts of digital mobility services on travel time and convenience for passengers. Such an analysis will not only substantiate the practical benefits of these services but also highlight the critical need to address the digital divide in the mobility sector. Based on empirical findings, it is crucial to develop feasible and sustainable strategies. This paper concentrates on devising actionable plans aimed at mitigating the digital divide in the mobility sector through a series of experiments and surveys. The main contributions of this research are summarized as follows:

1. This study introduces two basic approaches, developed through extensive literature reviews, to address the digital divide in mobility services.
2. A comprehensive pilot test has been executed to assess both the quantitative and qualitative impacts of these newly proposed approaches. Additionally, a survey was conducted to identify key factors influencing technology acceptance for one of these approaches. This dual methodology not only validates the effectiveness of the solutions but also enhances the robustness of the findings.
3. Drawing on the insights gained from the empirical evidence, this research outlines a phased implementation plan with short-term, medium-term, and long-term objectives. These plans are designed to gradually integrate the proposed solutions, ensuring sustainability and adaptability in improving digital mobility services.

1.1. Literature Review

1.1.1. Definition of Digital Divide

The digital divide refers to the disparity between countries, regions, and people in their access to digital services [9]. This disparity is caused by multiple factors, with the first set comprising inequalities of access to the internet and digital devices, and the second set involving inequalities in internet usage and skills. More recently, it has been defined as inequalities in the quality and ability to utilize information on outcomes effectively [10]. Accordingly, numerous studies have focused on comprehending the social determinants contributing to these inequalities, such as age, education, gender, income, and ability [11].

In the context of digital mobility services, previous studies have identified certain vulnerable groups: older people, people with a lower income, people with a lower education level, people with disabilities, migrants, and people in certain locations [12]. For example, people with higher income may have greater opportunities for access to and experience with digital devices and services compared to people with lower income. This results in an improvement in their ability to use digital technologies and adapt to new digital services [13]. Similarly, people with occupations that involve traditional methods of work often have limited exposure to digital devices. Aside from these digital skills issues, other groups face difficulty due to physical barriers, the absence of digital infrastructure, etc. However, these factors are not limited to the mobility sector and are issues that arise in all areas where digital technology has been introduced. Accordingly, many efforts to resolve the digital divide have been undertaken.

1.1.2. Digital Inclusion Policy

The UK government included ‘Digital Inclusion’ in the UK Strategy 2017 [14]. This policy is designed to create access environments and services centered on education, ensuring that all citizens can access digital technology without discrimination. The education program is operated through schools and regions, targeting digitally vulnerable groups. Furthermore, the City of London implemented a Mi Wifi pilot project from April 2017 to March 2018 [15]. The Lewisham Autonomous Region, showing the most significant digital exclusion in the city of London, was selected for a pilot project. Public libraries and

community centers in London provide citizens with free rental of tablet PCs with Wi-Fi access and offer basic usage education.

In the case of Singapore, the Digital Readiness Blueprint was launched in 2018. This blueprint is a concept to cover access to digital technologies, digital literacy to use this technology, and the promotion of digital participation [16]. Accordingly, three principles are recommended: (1) user-centric design for the goal of universal inclusion, (2) digital inclusion is more than access, and (3) digital readiness requires effort from the entire society [17]. This policy is focused on addressing the specific needs of vulnerable groups. For instance, seniors can learn basic digital skills that are available in community centers, public libraries, and at home through one-to-one guidance by Digital Ambassadors. Furthermore, recommendations for education programs after pre-competency diagnosis and experiential digital education operations are also provided for seniors [18].

Australia included the promotion and inclusion of digital skills in Australia's Tech Future in 2018 [19]. This aims to improve digital skills for older people, women, indigenous people, people with disabilities, people in low socio-economic groups, and people living in regional and remote areas. The policy focuses on providing training and support to these groups, fostering digital literacy and inclusion. Another case involves digital education for older people. Seniors over 65 years of age participate as digital instructors to provide training on smart devices, operating system use, and application use [20].

In the United States, the Cyber-Seniors project, where a youth mentor visits older families or related facilities to guide digital learning in a one-to-one manner, was launched in 2009 [21]. An educational model along with relevant resources and manuals was developed and provided to enable individuals or organizations globally to participate in the Cyber Senior project.

One of New Zealand's representative policies is the Digital Inclusion Map. This map aims to provide convenience in searching for digital inclusion resources and information such as computer accessibility and education, organizations related to digital inclusion projects, and locations of Wi-Fi [22].

The Danish Government adopted the National Strategy for Digitalization 2022–2026 in 2022 [23]. This strategy encompasses various digital solutions, including the development of digital skills. To strengthen digital knowledge, education is emphasized for children and young people in primary school. Additionally, graduates and the workforce are targeted for enhancement in higher education through regular programs and supplementary and continuing programs.

Sweden established Digital Centers in libraries that are easily accessible by citizens. These centers provide basic smart device education and counseling on device utilization [24]. The resident staff provides consultations on the use of IT devices and operates programs such as VR experiences, educational seminars, and maker spaces tailored to the characteristics of each center.

2. Methods

The fundamental plans for alleviating the digital divide in the related cases above can be summarized into the following two kinds of approaches:

1. Enhancing usage capability and utilization levels;
2. Providing easier access to the interface.

To enhance digital literacy for using transportation services, the primary solution is mobile app usage education. For the second approach, an AI (Artificial Intelligence)-based Mobility Service App is introduced to improve the accessibility of the digital interface of mobility sector mobile apps. The AI-based Mobility Service App is a service that supports the overall process of using transportation services by employing the app's built-in AI to perform functions (e.g., reservations, ticket purchases, cancellations, etc.) when the desired functions are input into the app by voice or text. This allows use of the services to be provided in the same form as offline services without making users access them through

an unfamiliar digital interface. Accordingly, this paper performed a pilot test using the two presented approaches.

