International Journal of Internet, Broadcasting and Communication Vol.15 No.1 97-112 (2023)
http://dx.doi.org/10.7236/IJIBC.2023.15.1.97

IJIBC 23-1-12

Design of Public Transportation Route Guidance System for Wheelchair Users Utilizing Public Data of Seoul City

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Abstract

The purpose of this study is to design and test a new way of public transportation route guidance system for persons with disabilities, including wheelchair users. The guidance system is smartphone app-based, using, routes that involve disabled-friendly facilities in the vicinity can be searched. A database that contains publicly available data on low-floor bus services, location and extent of disabled-friendly facilities, and suitable subways and stations, was developed for this purpose. The app uses the database to access and query the required information. A pilot study was conducted to test the effectiveness of the guidance system. It was found that the system was able to convey information about the disabled-friendly routes and related guidance information even inside subway stations, effectively. The performance of the system was compared with route guidance services that do not explicitly use data on disabled-friendly services. A notable difference was observed in the travel time estimated by this program and other guidance services. The difference was around 4 to 15 minutes. This is significant savings for persons with disabilities if they use the app and service. The study thus shows that exclusive use of disabled-friendly data in route guidance will bring more benefits for persons with disabilities.

Keywords: *Route Guidance System, Mobility-impaired, Public Transportation, Barrier-free Facilities, Wheelchair Use.*

1. Introduction

In the Act on Promotion of Mobility Convenience for the Transportation disadvantaged, people with disabilities, the elderly, pregnant women, accompanying infants and toddlers, and children, who feel inconveniences in daily life, are designated as transportation. Therefore, local governments are drawing up action plans to improve the mobility of the transportation disadvantaged. Accordingly, the Seoul Metropolitan Government (SMG) is continuously establishing service improvement plans to enhance the mobility rights of the transportation disadvantaged such as additionally distributing special transportation means operated for the

Manuscript Received: December. 15, 2022 / Revised: December. 18, 2022 / Accepted: December. 21, 2022
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severely disabled in the 2018 Mobility Convenience Promotion Plan. Special transportation is operated in the form of a call taxi through the call of the disabled person experiencing severe movement inconvenience. It is the most preferred means of transportation for disabled people because it can expect convenient and safe. To satisfy this demand, we are improving the coverage of such service by securing additional means of special transportation. However, the average waiting time was more than 30 minutes, with 30 minutes in 2020, 32 minutes in 2021, and 36.7 minutes in 2022 as a result of the average waiting time survey. It seems that supply is still not keeping up with the demand. Seoul Facilities Corporation Disabled Call Taxi Operation Department [1]. Since all transportation disadvantaged people cannot move using special transportation means, it is necessary to find a way to minimize inconvenience even when the transportation disadvantaged people use public transportation.

The SMG announced that it plans to complete 100% maintenance of all convenience facilities for the transportation disadvantaged inside subways and buses by 2025 under the installation standards stipulated in the Enforcement Rules of the Traffic Act [2]. Previous studies on the transportation disadvantaged have pointed out that it is necessary to provide services or prepare a system to create an environment for the transportation disadvantaged to use public transportation, along with the improvement of mobility convenience facilities such as those planned by the SMG. In response to these demands, we are operating services that provide low-floor bus information and subway transportation convenience facility information when using public transportation through various studies, but are limited to web services rather than mobile applications, or provide only subway internal routes rather than the entire movement route. On the other hand, since the popularized route guidance service targets general users, it is difficult to consider all the information necessary for the movement of the transportation disadvantaged, so a separate public transportation route guidance system targeting the transportation disadvantaged is required.

In this study, a public transportation route guidance system was designed focusing on wheelchair users who have the most mobility restrictions according to the presence or absence of convenience facilities when using public transportation among the transportation disadvantaged. Mobility convenience facility information such as bus and subway operation information was established and based on the established information, a subway station entrance search function, and a low-floor bus search function were added to provide easy and convenient route information. In addition, the smartphone application screen was designed so that public transportation route search results and information on mobile convenience facilities can be checked while moving. The pilot implementation results for case areas and currently used public/private services were compared and analyzed.

The spatial scope of the study is set to Seoul, which provides high-quality information on subway and bus usage information through public data portals, and provides periodic updates on additional bus routes and subway stations to ensure that the data is up-to-date and highly usable.

Wheelchair users are the main target of the system to be developed. The reason for selecting wheelchair users is that public transportation cannot be used without essential mobility facilities such as low-floor buses and elevators (EV), so dependence on mobility facilities is very high. Therefore, it was judged that it would be feasible to first establish a service for wheelchair users and expand the scope of the transportation disadvantaged subject to service through additional research in the future.

This study analyzed previous studies conducted on transportation disadvantaged people, reviewed data collection and processing methods to be used in the system, built a database and searched for subway entrances and floors to design a public transportation route system for wheelchair users. A public transportation route search was performed based on the timetable with the added bus search function. A mobile application was constructed and a system was implemented for case areas to effectively provide route guidance information for wheelchair users. To confirm the usability of the system, it was compared with the information provision service for the transportation disadvantaged and the route guidance service for the general public, and differences, limitations, and implications were derived.

