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Finding the optimal route for people with mobility impairments: A case study of the İnönü University campus

Students with mobility impairments have the right to move independently throughout university campuses. This study presents a model to evaluate routes based on accessibility criteria to determine the most suitable paths for disabled individuals navigating a university. First, the main factors of accessible mobility were determined and rated by students with physical disabilities. Within this context, this study used the analytical hierarchy process (AHP) to weight criteria and route alternatives. İnönü University was selected for quantifying the path network of its campus by physically handicapped students. Three main campus routes were evaluated to find the most accessible route for students. Based on the results, among ten key factors, ramp slope and paving are the most important. Furthermore, on-site analyses demonstrated the accuracy of the AHP method for this research. Contributions of the study include a model for determining the optimal route with the fewest physical obstacles to facilitate disabled individuals' daily movement.

Keywords: university campuses, urban design, analytical hierarchy process (AHP), mobility impairment, navigation, Turkey

1 Introduction

Persons with disabilities have the fundamental right to education, like all other people (Della Fina et al., 2017). As the most numerous among disabled students, students with mobility impairments experience challenges to education on poorly designed university campuses (Ashigbi et al., 2017). Certain characteristics of the built environment (e.g., pavements, ramps, steps, and curbs) pose barriers in the path network at universities for students with mobility impairments (SWMIs). Thus, the campus environment needs to be planned and designed with the fewest number of barriers that may impede effective access and participation of SWMIs in courses and other social programs (Imrie & Kumar, 1998; Ferreira & Sanches, 2007). Although much effort has been made to promote pedestrian networks to adapt them to persons with mobility impairments, accessible mobility has remained a challenge on campuses in particular (Chiarella & Vurro, 2020).

Mobility refers to the ability to move safely and independently for carrying out daily activities (Clarke et al., 2009). This has been a serious challenge for disabled persons, especially for individuals with mobility impairments. They may encounter some environmental barriers on routes such as high curbs, stairs, uneven paving, narrow pavements, poor paving, steep ramps, and so on (Kasemsuppakorn et al., 2015). Many mobility-impaired persons hesitate to take new routes due to unpredictable obstacles they may face in an unfamiliar environment. Navigating a route alone without prior information about its accessibility has been a problem for them (Ugalde et al., 2022). This is even more significant on university campuses located in suburban settings with daily commuting by students, longer distances travelled, and the predominance of car users (Miralles-Guasch & Domene, 2010). People typically take the shortest route, but individuals with mobility impairments may prefer a longer route without a slope. Because the number of SWMIs is growing at universities (UN, 2023), it is imperative to evaluate routes on campuses to create an accessible environment for SWMIs.

Path quality can be evaluated to create an accessible mobility model or map to identify the optimal route for disabled persons (Menkens et al., 2011). Kasemsuppakorn and Karimi (2009) identified the primary environmental obstacles that affect accessibility for wheelchair users and developed a technique that allows route personalization by defining the obstacle level for wheelchair users. Izumi et al. (2009) proposed a tool for determining optimal routes based on barrier-free information that assists persons with disabilities to determine the difficulty level of taking a route. Matthews et al. (2003) employed feedback from wheelchair users to identify the most important barriers and generate accessibility maps. Alfonzo (2005) developed a hierarchical model of walking needs with five decision-making levels, including the feasibility of walking (i.e., related to personal limits), accessibility, safety, comfort, and pleasure. Kasemsuppakorn et al. (2015) produced a model including some pavement parameters (slope, paving, pavement width, steps, distance, and pavement traffic) to personalize routes for wheelchair users using an analytical hierarchy process (AHP) method. They assigned a numerical weight to each pavement parameter based on user preferences and priorities. A study by Gharebaghi et al. (2021) estimated accessibility criteria to determine the most important factors, and then an approach for user-specific routing was proposed for a web-based platform. Finally, Ugalde et al. (2022) proposed a routing algorithm using a geographic information system to determine the shortest paths or barrier-free routes for use in a wheelchair navigation system. However, evaluating university campuses for SWMI mobility remains inadequate. Universities considering the needs of all students, including SWMIs, can serve as an ideal planning model for the entire city.

The share of disabled persons in Turkey is considerable, although there is currently no consensus on their exact number. The Turkey Health Survey conducted in 2016 by the Ministry of Family, Labor, and Social Services did not provide an exact figure, (Engelliler Konfederasyonu, 2020) but according to 2002 data from the Turkish Statistical Institute, the percentage of persons with disabilities is 12.29%, among whom 23.9% have mobility impairments (Engelsiz Yaşam Derneği, 2024). Compared to similar studies in European countries, 16.2% of the Turkish population can be categorized as disabled persons that constantly experience difficulties with basic activities. Furthermore, taking unregistered numbers into account, it is estimated that at least 8.5 million people have disabilities in Turkey (Engelliler Konfederasyonu, 2020). According to the higher education information system data, there were around 56,000 disabled students in Turkey during the 2022-2023 academic year (Yükseköğretim Kurulu, 2023). Turkey's national regulations have provided various legal provisions for disabled individuals to receive a university education (Zencir et al., 2017). Over the last few years, at every university, a disabled counselling and coordination centre has been established to ensure that university campuses are accessible to disabled students and to provide solutions (Pouya & Demirel, 2019). Apart from the good efforts by this centre, Turkish universities have not produced an accessible navigation map that can assist SWMIs in choosing optimal routes on campuses.