2.1. Pilot Test

2.1.1. Overview of Pilot Test

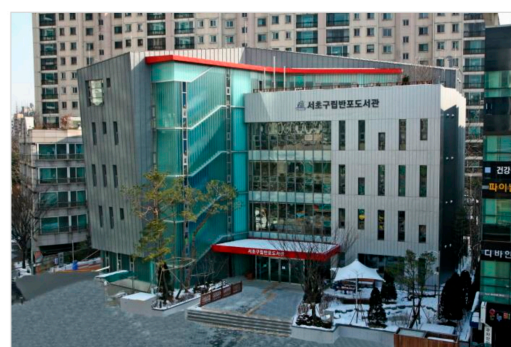
The pilot test that was performed in this paper has the following two goals:

1. Quantitatively verify the practical effects of mobile app usage on travel times and convenience when using transportation services;
2. Compare the effectiveness of the aforementioned two improvement approaches.

Mobile apps in the transportation sector are mostly used to search for a route of travel or make a transportation reservation. Accordingly, the pilot test was designed to be performed in two ways. First, participants traveled on a certain route using public transportation. Second, after arriving at their destinations, they used a railway ticket reservation app to reserve and cancel a train ticket. All of the actions for the pilot test were carried out in the presence of an investigator.

The pilot test was conducted in three groups: one control group and two experimental groups. The control group performed the pilot test under the investigator's control in circumstances where digital devices (e.g., smartphones, tablets) could not be used. Experimental group 1 performed the pilot tests after education by an investigator using previously prepared educational materials about a mass transit route search app (Naver Map) and a railway ticket reservation app (KorailTalk) 30 min before departure. Experimental group 2 performed the pilot test after receiving an explanation regarding the AI-based Mobility Service App 30 min before departure, and the investigator virtually performed the same function as the AI-based Mobility Service App. Finally, each group followed the instructions of the investigator to complete surveys regarding satisfaction, accessibility, efficiency, etc., and these were used as data for qualitative evaluations.

To limit the means of transportation to public transportation (bus or subway), a route that requires at least one transfer was selected. The study period was five weekdays between 17 June 2023 to 21 June 2023, during off-peak hours from 11 a.m. to 4 p.m. The pilot test was performed in three-person groups (one investigator per group) of eighteen people per day, and the departure times were 30 min apart. The origins were gradually adjusted so that the travel routes did not overlap between a group that departed at the same time. The accompanying investigator recorded the number of times the means of transportation were used, including departure times and arrival times, etc. Figure 1 shows the pilot test route.

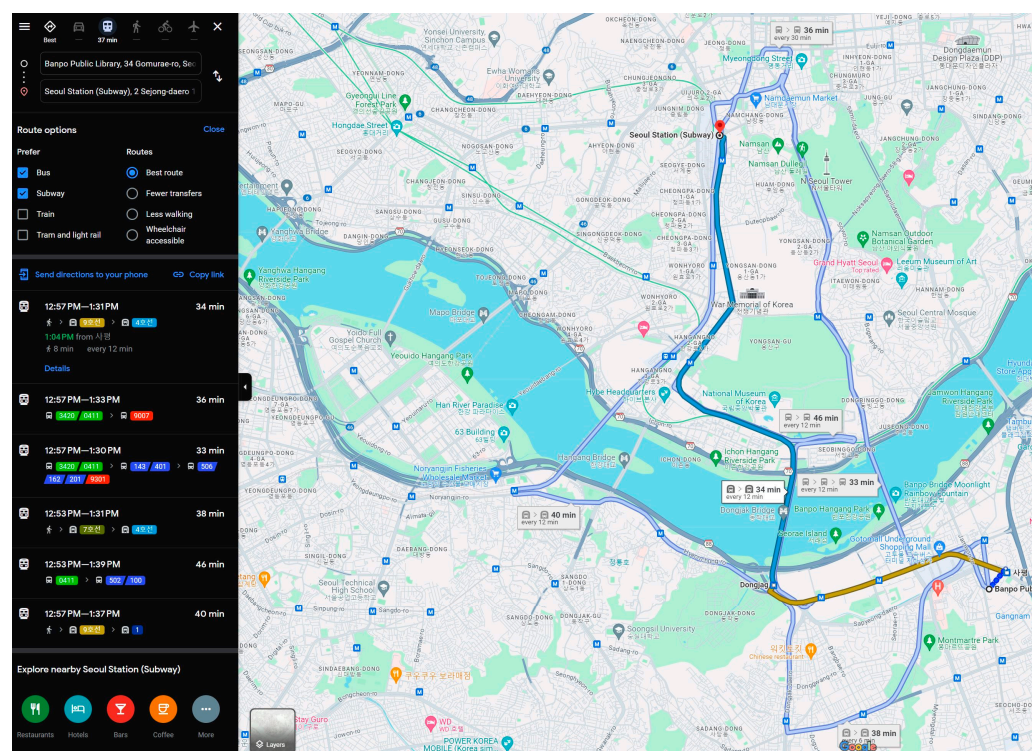


(a) Pilot test origin
(Seocho-gu Banpo Library)



(b) Pilot test destination
(Seoul Station)

Figure 1. Cont.



(c) Pilot test route

Figure 1. An overview of the pilot test route.

2.1.2. Sample

As described in Section 1.1.1, the digital divide in the mobility sector is attributed to a variety of socio-demographic factors. In this paper, the digitally disadvantaged groups were differentiated by age, education level, profession, household average monthly income, and disability class concerning [2,3] as follows:

- Age: those 50 years and over;
- Education level: less than middle school education;
- Profession: agriculture/forestry/livestock/fishery industry, skilled worker, self-employed, housewife, unemployed, retired, etc.;
- Household average monthly income: those earning less than 2 million won;
- Disability: disabled.

The pilot test subjects included 90 people who belonged to one or more digitally disadvantaged groups and had never used digital mobility services, specifically the public transportation route search app (Naver MAP) and the railway reservation app (KorailTalk). These subjects were assigned to three groups of 30 people each.

By age, there were 32 people in the low age group and 58 people in the high age group, so a fairly large number of people were in the high age group. Divided by level of education, there were 59 people with a low level and 31 people with a high level. Divided by occupation, there were 25 people in disadvantaged occupations and 65 people in advantaged occupations. Divided by household average monthly income, 36 people were low income, and 54 people were high income. Divided by disability, two people were disabled. The details of the group sample are shown in Table 1.

Table 1. Pilot test participant sample.