2. Literature Review

The purpose of this study is to lay the groundwork for developing a public transportation route guidance system that can provide information on transportation convenience facilities inside stations for the transportation disadvantaged who are suffering from a lack of information on transportation convenience facilities when using the subway.

A route guidance system targeting the transportation disadvantaged has to give information about transportation facilities to provide convenience in situations where mobilization is required and the factors that may hinder it; since the transportation disadvantaged that mobilizes uses equipment that reduces the senses such as sight and hearing, or in mobility such as canes and wheelchairs to relieve physical discomfort. Therefore, the information provided is voiced, tactile, or in an environment that can be operated with one hand so as not to interfere while using other equipment.

[3] identified inconveniences for visually impaired people who have more severe restrictions on mobility and information gap than other types of disabilities, and provides information on in-station movement routes for subway boarding and transfer in connection with smart canes and color barcodes. The system developed in this study vertically installs beacons on the ceiling at regular intervals, scans radio waves, and enables a return to the route through voice or vibration when the route is not voluntarily deviated. [4] planned an Android-based bus reservation and subway station exit direction service using voice recognition and beacons to support the use of public transportation by the visually impaired. [5] introduced a method for recommending a route with the least discomfort based on the transportation mobility inconvenience index, which is derived differently depending on the inconvenience factors of wheelchair users, pregnant women, and the elderly. In this study, the recommended routes of Google for the general public were rearranged according to the weight of inconvenience factors for each transportation disadvantaged person by utilizing the pre-established Google wayfinding service. [6] developed a CC2540-based intelligent system consisting of a smart cane, a navigation app, and a hands-free device in the form of glasses for the visually impaired to detect obstacles in front and transfer the information processed by the smartphone hands-free. [7] developed an indoor location estimation and guidance system for the visually impaired based on text-to-speech (TTS) using beacons and smartphone sensors. In this study, the TTS function of Google was used to receive input of the starting point and destination, and it was possible to check the value set by voice, and an information transmission function using vibration was added so that the user could recognize it immediately.

[8] organized five categories of user characteristics, information delivery, mobility, safety, and emergency response to improve the convenience of use for the physically and visually impaired people who have relatively low satisfaction with the usage among the transportation disadvantaged railway stations. The matters were organized, and based on this, a system capable of providing route information and convenience facility location information was designed to improve the satisfaction of the usage in the station. [9] derived universal requirements to resolve the requirements for route guidance services from the perspective of the transportation disadvantaged, and designed a system considering them. The system identified key components in route

guidance in consideration of the walking continuity of the transportation disadvantaged, developed user-customized efficiency indicators, and provides augmented reality services using image collection. [10] conducted a field test for a voice route guidance system in the form of a mobile app. A user satisfaction survey on the system was conducted through interviews with the visually impaired, and basic analysis and satisfaction analysis of the results, and requirements were derived and service stabilization measures were confirmed in the voice guidance content sector, information provision sector, and system commercialization sector.

[4] modified a medical electric scooter to manufacture equipment that can efficiently investigate walking space information that can be an obstacle to the transportation disadvantaged, and put the walking space information collected using the equipment into a database. [11] created a system that analyzes traffic information collected in the past from Cheongju City and uses it together with real-time traffic information to predict the traffic situation for each route and set up a route movement plan. [12] implemented user-participating geospatial information volunteered geospatial information (VGI)-based platform and route guidance service by using a walking network data model creation and convergence technology of obstacles, facility information, and network data for the transportation disadvantaged.

In previous studies, while the demand for information related to mobile convenience facilities was high, studies have mainly been conducted as the main service targets the blind or physically handicapped people who have difficulty checking information. Depending on the nature of the disability, additional equipment such as a smart cane and hands-free was required to provide voice or synesthetic information. Information transmission, mobility, and safety had to be considered according to the characteristics of the user when providing route guidance, and response to emergencies was also required. As for the data construction method for route guidance, facilities such as beacons were installed in stations, separate equipment for data collection was produced and collected, or the VGI technique, which expects voluntary contributions from users.

The difference between previous studies and this study can be summarized in three main points. First, the target of using the proposed system was limited to wheelchair users among the physically handicapped, who had the lowest satisfaction with facility use among the transportation disadvantaged, and related preceding studies lacked about this issue. Previous studies have been conducted to improve the mobility rights of the visually impaired with low satisfaction with facility use and lack of guide signs and guidance means. Wheelchair users who can use all routes are selected as the target of service use. Second, a system in which users can conveniently receive information was designed using a single system in the form of a mobile application without a separate auxiliary device. Even if mobility aids such as hands-free or smart canes are not provided, it is designed so that the transportation disadvantaged do not have difficulty in acquiring information, and it is designed so that one hand can operate the application, assuming that one hand controls a wheelchair. Third, when building data, additional facilities such as beacons are not newly installed, and established public data are used, so additional construction costs are not required when the target area is changed, so it is easy to apply and expand quickly.