SWMIs consider various physical characteristics of routes before deciding on a particular one. They compare possible routes based on these characteristics to determine the best route with the least physical barrier. This study hypothesizes that provid-

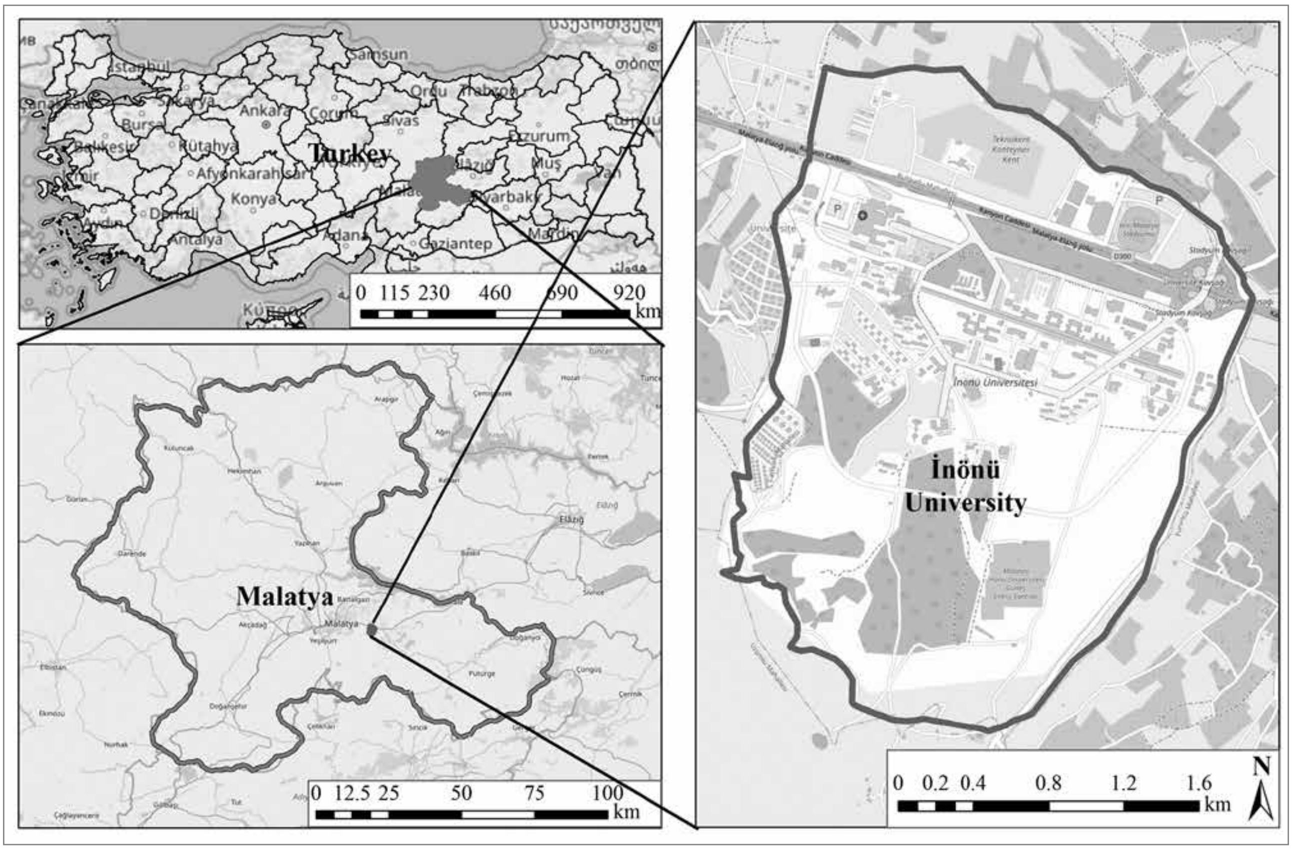

Figure 1: Location of İnönü University in Turkey (illustration: Hatice Kocaaslan).

ing a way to rank accessibility criteria and assess routes based on such criteria would provide useful information to designers and managers in creating an area accessible to all, including people with mobility impairments.

This study evaluates the main criteria for a barrier-free environment and how they can be used to determine the optimal route for SWMIs on a campus. İnönü University is used as a case study to analyse campus path networks for SWMIs. The AHP is a systematic approach to decision-making processes that provides weights and priorities for the mobility parameters. Therefore, common student routes on the campus are examined using the AHP model and on-site analyses. Regarding the right of SWMIs to independent and safe mobility on campus, this study provides practical information that can contribute to planning and managing campuses and to further addressing some aspects of this issue.

2 Methodology

Persons with physical disabilities face numerous mobility challenges mainly created by the built environment. Thus, they need to consider and choose the most accessible route. The main goal of this research is to determine the important criteria that SWMIs consider when choosing a route that is less difficult. It also offers a route assessment in terms of mobility criteria by involving individuals with mobility impairments in the project. For this study, the target group is the small category of students suffering from mobility impairments.