Group	Variable	Value	Number of Cases	Ratio (%)
Control Group	Age	Low	10	11.1
		High	20	22.2
	Education level	Low	20	22.2
		High	10	11.1
	Occupation	Disadvantaged	10	11.1
		Advantaged	20	22.2
Experimental group 1	Age	Low	11	12.2
		High	19	21.1
	Education level	Low	19	21.1
		High	11	12.2
	Occupation	Disadvantaged	9	10.0
		Advantaged	21	23.3
Experimental group 2	Age	Low	11	12.2
		High	19	21.1
	Education level	Low	20	22.2
		High	10	11.1
	Occupation	Disadvantaged	6	6.7
		Advantaged	24	26.7
Experimental group 2	Age	Low	13	14.4
		High	17	18.9
	Education level	Low	13	14.4
		High	17	18.9
	Occupation	Disadvantaged	0	0
		Advantaged	30	33.3

2.1.3. Used Means of Public Transportation

As for the means of transportation that the subjects used, the highest number of people replied that they only used the “subway” at 43.4%, followed by “bus and subway” at 34.4%. Divided by group properties, “subway” was the highest in the control group at 63.3%, “subway” was 43.3% in the experimental group 1, and “bus and subway” was 40.4%, respectively. The result is shown in Table 2.

Table 2. Results of used means of transportation (unit: %).

Category	Number of Cases	Bus	Subway	Bus + Subway
Total	(90)	22.2	43.3	34.4
Group properties	Control group	(30)	10.0	63.3
	Experimental group 1	(30)	20.0	43.3
	Experimental group 2	(30)	36.7	23.3

2.1.4. Public Transportation Usage Total Travel Time

To examine total travel times from the origin to the destination when using public transportation, times were measured for the following three cases. First, wait time refers to

the time from when the subject arrived at the bus stop or subway station until they boarded the means of transportation. Second, walking time refers to the time spent walking to arrive at the destination from the origin, and it also applies to transfers. Third, the means of transportation usage time is defined as the means of transportation embarkation time until the disembarkation time. Finally, the total travel time refers to the total travel time from the origin to the destination.

- Total wait time: (bus stop or subway station arrival time + means of transportation embarkation time);
- Walking time: (departure time~arrival time at first bus stop or subway station) + (first means of transportation disembarkation time~second bus stop or subway station arrival time);
- Means of transportation usage time: (means of transportation embarkation time + means of transportation disembarkation time);
- Total time spent: wait time + walking time + means of transportation usage time.

Looking at the total travel times for public transportation usage by group, the experimental group 2 had the lowest time at 52 min and 40 s, followed by the experimental group 1 at 54 min and 36 s, and the control group at 55 min and 36 s. In the case of means of transportation usage time, experimental group 2 had the highest time at 30 min and 24 s, followed by experimental group 1 at 26 min and 34 s, and the control group at 25 min and 18 s. On the other hand, the walking time was highest in the order of the control group, experimental group 1, and experimental group 2. For the waiting time, the order of the control group, experimental group 1, and experimental group 2 was lower. The detailed result is shown in Table 3.

Table 3. Results of public transportation usage total travel time.

Category		Number of Cases	Total Wait Time	Walking Time	Means of Transportation Usage Time	Total Travel Time
Overall (Average)		(90)	0:07:51	0:19:00	0:27:25	0:54:17
Group	Control group	(30)	0:06:12	0:24:06	0:25:18	0:55:36
	Experimental group 1	(30)	0:09:08	0:18:54	0:26:34	0:54:36
	Experimental group 2	(30)	0:08:14	0:14:02	0:30:24	0:52:40

2.1.5. Railway App Usage Time

For the total railway app usage time, this study aimed to measure the time taken to perform two functions, consisting of the following items:

- Purchase time: time from arriving at Seoul Station until purchasing a train ticket;
- Cancellation time: time from purchasing the train ticket until cancellation of the train ticket;
- Total railway app usage time: purchase time + cancellation time.

To purchase a train ticket, it is necessary to check the information, such as the destination, departure, and time of the train, as well as the payment. Likewise, canceling the ticket requires checking the reserved ticket, as well as the cancellation. In other words, these functions can be processed after involving various actions, which is the same as other ticket reservation and payment apps such as intercity/high-speed buses, taxi-hailing and flight, etc.

The railway app total usage time was 9 min and 20 s for the control group, 7 min and 25 s for experimental group 1, and 4 min and 34 s for experimental group 2 in descending order, showing a fairly large difference. The other results were in the same order, which is shown in Table 4.

Table 4. Results of railway app total usage time.

	Category	Number of Cases	Time from App Start Until Purchase	Time Until Reserved Ticket Cancellation	Railway App Total Usage Time
	Overall	(90)	0:06:09	0:00:56	0:07:06
Group	Control group	(30)	0:08:07	0:01:13	0:09:20
	Experimental group 1	(30)	0:06:19	0:01:05	0:07:25
	Experimental group 2	(30)	0:04:01	0:00:32	0:04:34

2.1.6. Satisfaction

Lastly, to make a qualitative comparison, satisfaction levels were divided into convenience, accessibility, efficiency, and reliability. This survey used a five-point response scale from ‘completely dissatisfied’ to ‘completely satisfied,’ then modified into a 100-points unit. All of the items were the highest in experimental group 2, followed by experimental group 1 and the control group. The result is shown in Table 5.

Table 5. Results of satisfaction levels.

	Category	Number of Cases	Convenience	Accessibility	Efficiency	Reliability
	Overall	(90)	81.4	78.3	79.4	81.7
Group	Control group	(30)	76.7	72.5	73.3	74.2
	Experimental group 1	(30)	79.2	76.7	79.2	81.7
	Experimental group 2	(30)	88.3	85.8	85.8	89.2

2.2. Technology Acceptance Factor

2.2.1. Overview of Technology Acceptance Factor

The AI-based Mobility Service App is a new technology proposed by this study; therefore, understanding the factors that determine whether people intend to use the technology is important for increasing users’ technology acceptance. As such, this study used the Technology Acceptance Model (TAM) to examine the factors that influence users’ intention to use AI-based Mobility Service Apps, and this was carried out through a survey. Figure 2 shows the overview of the TAM.

For AI-based Mobility Service App’s technology acceptance factors, this study considered (1) Subjective norm, (2) innovativeness, (3) perceived security, and (4) perceived usefulness and perceived ease of use.

Subjective norm is a social factor that explains technology acceptance in the theory of reasoned action [25] and the theory of planned behavior [26]. Also, this is defined as an individual’s perception that most of the people who are important to that individual think that an action should be performed or not.