3. System Design

The overall composition of the public transportation route guidance system proposed in this study is shown in **Figure 1**. This system designed is divided into; (1) data construction areas through data collection and processing (2) a route search area for route recommendation (3) a mobile application area for visualization. Necessary information such as buses, subways, and mobile convenience facilities used in the system was collected based on public data provided by various organizations. The collected information was applied to the route search algorithm after removing and refining unnecessary parts. The recommended route based on public transportation operation time derived as a result of the route search was designed in consideration of mobility convenience facilities, which allowed wheelchair users to move without additional search and delay time in the process of reaching a specific destination. The searched route information can be checked with a smartphone mobile application like a popular route guidance system.

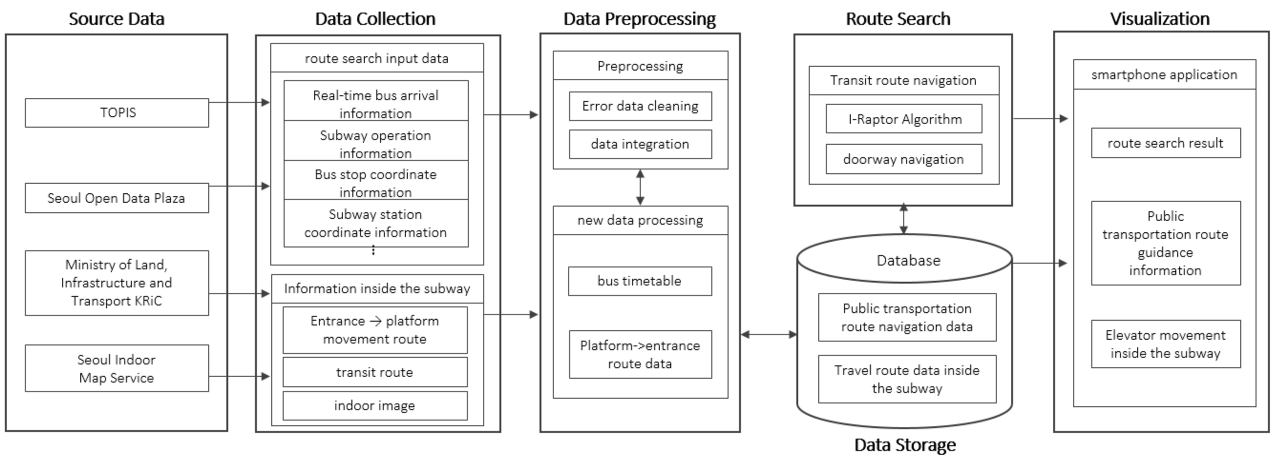


Figure 1. The overall design of the Route Guidance System.

3.1 Route Search Data Creation

The data used in this study is divided into the algorithm input data for route search and the data for route guidance inside subway stations. Various sensors and devices were used in previous studies related to transportation disadvantaged systems. The data used in this study is public, and information on Seoul City is established to build a public transportation route guidance system for wheelchair users with high practical applicability and usability.

In this study, the route search algorithm is based on timetables to provide recommended routes for wheelchair users. This algorithm utilizes timetables of buses and subways to provide routes that can reach the destination in the shortest time for operating times that vary depending on departure times. For route search, location information and operation information on the means of transportation is required. The departure time and arrival time of the operation route is calculated for multiple routes that can be traveled, and the route that takes the shortest time is provided. Therefore, it is necessary to establish operation information including bus and subway operation timetables for timetable route search. To this end, necessary public data was collected from the Seoul Transport Operation & Information Service (TOPIS) and the Seoul Open Data Plaza [13]. The original data is provided in the form of OpenAPI and File. In this study, the data was collected using an OpenAPI to implement the data. Coordinate information on subway stations and bus stops, route information, operation information, and mobility convenience facility information were collected and preprocessed through data integration and outlier removal to refine them into input data.

In the case of subways, the managing body is a public institution. Therefore, fixed timetables can be collected as public data. However, there is no public data that can be collected for buses whose schedules are managed by transportation companies. The bus timetable was constructed by processing bus arrival time information at bus stops by day to check bus operating times that can vary during weekdays, weekends, and specific days. For the data construction, 'Search for list of expected arrival information for the transportation disadvantaged by bus stop route' of TOPIS Seoul Traffic Information System was used. Finally, a low-floor bus operation timetable was established for wheelchair users (system main users) so that only low-floor buses can be used when searching routes.

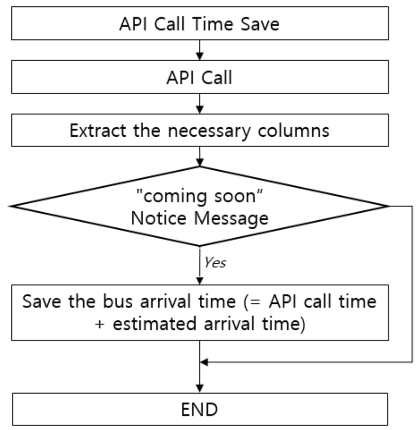


Figure 2. Low-floor Bus Timetable Extraction Process

The information used is called the expected arrival time of route buses arriving at a specific stop at the time of calling through the API. This information is displayed in 87 columns including information on the first and second scheduled buses, as well as stop and route information. As shown in **Figure 2**, during the low-floor bus timetable extraction process, it is necessary to provide the necessary columns for the bus stops, route information, and estimated arrival times (seconds) of the first and second scheduled buses. The arrival information messages are extracted, and scheduling is performed so that the corresponding API can be called in units of 1 minute to arrive at the bus stop. At this time, the information message of the first expected arriving bus is “coming soon”. The bus arrival time is stored by adding the estimated arrival time (seconds) to the API call time. The “coming soon” notification in the information message is designed to be displayed only when the bus departs from the previous stop and it takes less than 2 minutes to arrive at the stop. If the call is repeated every minute, the first bus is replaced by the second bus, and the arrival time of the bus arriving at the stop can be stored under the same conditions. The data repeatedly stored according to fixed scheduling is reprocessed and used in a form applied to route search.