2.1 Case study

İnönü University campus was selected as a case study for this research (Figure 1). The university is 10 km from Malatya, a city in the Eastern Anatolia region of Turkey. With an area of 700 hectares, it is located on the borders of the Yıldıztepe neighbourhood. İnönü University was founded in 1975 and has approximately 40,000 students (İnönü University, 2022). It comprises thirteen faculties, one state conservatory, two colleges, four vocational-technical schools, six institutes, one techno city (a science park), and thirty-one research centres. The built structures on the campus include administrative buildings, academic buildings, social buildings such as dining halls and sports facilities, and dormitories and other residences. The TramBüs trolleybus line is the main public transport system in Malatya. It has a 37 km route, and it operates between the Maşti bus terminal and the university. The trolleybus line has thirty-seven stops, eight of which are on the university campus (Motaş, 2022).

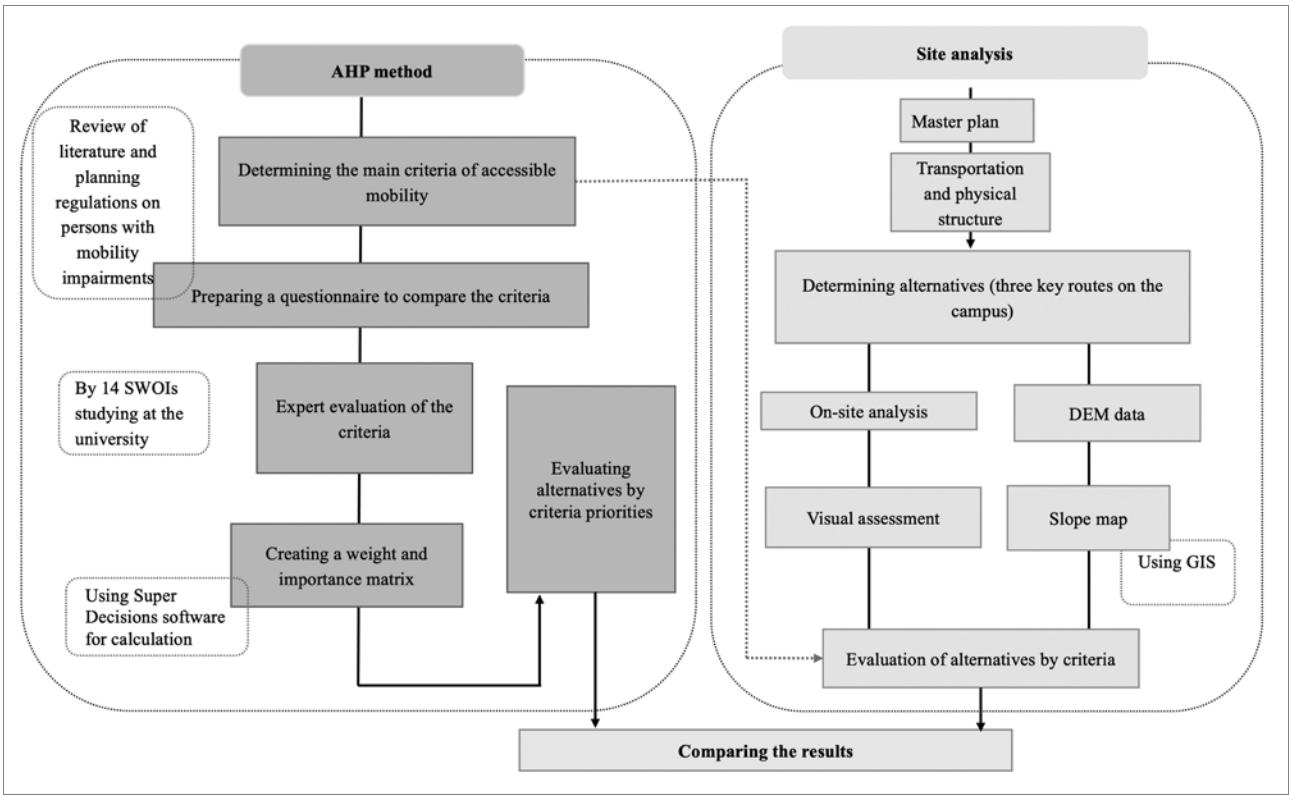

Figure 2: The process applied (illustration: Sahar Sönmez).

According to the estimate for the 2022-2023 academic year, 120 persons with disabilities (e.g., hearing impairment, visual impairment, mobility impairment, or other chronic diseases) were studying at the university. Forty-seven students (39%) had mobility impairments, limiting their ability to perform their daily activities. Among SWMIs, four persons were in vocational schools, forty were undergraduates, and three were graduate students. The majority of SWMIs were receiving formal education, but some were engaged in evening courses and distance learning (Yükseköğretim Kurulu, 2023).

On the university campus, there is a special administrative unit for students with disabilities. Among its achievements is a handbook on individuals with disabilities that contains necessary information about their conditions and their specific requirements. At the university, various conferences and social events are also held for students with disabilities on special days every year. In 2022, İnönü University was one of ten universities in Turkey to receive the Barrier-Free University Award, and it also received the Orange Flag, which is conferred on universities with easy accessibility to all on behalf of the Turkey Council of Higher Education (Engelsiz İnönü Koordinatörlüğü, 2022).