Innovativeness refers to the degree to which a user adopts a new idea more quickly than other users [27], and it generally indicates an interest in new products and services [28]. That is, innovativeness must be considered regarding the acceptance of new technologies such as the AI-based mobility service app because users have almost no knowledge about new technology in the initial stages of that technology [29].

Perceived security refers to the security problems that can be perceived by users when they are using a product [30]. Security problems are the biggest concern for users when using mobile applications [31], and it has been reported that decreases in perceived security help users trust a product or service [32].

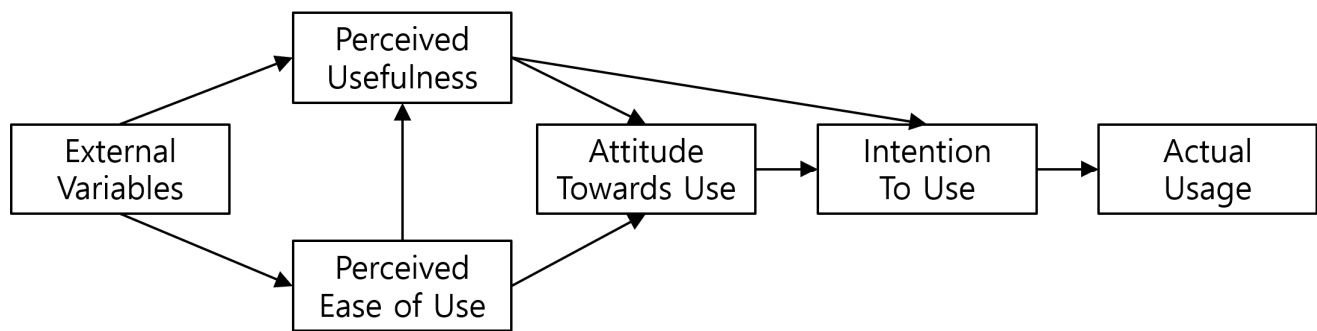


Figure 2. Technology acceptance model [33].

Perceived usefulness refers to the subjective degree to which one believes that task success and effectiveness will be high when using technology [33]. According to TAM, if a user feels that a technology is more useful, the user will rate the use of the technology more positively, usage will increase, and acceptance will occur.

Perceived ease of use is a core factor that determines users' intention to use technology in TAM, similar to perceived usefulness. In comparison to perceived usefulness, perceived ease of use defines the process-related aspects of using new technology [34]. Perceived ease of use not only has a direct influence on the intention to use technology, but it also influences this intention indirectly through the medium of perceived usefulness [33].

Accordingly, the technology factor questions that were examined in this study are shown in Table 6. All of the items were answered with a five-point response scale from 'completely disagree' to 'completely agree.'

Table 6. Technology acceptance factor questions.

Category	Survey Content	Source
Attitude toward behavior	Using the AI-based mobility service app is a good idea. I want to use the AI-based mobility service app.	Davis, Bagozzi, and Warshaw, 1989 [34]; Chen & Chan, 2014 [35]
Perceived usefulness	It seems like using the AI-based mobility service app will increase the efficiency of my life. It seems like using the AI-based mobility service app will make my life more comfortable. The AI-based mobility service app is a useful technology for my lifestyle.	Davis, Bagozzi, and Warshaw, 1989 [34]; Chen & Chan, 2014 [35]
Perceived ease of use	It seems like the AI-based mobility service app will be easy to use. It seems like I will be able to use the AI-based mobility service app proficiently.	Davis, Bagozzi, and Warshaw, 1989 [34]; chen & chan, 2014 [35]
Intention to use the system	I think I will use the AI-based mobility service app within the next few months. I have plans to use the AI-based mobility service app within the next few months.	venkatesh et al., 2003 [36]
Subjective norm	People around me think that I can use the AI-based mobility service app. People who are important to me think that I should use the AI-based mobility service app.	Ajzen, 1991 [26]; venkatesh et al., 2003 [36]
Perceived security	I am confident that the AI-based mobility service app is secure. I think that secrets regarding my personal information will be kept when I use the AI-based mobility service app. I think that I am safe from external hacking risks when I use the AI-based mobility service app.	Chiu et al., 2014 [37]

2.2.2. Sample

A survey was conducted to understand the technology acceptance factors for the AI-based Mobility Service App in digitally disadvantaged groups, which was defined in Section 2.2.1. The valid sample was 1005 people, and the survey was conducted online using a structured survey. However, considering that the survey subjects are in digitally disadvantaged groups, the survey was conducted with the assistance of welfare center workers after contacting national welfare centers for seniors and disabled people, and additional explanations were provided by phone when there were questions about the survey form. The survey period was around 10 days from 15 May until 25 May 2023. The sample distribution of the survey is shown in Table 7.

Table 7. Sample distribution.

Category		Number of Cases	Ratio (%)
Total		1005	100.0
Age	low	548	54.5
	high	457	45.5
Education level	low	294	29.3
	high	711	70.7
Occupation	disadvantaged	406	40.4
	advantaged	599	59.6
Household monthly average income	low	411	40.9
	high	594	59.1
Disability	disabled	(202)	20.1
	not disabled	(803)	79.9

2.2.3. Technology Acceptance Factor Levels

Overall, the factor that had the highest score among the technology acceptance factors was usefulness at 3.76. Next was ease of use at 3.62, subjective norm at 3.56, and perceived security at 3.20. Looking at the levels for each digitally disadvantaged group there are some differences in the scores, but the order of the factors is the same as the overall results. The acceptance factors for each digitally disadvantaged group is shown in Table 8.

Table 8. AI-based Mobility Service App technology acceptance factors for each digitally disadvantaged group (unit: out of 5 points).