Wheelchair users are highly dependent on mobility convenience facilities, especially when using the subway. Appropriate mobility convenience information guidance services are required according to the movement situation. In addition, it is not possible to move on the path connected by stairs and escalators when using the subway. Therefore, making movement possible only by wheelchair lifts and elevators. However, relatively few elevators are installed in stations compared to stairs and escalators. This issue makes it difficult to find an elevator boarding location when using a station with a large scale and complicated transfer lines. Therefore, there is a need for a service that can immediately check the location and movement route of a mobile convenience facility in a real situation.

For this, Seoul subway convenience facility data and movement route data of mobile convenience facilities were collected, and the necessary information was additionally processed and constructed. The test data is collected based on public data and is additionally collected through OpenAPI from the KRiC rail portal of the Ministry of Land, Infrastructure, and Transport. Information on the location of convenience facilities such as subway elevators, escalators, and restrooms for the disabled, as well as information on the route from the entrance to the platform and the transfer route when using the subway were collected. After getting off the subway, the route from the platform to the station entrance was not provided as public data. Therefore, the route information from the entrance to the platform was processed and constructed. The transportation route data provided by the API is a route to check the sequential movement by giving guidance information at each movement step and guiding the mobility convenience facility route for the transportation at the stage where vertical movement is required. When this series of movement route data is guided in reverse order, a route moving from a platform to an entrance may be provided arbitrarily. The constructed subway movement route data is divided into three types: entrance to the platform, a platform to the entrance, and a transfer section so that guidance information can be checked according to how the subway is being used.

In addition, guide images for the route inside the subway station at each stage of the movement were collected to easily and quickly check the location information on the moving route. The guide information provided in sentences is expressed as visual information such as an indoor map so that the location of the person and the desired route can be confirmed beforehand in the route image corresponding to the subway movement route guide step. Meaning that, is possible to conveniently receive route guidance by checking the image route on the screen even in an unfamiliar or complicated subway station. The route image data was constructed using the S-map service of the SMG. Since the system designed in this study does not provide a 3D map in consideration of the network speed and cost of the user, the necessary indoor map images were extracted according to the order of subway movement route guidance without using the API directly. Images were extracted based on the gaze moving along the movement route guide as if using an actual subway station by using the indoor map service for each station. In addition, an arrow mark is added to provide an accurate movement route when it is necessary to move by elevator or ticket barrier.

3.2 Public Transportation Route Search

For a wheelchair user to use public transportation, a service that can provide a route that considers elevator and wheelchair lift information, low-floor bus arrival information, and convenience facility information is needed. To recommend public transportation routes for wheelchair users, a timetable-based route search algorithm is applied. Also, bus and subway timetable information for the study is used. The timetable-based route search method can provide a route that can travel in the shortest time for a specific origin/destination route and has a shorter calculation processing time than a graph theory-based search method because it has lower computational complexity and a faster route. It has also the advantage of being able to dynamically search according to the departure time. In addition, additional data preprocessing is not required even if the timetable is changed or new stop routes and subway stations are changed. Thus, it can be applied more flexibly than existing route search methods [14].

The input data of the route search algorithm utilizes subway timetables and low-floor bus timetables collected and processed from various public data, as well as route information, subway history information, and mobile convenience facilities. The route can be guided from the routes available to the final destination to the route on which boarding can be done quickly by calculating the subway arrival/travel time and bus arrival/travel time of the moving route. In addition, a subway station entrance search is added for route guidance so that useful route information can be provided to the user when passing through the subway as a result of the route search. When the general public passes through the subway using transportation, they are guided to the closest entrance due to distance in the previous movement step, but wheelchair users take additional time to search for information on exits with transportation conveniences and move if there are no transportation facilities at the entrance indicated. Therefore, the system was designed to guide the route only to the exit with the elevator when using the subway during the route search process.

Based on the collected subway station mobility facility data, the entrance with the elevator is stored separately. As a result of the route search, the route is guided to the elevator entrance of the corresponding subway station if route guidance using the subway is needed. The designed subway station entrance search allows you to move in a minimum amount of time without additionally searching for and checking mobile convenience facilities around the subway station when using a new subway station that you have not experienced or using a complex station with many exits. As a result of public transportation route searches, wheelchair users can receive route guidance in consideration of flexible operating hours that change by the day, check bus information for low-floor buses, and use elevators when moving via subway stations. You can check the route to move safely and quickly by being guided only by the entrance to the subway station.