2.2 The AHP method

The main method utilized in this research is the AHP. To deal with large and complex decision-making, it is essential to break this down into a hierarchy. Saaty (1988) developed a means of deconstructing a problem into a hierarchy of sub-problems that can more easily be understood and evaluated. Using the AHP, subjective evaluations are converted into quantitative values and then processed to rank each alternative on a numerical scale. The AHP provides all the criteria that have some impact on the given problem, and all the relevant alternatives are represented in the hierarchy (Bhushan & Rai, 2014). It involves four main steps: structuring multiple-choice criteria into a hierarchy, evaluating the relative importance of these criteria, comparing alternatives for each criterion, and determining the general ranking of the alternatives.

This method has been used successfully in similar research to evaluate accessibility for persons with reduced mobility in public spaces (Lima & Machado, 2019), to rank existing Mobility as a Service (MaaS) applications (Belossarov et al., 2023), to investigate gaps between users' needs and practitioners' prioritization of accessibility features (Park et al., 2020), to identify the factors influencing the selection of the best route for people with mobility disabilities (Ugalde et al., 2022), and to analyse accessibility and site suitability for healthcare services (Parvin

Table 1: Main criteria (physical factors) for accessible mobility of people with mobility impairments.

Criterion	Aspects	Labelled
Ramps	Appropriate ramp slope, 5% or less	C1
	Handrails and edge protection on both sides of ramp	C2
Covering	Paving or covering with suitable material (smooth, solid, durable, soft non-slip fabric)	C3
Path width	Appropriate width of path (120 cm in lightly populated areas and 150 cm in busier area)	C4
Garbage bins	Accessible height of garbage bins on path (90 to 120 cm)	C5
Marking and signs	Adequate and readable directions, marking, and signs	C6
Lighting	Adequate lighting	C7
Bus or train station/stops	Accessibility to stops so disabled people can reach them safely, without obstacles or needing assistance	C8
	Dedicated place at stops (at least 120 cm must be left free next to the benches at stops for wheelchair users)	C9
Plants	Plants not obstructing path (without drooping branches, not thorny plants, less than 220 cm high).	C10

Note: C = criterion.

Source: European Conference of Ministers of Transport (2000); Erkovan (2013); Kuter & Çakmak (2017); Saplıoğlu & Ünal (2019); Department of Transport (2021)

et al., 2021). This study also shows the potential and accuracy of the AHP as a method for determining the most accessible route with a minimum number of barriers for SWMIs.

According to the AHP, first of all, the key criteria of SWMI mobility were determined. Then the factors were evaluated and ranked by the sample group. Finally, route alternatives were assessed based on the weights of each parameter.

Furthermore, on-site analyses and site slope assessments were conducted to confirm the findings and provide a better discussion of the results obtained by the AHP process. As Figure 2 shows, the study applied two key techniques to provide an assessment model for route evaluation in terms of SWMI mobility criteria: the AHP and site analysis. The steps of the method are explained below.

2.2.1 Determining the main criteria of accessible mobility

The first step of the AHP included determining the key parameters that a route should have to provide easy mobility for individuals with mobility impairments. According to various studies in which pedestrian network was evaluated by users with mobility impairments, the main challenges such individuals encounter are insufficient width of pavements and narrow corridors, steps, steepness and incline, a lack of ramps, poor flooring materials, raised manhole covers, cracks, uneven paving, immovable fixtures on the route, high curbs, and less accessibility to public transport with compatible standards (Lysack et al., 1999; Meyers et al., 2002; Inada et al., 2014; Kasemsuppakorn et al., 2015)

People with mobility impairments may use aids to promote their mobility, such as prosthetic limbs, wheelchairs, crutches, and walking sticks, or they may walk but only with difficulty (Department for Transport, 2021). They have specific needs for mobility. Considering their requirements for outdoor and urban mobility, some specific standards and guidelines have been defined for planning pedestrian routes in Europe and the US (European Conference of Ministers of Transport, 2000). Similarly, in Turkey, planning and design regulations have been adopted to address the mobility of disabled populations in open spaces. This study explored significant elements related to accessible mobility for people with mobility impairments. The most critical factors common to persons with mobility impairments were evaluated. A review of international and Turkish sources identified ten key factors linked to the movement of these populations (Table 1).

These factors were weighted and evaluated by people with mobility impairments. Some issues were not included in the list of important criteria because they are not an issue for all physically disabled individuals For example, stairs and steps are not used by wheelchair users, and so this factor was ignored.