Category	Overall (n = 1005)	Seniors (n = 457)	Low Education (n = 294)	Disadvantaged Occupation (n = 406)	Low Income (n = 411)	Disability (n = 202)
Intention to use	3.49	3.54	3.37	3.37	3.36	3.49
Attitude toward use	3.73	3.82	3.61	3.62	3.59	3.74
Usefulness	3.76	3.88	3.68	3.67	3.65	3.80
Ease of use	3.62	3.67	3.51	3.51	3.49	3.55
Subjective norm	3.56	3.62	3.46	3.45	3.44	3.52
Perceived security	3.20	3.22	3.19	3.10	3.11	3.42

2.2.4. Technology Acceptance Factor Verification Results for All Groups

The AI-based Mobility Service App's technology acceptance factors for all digitally disadvantaged groups were verified, and the results are as follows. First, looking at the correlation between innovativeness, intention to use, and technology acceptance factors, as innovativeness increased, subjective norm (path coefficient = 0.476, $p < 0.001$) and perceived security (path coefficient = 0.367, $p < 0.001$) increased. Finally, the technology acceptance

factors (usefulness, ease of use) that influenced the intention to use the AI-based Mobility Service App were verified, and the results show that usefulness (path coefficient = 0.241, $p < 0.001$) and ease of use (path coefficient = -0.708 , $p < 0.001$) both influence the intention to use the AI-based Mobility Service App. In the case of ease of use, in particular, there is a correlation in the negative (-) direction, such that the intention to use increases as ease of use decreases. To explain these results, this study performed a cross-tabulation analysis between ease of use and intention to use, as well as a regression analysis using only these two variables. The results can be interpreted as showing that intention to use increases as ease of use increases (regression coefficient = 0.780, $p < 0.001$), and there was a distortion of the correlation between the variables due to cross-sectional data. The results are shown in Table 9.

Table 9. Results of verification of AI-based Mobility Service App’s technology acceptance factors for digitally disadvantaged groups.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Subjective norm	0.476 ***	0.331	0.027	12.190
Innovativeness → Perceived security	0.367 ***	0.304	0.029	10.340
Innovativeness → Ease of use	0.011	0.009	0.028	0.301
Subjective norm → Ease of use	0.965 ***	1.095	0.066	16.578
Perceived security → Ease of use	0.004	0.003	0.046	0.073
Innovativeness → Usefulness	−0.022	−0.016	0.027	−0.598
Subjective Norm → Usefulness	0.901 ***	0.987	0.224	4.416
Perceived Security → Usefulness	−0.067	−0.062	0.044	−1.410
Ease of use → Usefulness	−0.027	−0.026	0.189	−0.139
Innovativeness → Intention to use	−0.016	−0.014	0.040	−0.360
Subjective norm → Intention to use	1.299 ***	1.797	0.352	4.931
Perceived security → Intention to use	0.093	0.105	0.065	1.600
Ease of use → Intention to use	−0.708 **	−0.835	0.284	−2.936
Usefulness → Intention to use	0.241 ***	0.294	0.076	3.785

Note (1) $X^2 = 245.82$ ***, $df = 83$, $TLI = 0.977$, $CFI = 0.984$, $RMSEA = 0.044$. Note (2) ** $p < 0.01$, *** $p < 0.001$.

2.2.5. Technology Acceptance Factor Verification Results for Seniors (n = 457)

As for seniors, the results are as follows. First, the correlations between innovativeness, intention to use, and technology acceptance factors (usefulness, ease of use, subjective norm, and perceived security) were examined. The results show that as seniors’ innovativeness increased, subjective norm (path coefficient = 0.460, $p < 0.001$), perceived security (path coefficient = 0.306, $p < 0.001$), and ease of use (path coefficient = 0.110, $p < 0.05$) increased.

Next, the correlations between subjective norms, perceived security, intention to use, and technology acceptance factors (usefulness, ease of use) were examined. The results show that only subjective norm influenced the intention to use (path coefficient = 1.338, $p < 0.05$), usefulness (path coefficient = 1.068, $p < 0.05$), and ease of use (path coefficient = 0.884, $p < 0.001$) of the AI-based Mobility Service App. That is, perceived security did not have a statistically significant correlation with either intention to use or the technology acceptance factors.

Finally, the technology acceptance factors (usefulness, ease of use) that influenced seniors’ intention to use the AI-based Mobility Service App were verified, and the results show that neither usefulness nor ease of use influenced the intention to use the AI-based Mobility Service App at a statistically significant level. The results are shown in Table 10.

Table 10. Results of verification of AI-based mobility service app’s technology acceptance factors for seniors.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Subjective norm	0.460 ***	0.315	0.040	7.902
Innovativeness → Perceived security	0.306 ***	0.264	0.045	5.868

Table 10. Cont.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Ease of use	0.110 *	0.083	2.050	5.251
Subjective norm → Ease of use	0.884 ***	0.974	0.117	8.305
Perceived security → Ease of use	−0.021	−0.018	0.066	−0.275
Innovativeness → Usefulness	0.021	0.015	0.046	0.333
Subjective norm → Usefulness	1.068 *	1.136	0.443	2.562
Perceived security → Usefulness	−0.101	−0.085	0.080	−1.059
Ease of use → Usefulness	−0.257	−0.248	0.356	−0.696
Innovativeness → Intention to use	−0.061	−0.059	0.064	−0.921
Subjective norm → Intention to use	1.338 *	1.895	0.907	2.088
Perceived security → Intention to use	0.074	0.083	0.129	0.647
Ease of use → Intention to use	−0.470	−0.604	0.587	−1.028
Usefulness → Intention to use	−0.069	−0.092	0.241	−0.383

Note (1) $\chi^2 = 245.82$ ***, $df = 83$, $TLI = 0.977$, $CFI = 0.984$, $RMSEA = 0.044$. Note (2) * $p < 0.05$, *** $p < 0.001$.

2.2.6. Technology Acceptance Factor Verification Results for People with Low Education (n = 294)

In the case of people with low education, the results are as follows. First, the correlations between innovativeness, intention to use, and technology acceptance factors (usefulness, ease of use, subjective norm, perceived security) were examined, and the results show that as the low-education subjects' innovativeness increased, subjective norm (path coefficient = 0.596, $p < 0.001$) and perceived security (path coefficient = 0.439, $p < 0.001$) increased.

Next, the correlations between subjective norms, perceived security, intention to use, and technology acceptance factors (usefulness, ease of use) were examined. The results show that only subjective norm influenced the AI-based Mobility Service App's usefulness (path coefficient = 0.995, $p < 0.001$). That is, neither subjective norm nor perceived security had a statistically significant correlation with the intention to use the AI-based Mobility Service App.

Finally, the technology acceptance factors (usefulness, ease of use) that influenced low-education subjects' intention to use the AI-based Mobility Service App were verified. The results show that neither usefulness nor ease of use influenced the intention to use the AI-based Mobility Service App at a statistically significant level. The results are shown in Table 11.