3.3 Mobile Application Design

Since the wheelchair user needs to check the peripheral vision and drive the wheelchair while moving, it is necessary to easily check the guidance information even with a one-handed operation. Also, it is judged that quick and intuitive information transmission is required. Therefore, a mobile application was selected as a way to provide information on the designed and constructed route search algorithm and mobile convenience facilities. The screen was designed to enable quick visual confirmation by applying related image data for effective information delivery. This application consists of; (1) an initial screen for inputting the starting point and destination (2) a public transportation route guide screen (3) a subway station movement route screen that guides the movement route inside the subway.

On the initial screen, you can set the departure time, starting point, and destination, and the current location and destination location are displayed. If you enter the starting point and destination, a recommended route for the wheelchair user is provided as a route search result. When a route is selected, the route is displayed on the map, and detailed route guidance is provided for each step of the movement. When using public transportation, an image of the movement line is provided on the station guide map so that you can check the approximate route inside the subway if you are passing through the subway when you touch the station.

Since the location of the user cannot be confirmed in real-time inside the subway, it is designed in a turn-by-turn method so that the user can move while checking his or her location at each stage of the movement. A short information message when moving is provided along with an image of the path directly from the viewpoint of the wheelchair user when moving inside the subway so that they can quickly move to the convenient transportation facility even in the complex station. Not only the route from the subway station to the platform, but also the route from the platform to the outside and the transfer route are provided, and the travel direction and transfer direction are set according to the selected route. When transferring, a transfer route guidance message and an arrow-marked route image are displayed together, allowing you to move quickly and safely through complex transfer routes. In the case of walking and bus movement, the movement route is displayed on the map to guide the user to reach the destination.

4. Area Simulation Test

To test the designed system and screen UI/UX, a route from a residential area near Namtaeryeong Station on Line 4, Seocho-gu, Seoul to Asan Medical Center was selected as a case area that has a complex and high amount of users passing by. The results of the mobile application simulation test targeting the case area are shown in **Figure 3**, **Figure 4**, and **Figure 5**.

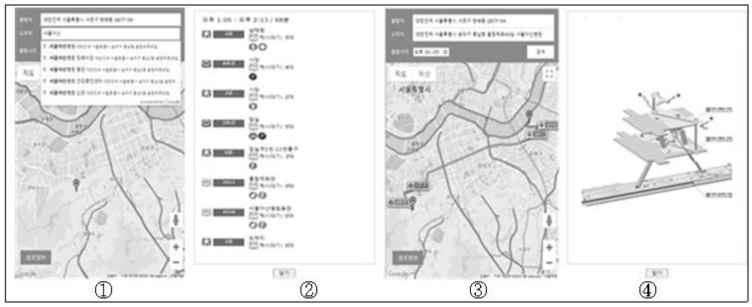


Figure 3. Public transportation route guidance screen.

Figure 3 shows the initial and public transportation route guidance screens of the system. ① On the initial screen, a house near Namtaeryeong Station in Seocho-gu was entered as the starting point and Asan Medical Center in Seoul as the destination. You can check the location of the starting point and destination on the map. ② Depending on the origin and destination, it provides customized routes for the transportation disadvantaged, derived from timetable-based route search results. The order of movement of the entire route is Namtaeryeong Station (Line 4) Exit 2 → Transfer to Sadang Station → Jamsil Station (Line 2) Exit 1 → Jamsil Station Exits 1 and 11 stop, 341 route → Olympic Hall stop, 4311 route → Asan Medical Center, subway and lower floors. The final destination is reached by using the bus thanks to the guidance. ③ Clicking the corresponding route will connect to the detailed public transportation route information screen, and you can check the entire route on the map by walking, bus, and subway (In general, walking means walking without riding on an object, but in the case of wheelchair users, moving using a wheelchair corresponds to 'walking' of the general public). ④ After checking the route, you can check the image of the movement route on the guide map inside the subway station when entering the subway and move according to the guidance. The screen is a guided road showing the internal route from Namtaeryeong Station to the platform. When pressed, the screen provides detailed route guidance information inside the subway.

Figure 4. Subway station route guidance screen.

Figure 4 shows a part of the route guidance screen for moving from the external entrance to the platform to board the subway from Namtaeryeong Station to Sadang Station. ① When entering Namtaeryeong Station, the guide guides you to exit 2 with an elevator instead of exit 1, which is closest to the location, so that wheelchair users can enter directly without additional search for the elevator location. ②~④ Provide route information and images of the inside of the subway moving from where you enter the inside by riding the elevator to the platform. The route guidance image helps to quickly identify the location of the invisible elevator when moving inside the subway, and also displays an arrow on the image so that you can move on the correct route.

Figure 5. Subway transfer route guidance screen.

Figure 5 is a part of the screen that guides the transfer route inside the subway station, and guides the transfer route at Sadang Station to move from Namtaeryeong Station to Jamsil Station. ① When transferring to a subway station, you can check the entire route by providing a guide map inside the subway station. If you press the guide map, a guide phrase is provided along with a step-by-step route image. ②~④ are screens that guide the route from the platform of Line 4 to the platform of Line 2, and a transfer route guide message and an image of the route with arrows are displayed together, so you can move quickly and safely during complicated transfers. In the same way, it guides the route from Jamsil Station to the outside and guides you to the ‘Jamsil Station Exit 1 and 11’ stop so that you can use a low-floor bus to arrive at Asan Medical Center.