2.2.2 Determining route alternatives

The next step determined the routes on the campus as alternatives to evaluate based on the criteria selected. One key question of the research was which would be the best route for SWMIs to get from their trolleybus stop to the university campus. Analysing the campus transport system and the master plan of the university shows that: 1) the trolleybus has three stops on the campus, and so students have three choices for

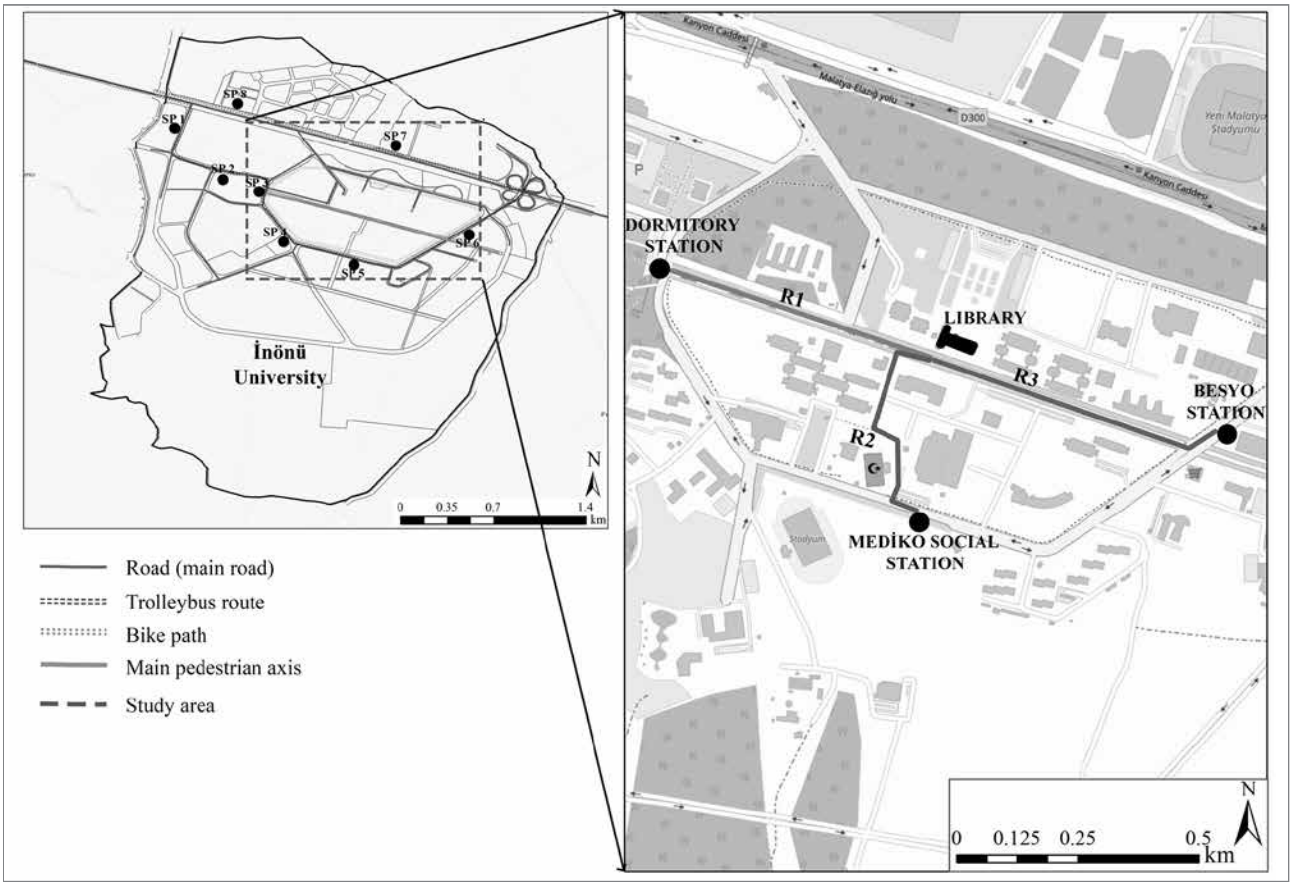

Figure 3: Routes evaluated in the study (illustration: Hatice Kocaaslan).