Table 11. Results of verification of AI-based mobility service app's technology acceptance factors for people with low education.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Subjective norm	0.596 ***	0.422	0.050	8.493
Innovativeness → Perceived security	0.439 ***	0.383	0.054	7.033
Innovativeness → Ease of use	−0.018	−0.013	0.064	−0.206
Subjective norm → Ease of use	0.995 ***	1.041	0.245	4.246
Perceived security → Ease of use	−0.038	−0.032	0.149	−0.217
Innovativeness → Usefulness	−0.136	−0.106	0.119	−0.884
Subjective norm → Usefulness	1.796	1.973	1.519	1.299
Perceived security → Usefulness	−0.260	−0.232	0.291	−0.798
Ease of use → Usefulness	−0.662	−0.695	1.107	−0.627
Innovativeness → Intention to use	−0.237	−0.230	0.281	−0.819
Subjective norm → Intention to use	2.142	2.929	4.572	0.641
Perceived security → Intention to use	−0.169	−0.188	0.681	−0.276
Ease of use → Intention to use	−0.609	−0.796	2.385	−0.334
Usefulness → Intention to use	−0.374	−0.465	1.265	−0.368

Note (1) $\chi^2 = 166.68$ ***, $df = 85$, $TLI = 0.968$, $CFI = 0.977$, $RMSEA = 0.057$. Note (2) *** $p < 0.001$.

2.2.7. Technology Acceptance Factor Verification Results for People with Disadvantaged Occupations (n = 406)

For people with disadvantaged occupations, the correlations between innovativeness, intention to use, and technology acceptance factors (usefulness, ease of use, subjective norm, and perceived security) were examined. The results are that the disadvantaged occupation subjects' innovativeness increased, subjective norm (path coefficient = 0.499, $p < 0.001$) and perceived security (path coefficient = 0.346, $p < 0.001$) increased.

Next, the correlations between subjective norms, perceived security, intention to use, and technology acceptance factors (usefulness, ease of use) were examined. The results show that only subjective norm influenced intention to use (path coefficient = 1.123, $p < 0.01$), usefulness (path coefficient = 1.130, $p < 0.001$), and ease of use (path coefficient = 0.891, $p < 0.001$) of the AI-based Mobility Service App. That is, perceived security did not have a statistically significant correlation with either intention to use or technology acceptance factors.

Finally, the technology acceptance factors (usefulness, ease of use) that influenced low-education subjects' intention to use the AI-based Mobility Service App were verified. The results show that neither usefulness nor ease of use influenced the intention to use the AI-based Mobility Service App at a statistically significant level. The results are shown in Table 12.

Table 12. Results of verification of AI-based mobility service app's technology acceptance factors for people with disadvantaged occupations.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Subjective norm	0.499 ***	0.373	0.043	8.571
Innovativeness → Perceived security	0.346 ***	0.283	0.045	6.287
Innovativeness → Ease of use	0.052	0.042	0.043	0.964
Subjective norm → Ease of use	0.891 ***	0.964	0.102	9.486
Perceived security → Ease of use	−0.031	−0.030	0.070	−0.432
Innovativeness → Usefulness	−0.061	−0.046	0.045	−1.023
Subjective norm → Usefulness	1.130 ***	1.137	0.272	4.177
Perceived security → Usefulness	−0.150	−0.138	0.080	−1.715
Ease of use → Usefulness	−0.172	−0.160	0.195	−0.822
Innovativeness → Intention to use	−0.092	−0.086	0.053	−1.630
Subjective norm → Intention to use	1.123 **	1.403	0.458	3.062
Perceived security → Intention to use	0.064	0.073	0.103	0.710
Ease of use → Intention to use	−0.197	−0.228	0.235	−0.970
Usefulness → Intention to use	−0.026	−0.032	0.189	−0.172

Note (1) $X^2 = 193.13$ ***, $df = 85$, $TLI = 0.967$, $CFI = 0.976$, $RMSEA = 0.056$. Note (2) ** $p < 0.01$, *** $p < 0.001$.

2.2.8. Technology Acceptance Factor Verification Results for People with Low Income (n = 411)

For people with low income, the correlations between innovativeness, intention to use, and technology acceptance factors (usefulness, ease of use, subjective norm, and perceived security) were examined. the result is that as low-income subjects' innovativeness increased, there was an increase in intention to use (path coefficient = -0.105 , $p < 0.05$), subjective norm (path coefficient = 0.506 , $p < 0.001$), and perceived security (path coefficient = 0.351 , $p < 0.001$) of the AI-based Mobility Service App. In the case of innovativeness and intention to use in particular, there is a correlation in the negative (-) direction, such that intention to use increased as innovativeness decreased. To provide an additional explanation of these results, this study performed a cross-tabulation analysis between innovativeness and intention to use, as well as a regression analysis using only the two variables. The results can be interpreted as showing that intention to use increases as innovativeness increases (regression coefficient = 0.356 , $p < 0.001$), and there was a distortion of the correlation between the variables due to cross-sectional data.

Next, the correlations between subjective norms, perceived security, intention to use, and technology acceptance factors (usefulness, ease of use) were examined. The results show that only subjective norm influenced intention to use (path coefficient = 0.883, $p < 0.01$) and ease of use (path coefficient = 0.894, $p < 0.001$) of the AI-based Mobility Service App. Perceived security did not have a statistically significant correlation with either intention to use or technology acceptance factors.

Finally, the technology acceptance factors (usefulness, ease of use) influenced the low-income subjects' intention to use the AI-based Mobility Service App at a statistical level. In addition, ease of use (path coefficient = 0.796, $p < 0.001$) had a statistically significant influence on usefulness. that is, as ease of use increased, usefulness increased. The results are shown in Table 13.