As a result of the simulation test of the case area, it was confirmed that route search and guidance information to arrive at Asan Medical Center from a house near Namtaeryeong Station in Seocho-gu, Seoul was normally displayed. The system designed in this study can provide a route for all transportation disadvantaged people except visually disabled people. The elderly or pregnant women, who have difficulty using the stairs, can check route information using elevators and low-floor buses like wheelchair users through the system. In addition, it is judged that it is necessary to adjust the size of convenience facility icons and partially modify the screen UI/UX when actual services are performed in the future.

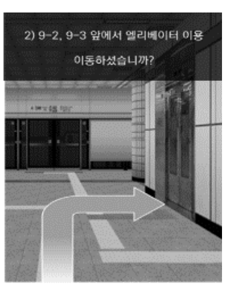
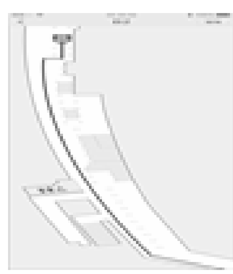
5. Comparative Analysis

In this study, a system that guides users to public transportation was designed and the service was implemented. In this chapter, the convenience, differences, and limitations of the system were confirmed by referring to existing services that provide similar functions and services to the system implemented earlier in the case area. Existing services refer to services provided at places that currently provide facility guidance information to guide the transportation disadvantaged, and mobile route guidance services using marked buses, subways, and walking.

5.1 Transportation disadvantaged Comparison with Target Guidance Services

To check the information of services for the transportation disadvantaged, as a result of checking the mobile application-based transportation disadvantaged service registered in the Google Store, most domestic services were provided to reserve and check the reservation status of vehicles exclusively developed for the transportation disadvantaged by local governments. It has been determined that a similar application to the public transportation navigation service utilized by general users, to assist disabled individuals, could not be found. However, services offering similar guidance information from the perspective of accessibility information have been identified. It has been confirmed that information for individuals with disabilities regarding route information for public transportation such as subways or buses and information on accessible travel facilities can be obtained from the "Seoul Subway Accessible Transfer Map" website of the non-profit association, the "Totta Subway" application provided by the Seoul Transportation Corporation, and the "Kakao Map" of Daum Kakao. **Table 1** shows the comparison of major items related to the transportation disadvantaged of each service and the system proposed in this study. Items were divided into service platform type, range of route information, range of subway station information, the information provided to the transportation disadvantaged, subway information main screen for the transportation disadvantaged, subway route guidance data, and service visualization method.

Table 1. Comparison results with information provision services for the transportation disadvantaged.

	Our Study System	Seoul Subway Transfer Map	Seoul Transportation Corporation “Totta Subway”	Daum Kakao “Kakao Map”
Service Platform	Mobile App	Web Service	Mobile App	Mobile App and Web Services
Route Information	Public Transport	Subway	Subway	Public Transport, Vehicle
Subway Coverage	Seoul 304 Stations	53 stations in Seoul 7 stations in Incheon	Nationwide	Nationwide
Scope of information provided for persons with reduced mobility	· Subway station elevator and entrance information · Subway route map · Subway route guide text · Subway route image by step · Vertical movement facility location information · Low-floor bus information	· Subway transfer section · Cross section of subway transfer route information	· Subway route map · Subway route guide text · Elevator inspection and maintenance status · Electric wheelchair rapid charger · Wheelchair lift information · Wheelchair safe boarding and disembarking information	· Subway route map · Subway route guide text · Vertical movement facility location information · Low-floor bus information
Subway Information Main Screen				
Subway Route Guidance Data	· Entrance→Platform · Transit · Platform → Entrance	· Entrance→Platform (partial) · Transit · Platform → Entrance (partial)	· Entrance→Platform · Transit	· Entrance→Platform · Transit
Data Representation	· External route: turn-by-turn · Internal route: turn-by-turn	· External path: not provided · History inside: map type	· External path: not provided · History inside: map type	· External route: turn-by-turn · Internal route: map type

The comparison results of the main items related to the accessibility service are as follows: First, the service platform mostly supports application form in terms of usability and accessibility, so that users can easily use it when moving. In a mobile environment, the application is more accessible than the web page and is more suitable for using changing signal strength and network environment during movement. "Tottori Subway" and "Kakao Map" are also served as mobile applications. The "Seoul Subway Accessibility Transfer Map" is supposed to be an application-based service based on the photos provided on the website, but it is currently being provided in the form of a web page.

Second, the result of comparing route provision types shows that 'Seoul Subway Handicapped Transfer Map' and 'Totta Subway' are guiding the route based on the subway lines, while 'Kakao Map' and the system of this study are guiding public transportation routes including information on walking, bus, and subway routes in a similar form. In the case of route guidance centered around the subway line, it is helpful during movement within the station, including entering the subway station, moving through the interior passageway, and boarding, but it cannot be used during movement to the subway station. Additionally, the system in this study provides information about all subway stations in Seoul, not just the number of stations provided by "Seoul Subway for the Disabled Transfer Map," while compared to the nationwide services of "Ttoto Subway" or "Kakao Map," it provides information about all the subway lines that can be used in Seoul, such as Lines 1-9, Gyeongchun Line, Airport Express, Shinbundang Line, and Gyeongui Central Line, even though it has a smaller coverage.