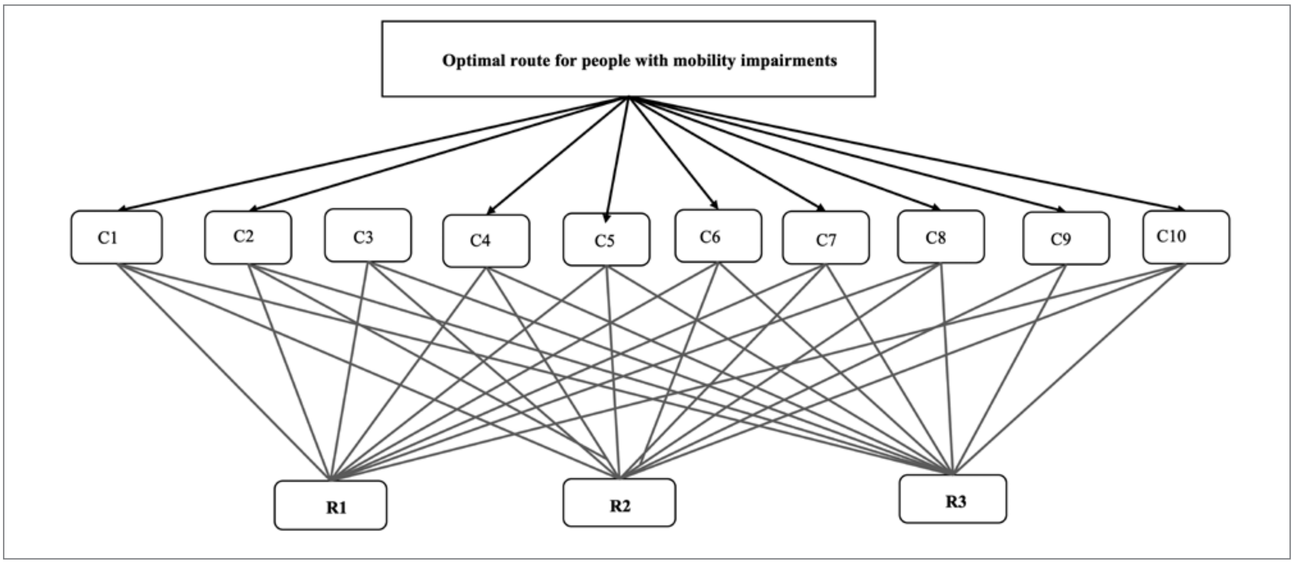

Figure 4: Hierarchy structure of the AHP method considered in this study; C = criteria (illustration: Sahar Sönmez).

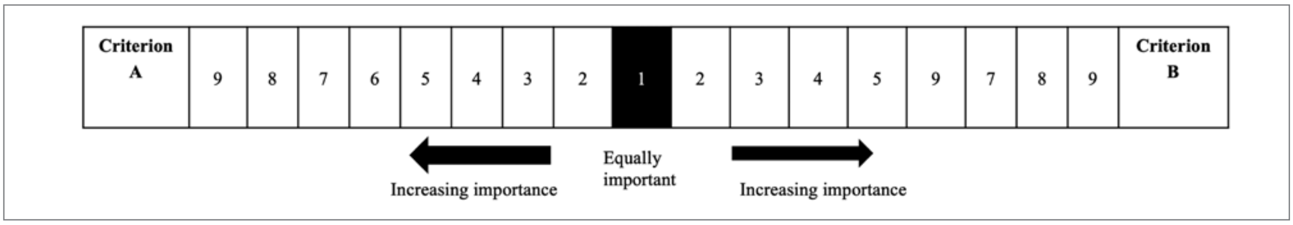

Figure 5: The importance scale in pair comparison of two criteria (A and B). The importance of the criteria increases by choosing high numbers for each criterion (source: Saaty, 1994).

Table 2: Definition of importance in the AHP structure.

Importance	Definition
1	Equally important
3	Moderately important
5	Strongly important
7	Very strongly important
9	Extremely important

Source: Saaty (1994).

entering the university, and 2) the library with its central location is on the main pedestrian route and has good accessibility to other buildings. It is also a meeting point for students, including the disabled.

Therefore, the routes from the trolleybus stops to the central library (as common daily directions for most students) were selected as three route alternatives to be evaluated. These three paths are shown in Figure 3: Route 1 from the student dormitory station to the library, Route 2 from the Mediko social station to the library, and Route 3 from the Besyo station to the library.

2.2.3 Ranking the criteria and alternatives

During the last steps, the general structure for the AHP method was created, with one level of substantial criteria and a level of three alternatives (Figure 4).

In this step, first ten key factors related to the built environment for mobility of people with mobility impairments were quantitatively compared and valued. Then, the three alternatives were compared in terms of the determinant criteria. In this way, two types of questionnaires were prepared: one for pairwise comparison and ranking the main criteria (forty-five questions), and one for ranking the routes (thirty questions).

The format of the questionnaires was created based on the pairwise structure of the AHP, which has a value scale (Table 2) with numbers allowing a choice between two factors, as shown in Figure 5.

The questionnaires were completed by SWMIs. It was hypothesized that persons with mobility impairments would know more about their challenges on a particular route than persons without disabilities. They also knew the three route alternatives well because they were using them regularly. Because the SWMIs' personal information was confidential, it was not possible to meet with them face to face. Therefore, they were reached through the WhatsApp group Disabled İnönü. A general message was first sent to the students' group and then the students were sent the questions through a private message. If necessary, telephone calls were made to assist them. A total of fourteen SWMIs at İnönü University participated in the survey. Among them, two groups of answers were not valid, and the judgments of only twelve SWMIs were useable for later analyses. It took approximately four months, from June to September 2022, to fully collect the responses.

2.2.4 Data calculation and prioritization

According to the AHP, experts' responses to the criteria comparisons should be calculated and normalized to obtain prioritizations. The mean values are arranged into matrices, and the partial importance of various factors is achieved by calculating the principal eigenvalue of the matrices and normalizing the answers. The principal eigenvalue is obtained by multiplying the elements in each row of the matrix and then taking the nth root of the product (Equation 1).

$$n\text{th root of data multiple} = \Pi = \sqrt[n]{a1a2a3a4\ldots\ldots}$$

where n = the number of judgments in each particular matrix and a = elements in each row of the matrix.

The final step is to prioritize the alternatives. The value of each alternative is multiplied by the weights of the criteria and aggregated to obtain global ratings concerning each criterion.

The AHP also includes a measure of consistency for the individual comparison matrix of the decision problem. The consistency ratio (CR) shows the validity of the responses using a quotient between a consistency index (CI) and a random index (RI; Equation 2). The CR formula is:

$$CR = CI / RI$$

where RI = random index, dependent on the matrix degree.