Table 13. Results of verification of AI-based mobility service app's technology acceptance factors for people with low income.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Subjective norm	0.506 ***	0.381	0.045	8.470
Innovativeness → Perceived security	0.351 ***	0.307	0.049	6.322
Innovativeness → Ease of use	0.063	0.052	0.048	1.084
Subjective norm → Ease of use	0.894 ***	0.980	0.143	6.848
Perceived security → Ease of use	−0.039	−0.036	0.094	−0.386
Innovativeness → Usefulness	−0.024	−0.020	0.039	−0.497
Subjective norm → Usefulness	0.058	0.063	0.231	0.274
Perceived Security → Usefulness	0.000	0.000	0.074	0.004
Ease of use → Usefulness	0.796 ***	0.796	0.182	4.364
Innovativeness → Intention to use	−0.105 *	−0.098	0.045	−2.177
Subjective norm → Intention to use	0.883 **	1.091	0.334	3.270
Perceived security → Intention to use	−0.018	−0.020	0.101	−0.194
Ease of use → Intention to use	−0.052	−0.058	0.255	−0.229
Usefulness → Intention to use	0.204 *	0.229	0.101	2.273

Note (1) $\chi^2 = 198.21$ ***, $df = 86$, $TLI = 0.966$, $CFI = 0.975$, $RMSEA = 0.056$. Note (2) * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

2.2.9. Technology Acceptance Factor Verification Results for People with Disability (n = 203)

For disabled people, the correlations between innovativeness, intention to use, and technology acceptance factors (usefulness, ease of use, subjective norm, perceived security) were examined. The results show that disabled subjects' innovativeness increased, subjective norm (path coefficient = 0.420, $p < 0.001$), and perceived security (path coefficient = 0.493, $p < 0.001$) increased.

Next, the correlations between subjective norms, perceived security, intention to use, and technology acceptance factors (usefulness, ease of use) were examined. The results show that only subjective norm influenced intention to use (path coefficient = 1.404, $p < 0.01$), usefulness (path coefficient = 0.992, $p < 0.01$), and ease of use (path coefficient = 0.778, $p < 0.001$) of the AI-based Mobility Service App. Perceived security did not have a statistically significant correlation with either intention to use or technology acceptance factors.

Finally, the technology acceptance factors (usefulness, ease of use) that influenced the disabled subjects' intention to use the AI-based Mobility Service App were verified, and the results show that neither usefulness nor ease of use influenced the intention to use the AI-based mobility service app at a statistically significant level. The results are shown in Table 14.

Table 14. Results of verification of AI-based mobility service app’s technology acceptance factors for people with disability.

Path	Standardized Coefficient	Non-Standardized Coefficient	S.E	t-Value
Innovativeness → Subjective norm	0.420 ***	0.353	0.067	5.293
Innovativeness → Perceived security	0.439 ***	0.394	0.069	5.718
Innovativeness → Ease of use	0.079	0.066	0.049	1.358
Subjective norm → Ease of use	0.778 ***	0.777	0.116	6.695
Perceived security → Ease of use	0.151	0.141	0.095	1.479
Innovativeness → Usefulness	0.002	0.002	0.048	0.033
Subjective norm → Usefulness	0.992 **	0.863	0.296	2.915
Perceived Security → Usefulness	−0.081	−0.066	0.089	−0.743
Ease of use → Usefulness	−0.032	−0.028	0.286	−0.097
Innovativeness → Intention to use	0.020	0.020	0.072	0.275
Subjective norm → Intention to use	1.404 **	1.628	0.791	2.058
Perceived security → Intention to use	0.179	0.194	0.141	1.375
Ease of use → Intention to use	−0.354	−0.411	0.481	−0.854
Usefulness → Intention to use	−0.317	−0.422	0.427	−0.987

Note (1) $\chi^2 = 198.21$ ***, $df = 86$, $TLI = 0.966$, $CFI = 0.975$, $RMSEA = 0.056$. Note (2) ** $p < 0.01$, *** $p < 0.001$.

3. Discussion

3.1. Pilot Test

The preliminary results of the pilot test carried out in this paper are discussed comprehensively. In the case of used means of public transportation, “bus and subway” were the highest in the order of the experimental group 2, experimental group 1, and control group. The public transportation route search app (Naver MAP) provides various routes, such as minimum transfer, minimum travel time, minimum walking, etc. Therefore, finding an optimal route through a combination of various means can reduce travel time. That is, the effectiveness of using the mobile app and the AI-based Mobility Service App is proved by the result of the total travel time in Section 2.2.3.

An interesting thing is that the transportation usage time was lower in the order of the control group, experimental group 1, and experimental group 2, contrary to the total walking time. When traveling using public transportation, the lower the walking and the higher the transportation time, the greater the convenience of passage. Accordingly, using the mobile app through education and the AI-based Mobility Service App have a positive effect on the convenience of passage as well as the travel time. Likewise, the railway app usage time also showed the same results. Finally, the previous results appear to have affected the items in Section 2.2.3.

As a result, the pilot test conducted in this study demonstrated the importance of education and the need for an AI-based Mobility Service App in the transportation sector. Especially, experimental group 2 exhibited the most favorable outcomes, indicating a potential impact on enhancing the overall experience of using the transportation services. For this reason, there is a need to widely promote and spread the use of AI-based Mobility Service Apps such that users can realize the associated benefits.

3.2. Technology Acceptance Factors

First, the intention to use the AI-based Mobility Service App of all digitally disadvantaged groups was 3.49 (out of 5 points). By group, seniors had the highest intention to use at 3.54, followed by disabled people at 3.49, people with disadvantaged occupations and low education at 3.37, and people with low income at 3.36. This indicates that all of the digitally advantaged groups perceive a need for the AI-based Mobility Service App.

Comprehensively, the technology acceptance factors that affect the use of the AI-based Mobility Service App by digitally disadvantaged groups turned out to be usefulness, ease of use, and subjective norm. Also, subjective norm affected usefulness and ease of use, and innovativeness affected subjective norm and perceived security. These results are consistent

with the findings of previous studies that verified usefulness, ease of use, subjective norm, and innovativeness as AI-based new technology acceptance factors [28,38,39].

Subjective norm was found to be a technology acceptance factor that influenced seniors' intention to use the AI-based Mobility Service App, affecting both usefulness and ease of use. Furthermore, although innovativeness was not statistically significant regarding the intention to use, it did influence subjective norms, perceived security, and ease of use at statistically significant levels. These results were consistent across individuals with disadvantaged occupations and disabilities.

For people with low education, no technology acceptance factors were identified. However, innovativeness influenced subjective norm and perceived security, while subjective norm only influenced usefulness at statistically significant levels.