Thirdly, comparing based on the range of information provided for disabled individuals, both the system and 'KakaoMap' provide the same information on disabled access information for subways and dedicated bus routes for low-floor buses, but the system provides information on the routes of subway elevators and dedicated bus routes for low-floor buses, whereas 'KakaoMap' does not differentiate between general/low-floor buses, but instead recommends the optimal route and indicates whether the arriving bus is low-floor or not. "Seoul Subway Accessibility Map" and "Ttota Subway" only provide accessibility information on the subway and "Ttota Subway" additionally provides information on the maintenance status of elevators and safe boarding and disembarking for wheelchairs, considering the convenience of wheelchair users. This system provides step-by-step subway guidance images and guidance text, while services like KakaoMap and Totta subway provide route guidance and overall station information on one screen. The "Seoul subway accessible transfer map" provides a subway cross-sectional view on each floor. These route guidance services generally provide entrance→platform, and transfer path information, while this system and the "Seoul subway accessible transfer map" also provide platform→entrance information. The "Seoul subway accessible transfer map" provides platform→entrance information only for certain subway stations because it is constructed by actually moving on the relevant route. Finally, this system applies Turn-by-Turn to both the inside and outside of the subway, which differs from other systems.

5.2 Comparison with Public Transportation Route Guidance Service

The study aimed to compare the recommended route of a guidance system developed in research and that of popular public transportation guidance systems and to compare the time it takes for a pedestrian and a wheelchair user to reach their destination. The study compared the top 5 recommended routes of the popular Korean guidance systems, KakaoMap and NaverMap, with the optimal route recommended by the system. The departure time was set to be the same and the route was set to start from a residential area in Seocho-gu, Bangbae-dong, and end at Seoul Asan Hospital.

Table 2. Route guidance service route (test route).

No.	Route	Recommended Route	Number of Transfer	Total Walking Time	Total Time Taken
1	Our System	Line 4 Namtaeryeong Station Exit 2 → Transfer to Sadang Station → Line 2 Jamsil Station Exit 1 → Jamsil Station Exit 1, 11 bus stop Route 341 → Olympic Hall bus stop Route 4311 → Asan Medical Center	Subway: 1-time Bus: 2-times	11 minutes	68 minutes
2	Naver Maps 1	Line 4 Namtaeryeong Station Exit 1 → Transfer to Sadang Station → Line 2 Jamsil Station Exit 7 → Jamsil Station Bus Stop 4318 → Asan Medical Center	Subway: 1-time Bus: 1-time	10 minutes	61 minutes
3	Naver Maps 2	Line 4 Namtaeryeong Station Exit 1 → Transfer to Sadang Station → Line 2 Gangbyeon Station Exit 4 → Gangbyeon Station (B) Bus Stop Route 97 → Asan Medical Center	Subway: 1-time Bus: 1-time	10 minutes	61 minutes
4	Naver Maps 3	Line 4 Namtaeryeong Station Exit 1 → Transfer to Sadang Station → Line 2 Jamsil Naru Station Exit 4 → Asan Medical Center	Subway: 1-time	26 minutes	53 minutes
5	Naver Maps 4	Namtaeryeong Station (Middle) Bus Stop 4212 → Sadang Station (Middle) Bus Stop → Sadang Station Exit 3 → Jamsil Station Exit 7 → Jamsil Station Bus Stop 4318 Route → Asan Medical Center	Subway: 1-time Bus: 1-time	15 minutes	59 minutes
6	Naver Maps 5	Namtaeryeong Station (Middle) Bus Stop 502 Route → Sadang Station (Middle) Bus Stop → Sadang Station Exit 3 → Jamsil Station Exit 7 → Jamsil Station Bus Stop 4318 Route → Asan Medical Center	Subway: 1-time Bus: 1-time	15 minutes	59 minutes
7	Kakao Maps 1	Line 4 Namtaeryeong Station Exit 1 → Transfer to Sadang Station → Line 2 Jamsil Station Exit 7 → Jamsil Station Bus Stop 4318 → Asan Medical Center	Subway: 1-time Bus: 1-time	13 minutes	60 minutes
8	Kakao Maps 2	Line 4 Namtaeryeong Station Exit 1 → Transfer to Sadang Station → Line 2 Jamsil Naru Station Exit 4 → Asan Medical Center	Subway: 1-time	26 minutes	54 minutes
9	Kakao Maps 3	Namtaeryeong Station (Middle) Bus Stop 502 → Sadang Station (Middle) Bus Stop → Sadang Station Exit 3 → Jamsil Naru Station Exit 4 → Asan Medical Center	Subway: 1-time	29 minutes	58 minutes
10	Kakao Maps 4	Namtaeryeong Station (middle) Bus Stop 4435 → Sadang Station Exit 3 Bus Stop → Sadang Station Exit 3 → Jamsil Naru Station Exit 4 → Asan Medical Center	Subway: 1-time	28 minutes	64 minutes
11	Kakao Maps 5	Line 4 Namtaeryeong Station Exit 1 → Transfer to Sadang Station → Transfer to Jamsil Station → Line 8 Gangdong-gu Office Station Exit 5 → Yeongpa Girls' High School/Gangdong-gu Office Station Bus Stop 112-5 → Asan Medical Center	Subway: 2-times Bus: 1-time	10 minutes	60 minutes