The consistency index is calculated with (Equation3):

$$CI = (\lambda\ max\_n) / (n\_1)$$

where λ max = maximum self-value (the maximum eigenvalue) of the comparison matrix of rank n and n = the number of characteristics compared.

CI can be compared with the RI shown in Table 3. According to Saaty (1994), the consistency ratio should not be more than 0.1.

Table 3: Random consistency index.

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Saaty (1994).

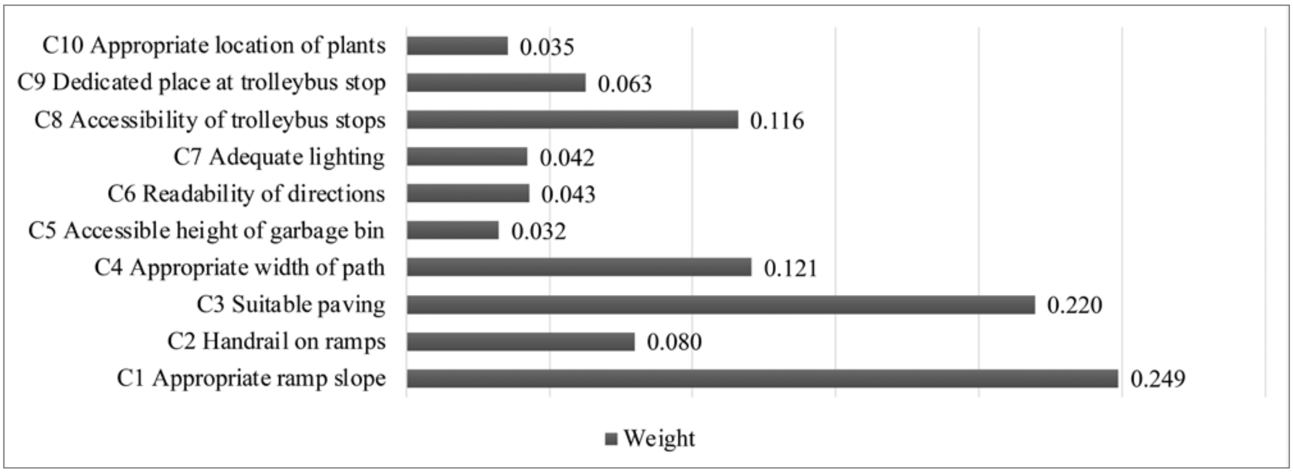

Figure 6: Relative weight and importance levels of the key criteria for accessible mobility of SWMIs (illustration: Sahar Sönmez).