It was found that innovativeness and subjective norms were the technology acceptance factors that influenced low-income people's intention to use the AI-based Mobility Service App. In particular, subjective norm also influenced ease of use, and innovativeness influenced subjective norm and perceived security at statistically significant levels. In addition, ease of use had a statistically significant positive correlation with usefulness.

As a result, subjective norms should be considered as a major factor to improve the intention to use the AI-based Mobility Service App. This means that digitally disadvantaged groups are significantly influenced by key figures around them when acquiring new skills, aligning with the findings of studies by [38,39]. In other words, it is imperative to facilitate access to the service through recommendations from individuals, such as family members and primary guardians, when providing the AI-Based Mobility Service App. On the other hand, people with low income had the lowest intention to use among the digitally disadvantaged groups. Their intention to use should be enhanced not only through subjective norms but also through innovativeness and usefulness. That is, it is crucial to foster interest in new technologies and services by assisting them to fully recognize the potential of the intended technology to be beneficial for them.

3.3. Challenges

The use of mobile apps has various benefits for people with low digital interface experience. In addition, it is expected that most future mobility services, such as Mobility as a Service (MaaS), Autonomous Vehicle (AV), Demand-Responsive Transport (DRT), and Urban Air Mobility (UAM), will primarily be available via mobile apps. Thus, if the digital divide remains unaddressed, there will be an escalation in discrimination regarding access to transportation services. Based on the findings in this paper, sustainable and feasible plans are presented for alleviating the digital divide focused on the mobility sector, categorized into the short, medium, and long term.

The short-term plan involves the development and operation of digital literacy education programs tailored specifically for the transportation sector. While numerous education programs cover diverse fields such as internet search, kiosk usage, AI, coding, etc., there is a notable absence of programs addressing the specific interface functions related to transportation services. These functions, limited to checking the means information, reservation, payment, etc., are comparatively less complicated. That is, in the context of mobility, the digital competence to use a transportation service demands low digital skills, including basic tasks such as switching screens and clicking icons to perform specific functions. Therefore, education programs for digital mobility services are expected to be highly effective for people who have low digital skills, as shown in Section 2. Furthermore, the mobility service apps should include tutorial screens to explain the experience and text explanations for icons, so that users can understand their functions. Similarly, another approach could be to make digital mobility service experience spaces.

For the medium-term plan, it will be necessary to develop standard guidelines for digital interfaces. As mentioned earlier, a limited number of functions are required to use digital mobility services. However, different designs are applied by each service provider, even when offering the same services. This can lead to confusion among users, even if

digital literacy levels are raised through education. In addition, users must adapt again if a new design is applied whenever a new mobility service app is released. Therefore, it is crucial to identify specific functions required for using digital mobility services and adopt unified or consistent interfaces for these functions.

The plans described above are targeted toward people with low digital skills. From a long-term perspective, an approach is needed to offer digital mobility services that are easily accessible to all users. In other words, all users should encounter the same level of service without requiring any special effort or digital interface competence. To achieve this, incorporating AI technology can be considered. The results of the pilot test conducted in this paper have sufficiently demonstrated the various effects of the AI-based Mobility Service App for people with low digital skills. Moreover, this app can cover people with disabilities. For example, it can support digital interaction via both voice and text for people with visual and auditory disabilities. This means that commands to execute a function can be input via voice or text, and the outcome of the function can be returned via voice or text. Also, the app can include features such as a walking assistance service for visually disabled people to navigate obstacles using a camera embedded in a smartphone, a GPS-based assistant call service for seniors and disabled people with limited mobility, etc. Similar examples can be found in the United States (Project Euphonia, WeWalk, and Aira) [40–42]. Hence, the AI-based Mobility Service App should be developed simultaneously with short- and medium-term plans, reflecting the needs of everyone.

3.4. Limitations

A limitation of this study is that the essential commands for experimental group 2 were entered by an accompanying investigator as if AI was integrated into the mobile phone. This implies the pilot test was carried out under the assumption that the AI-based Mobility Service App had already been developed. To materialize the AI-based mobility service, it is essential to first enhance the technological capabilities of sensors embedded in smartphones for tasks such as voice recognition, object detection, positioning, etc.

4. Conclusions and Future Works

This paper has performed a pilot test to demonstrate the effectiveness of a basic strategy and a survey-based analysis of the technology acceptance factor, aiming to develop digital divide alleviation plans in the mobility sector. Based on a review of previous case studies on digital inclusion, two improvement approaches were established: (1) improving digital literacy through education and (2) providing an easily accessible digital interface. Consequently, the pilot test verified the effectiveness of both approaches. Particularly, the utilization of the AI-based Mobility Service App could provide better performance such as a combination of different types of public transport modes, travel times, payment and cancellation of railway tickets, and satisfaction levels.

The Technology Acceptance Model was employed to understand the intent to use the AI-based Mobility Service App. The analysis results revealed variations depending on each disadvantaged group. Therefore, it will be necessary to take these factors into account when promoting the AI-based Mobility Service App.

As a result, this study has suggested educational initiatives on the use of digital mobility services as a short-term plan and the establishment of a standard digital interface as a medium-term plan. Ultimately, the digital divide in the mobility sector should be mitigated for everyone through AI-based Mobility Service Apps lowering the barrier to digital device utilization. As outlined in Section 3.4, the pilot test in this paper was conducted under the assumption that the AI-based Mobility Service App had been developed. Therefore, further work should focus on identifying the functional and technical requirements necessary to develop the AI-based Mobility Service App. Following its development, the pilot test should be performed again to evaluate improvements and additional requirements. Additionally, surveys should be periodically conducted to monitor the changes in the technology acceptance factors.

Author Contributions: Writing—original draft preparation, A.C. and J.S.; project administration, J.S., Y.K. and A.C.; supervision, J.S.; writing—review and editing, A.C. and J.S.; data analysis, S.K. and J.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Korea Transport Institute under A Study on Resolving Digital Divide to Improve Inclusion in Transport Sector (Grant No. 52-22-024).

Institutional Review Board Statement: The survey and pilot test conducted in this study obtained approval through review by the Institutional Review Board (IRB) of Kyung Hee University for ethical considerations prior to the investigation (KHGIRB-23-152).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data will be made available on request.

Acknowledgments: The authors would like to thank all of the participants in the research.

Conflicts of Interest: The authors declare no conflicts of interest.

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