KakaoMap and Naver Map provide different numbers of route information depending on the origin and destination setting. For the top 5 items, detailed information can be checked on the search result display screen, while other routes are only shown with general content. This is seen as recommending the top 5 UI items at a higher rank, and the top 5 routes were compared with the recommended route of the system. **Table 2** is a comparison of the route recommendation results of the public transportation guidance system for the transportation disadvantaged designed in this study, Naver Map, and KakaoMap. The number of transfers and the total walking and elapsed time, primarily considered in route selection, were checked.

When comparing the route generated by our designed system to the route generated by another guidance service, our system guides to the 2nd exit with an elevator, not the closest Namtaeryeong Station 1st exit as guided by the other service. This is to prevent elderly and disabled individuals from having to check additional facilities. Our system provides bus arrival information only for low-floor bus lines near Jamsil Station, while the other service provides bus arrival information for all general bus lines from the 2nd to the 11th. These are the differences between the two systems.

Table 3. Route guidance service route comparison result.

No.	Route	Number of Transfers	Total Walking Time	Total Time Taken
1	Our System	3-times	11 minutes	68 minutes
2	Naver Maps	Minimum: 1-time Maximum: 2-times	Minimum: 10 minutes Maximum: 26 minutes	Minimum: 53 minutes Maximum: 61 minutes
3	Kakao Maps	Minimum: 1-time Maximum: 3-times	Minimum: 10 minutes Maximum: 29 minutes	Minimum: 54 minutes Maximum: 64 minutes

Table 3 shows that using Naver maps and Kakao maps through the recommended routes of each navigation service, the way for the general public to travel the demonstration route takes a minimum of 53 minutes and a maximum of 64 minutes with a minimum of 1 and a maximum of 3 transfers of transportation. In the top 5 results of the demonstration route, Kakao maps prioritize routes with fewer transfers compared to Naver maps, while Naver maps prioritize routes with shorter walking time compared to Kakao maps.

The transfer times of the routes generated by the system are the same as the maximum of other services, which is 3 times. Walking time was spent less than other services by a maximum of 18 minutes. The total time required was 4 to 15 minutes less than other services, and this difference was due to two intentions considered in the system design process. Firstly, it was intended to use low-floor buses instead of ordinary buses, even if the number of transfers increases slightly when selecting transportation. Secondly, walking was minimized and transportation was used as much as possible, except in unavoidable cases.

6. Conclusion

To guarantee the mobility of the transportation disadvantaged, the SMG has been implementing policies for several years to install and improve public transportation convenience facilities and secure additional special vehicles. The special means of transportation preferred by the transportation disadvantaged can guarantee convenience and rapid movement, but it is insufficient to accommodate the continuously increasing trend of transportation disadvantaged people. As a result, many transportation disadvantaged people who cannot use special transportation still use public transportation. It is difficult to use a route that has not been experienced when moving. A public transportation route guidance system for transportation that can overcome these difficulties and support a wide range of movement is required.

In this study, a public transportation route guidance system was designed for wheelchair users with limited mobility. To this end, factors considering wheelchair users were reflected in building mobile convenience facilities and utilization data, route search, and designing mobile applications. When building basic input data for route search, a timetable dedicated to low-floor buses was established, and route information and images for subway movement route guidance were constructed. Data was collected based on public data and stored in a usable data form through additional processing and preprocessing. The route search was designed to search for the shortest route based on the low-floor bus timetable and subway timetable, and a subway elevator entrance search function was added. A mobile application that can effectively provide the built data and the designed route search results was designed and applied to case areas on a trial basis. Differences and complementary items were identified through comparison between the applied results and similar services currently in operation.

The proposed public transportation route guidance system for wheelchair users can be used as a basic service for providing information to promote the use of public transportation by the transportation disadvantaged. In addition, it is built based on various public data currently provided by the government without building additional facilities and equipment, enabling fast service application and ensuring the up-to-dateness of periodically supplemented data. In the future, like wheelchair users, we will additionally investigate and construct frequently used and preferred mobility convenience facility data according to the type of transportation disadvantaged, such as the visually impaired, hearing impaired, elderly, and accompanying infants and toddlers, who have difficulty using public transportation, so that various transportation disadvantaged people can be upgraded with an available route guidance system. Currently, data for this system are not being collected in local governments other than Seoul, so it is difficult to expand the service to other regions. In addition, in a follow-up study, it is expected that various information services can help the transportation disadvantaged when using public transportation by supplementing information such as platform and escalator maintenance status, wheelchair safe boarding and disembarking location information, and voice service.

Acknowledgment

This research was supported by the convergence of R&D over Science and Technology Liberal Arts through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (NRF-2018M3C1B6061020).

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