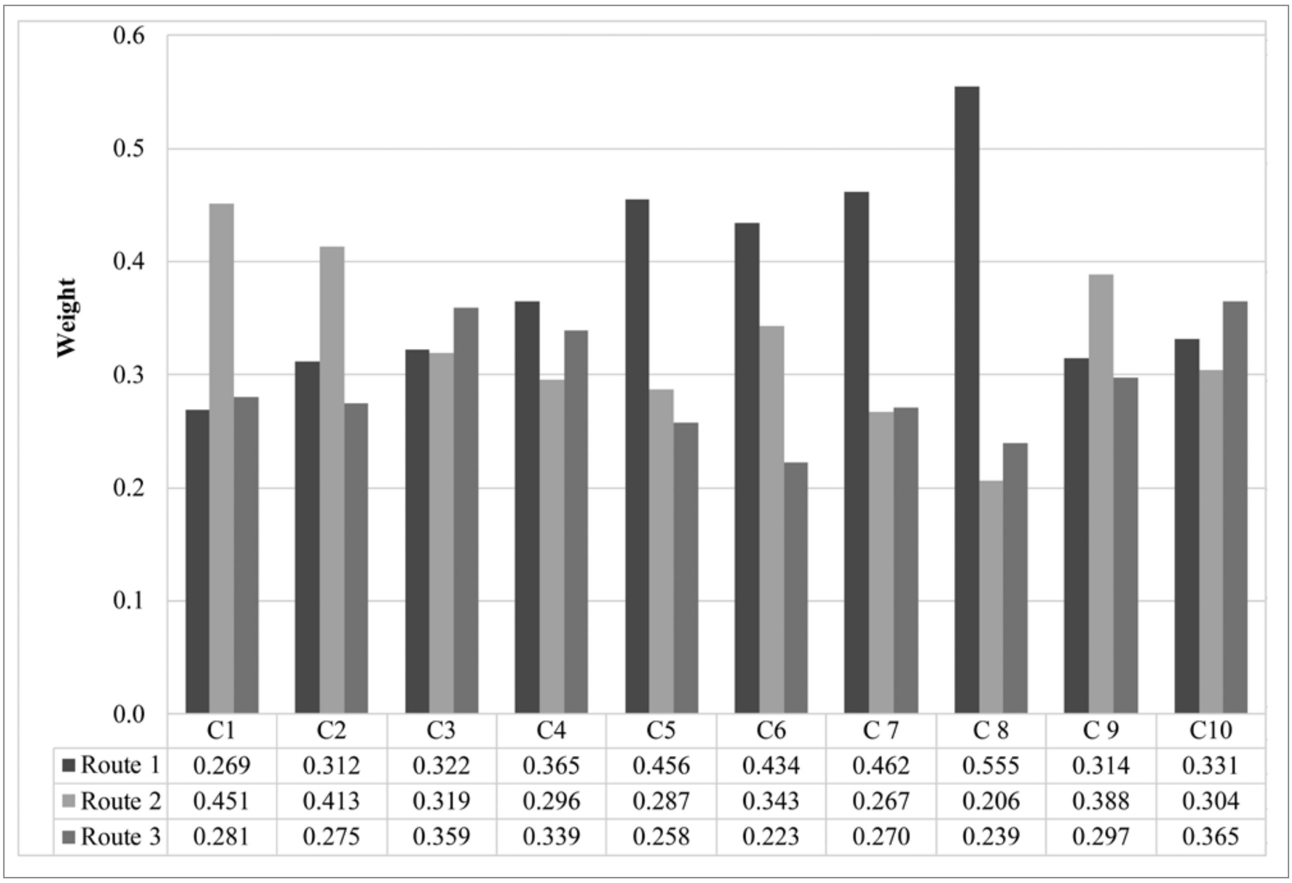

Figure 7: Comparing the normalized weights of alternatives obtained using the AHP method (illustration: Sahar Sönmez).

In this study, after collecting the students' answers, the average amount of pairwise comparisons was estimated for manual entry into the Super Decisions tool. This software is an online application that is able to perform the complex calculation of the AHP and CR. The scores of two students' answers out of fourteen were not considered for the evaluation because the CR of their evaluations was more than 0.1. Finally, the square matrix of values and prioritization diagrams with an acceptable consistency ratio (CR) were obtained.

2.2.5 Route slope classification and on-site analysis

On-site analyses were performed to collect more information for facilitating a good discussion of the AHP results. DEM data of the site were surveyed to generate a slope map. Thus, the data on the route slopes could be analysed. Moreover, through the on-site analyses, a checklist of positive and negative aspects of the routes was completed to understand the results. The results of the on-site analyses of the routes were evaluated in three separate tables in terms of predetermined criteria for the accessible mobility of persons with mobility impairments. Finally, the results of the on-site analyses were compared with the data obtained with the AHP method.

3 Results

3.1 Weights of criteria

The survey of the SWMIs provided the importance rates (numerical values) of the ten defined criteria related to the mobility parameters. After receiving the completed questionnaires, the mean of the comparisons was put into Super Decisions to obtain the final priorities and consistency rates. The final weight and numerical values obtained from the averaged participant answers are summarized in Figure 6.

According to the results, the appropriate slope of the ramp on the routes (C1) and the quality of the paving (C3) are the most important factors for people with mobility impairment when navigating or deciding to take a route. In contrast, garbage bins' height (C5) and the appropriate location of the plants (C10) have the lowest importance level.

3.2 Ranking the routes

This step compared the three routes selected for assessment with the AHP model. Values and normalized weights were calculated for each route in terms of each criterion. The numerical values obtained in this step are shown in Figure 7.

The final step was to prioritize the three route alternatives on the campus. The values of each alternative were multiplied by the weights of the criteria and aggregated to obtain the total scores for each alternative. The differences between the final priorities of the three routes were small: 0.355 for Route 1, 0.345 for Route 2, and 0.300 for Route 3.

Based on these results, the optimal route for people with mobility impairments was Route 1, which is the direction that the students take from the dormitory trolleybus station to the central library. In contrast, Route 3 (from the Besyo station to the library) had the most physical obstacles for SWMIs.

3.3 Classification of the routes' slope

The slope range of the three routes was classified and mapped through the ArcGIS program. As Figure 8 shows, the routes are categorized into six classes of slope range.

The slope ranges of each route and the length of each slope range are presented in Table 4. The most suitable slopes for people with mobility impairments are in the ranges of 0% to 2% and 2% to 6%. Thus, according to Table 4, the total length of routes with suitable slopes is around 36% on Route 1, 53% on Route 2, and 56% on Route 3.

Considering the length of routes with a suitable slope for easy mobility of people with mobility impairment, Route 1 has less length with the appropriate slope range. Apart from that, only Route 1 has a slope range of 20% to 30% in comparison to the other two paths. On Routes 2 and 3, the slopes do not exceed 20%, and Route 3 in particular has the least length with a 12% to 20% slope range. This means that Routes 3 and 2 have more length with an appropriate slope than Route 1.

In addition, comparing the total lengths of the routes, Route 3 has the longest distance to the university library, whereas Route 2 is the shortest path from the trolleybus stops to the library. However, the two routes have similar lengths with a suitable slope for the mobility of SWMIs. Based on the slope analysis, Route 3 is the most suitable route and Route 2 is the next most suitable route on the campus from the stops to the library. However, based on prioritization using the AHP method, Route 1 has the highest priority. This may mean that the high slope of Route 1 could be correctly addressed by physical solutions so that it is not a serious obstacle to SWMIs.

3.4 On-site analyses

A visual evaluation performed as part of the on-site analyses of the routes can contribute to a better analysis of the results of the AHP. Some photos of the routes' physical features were

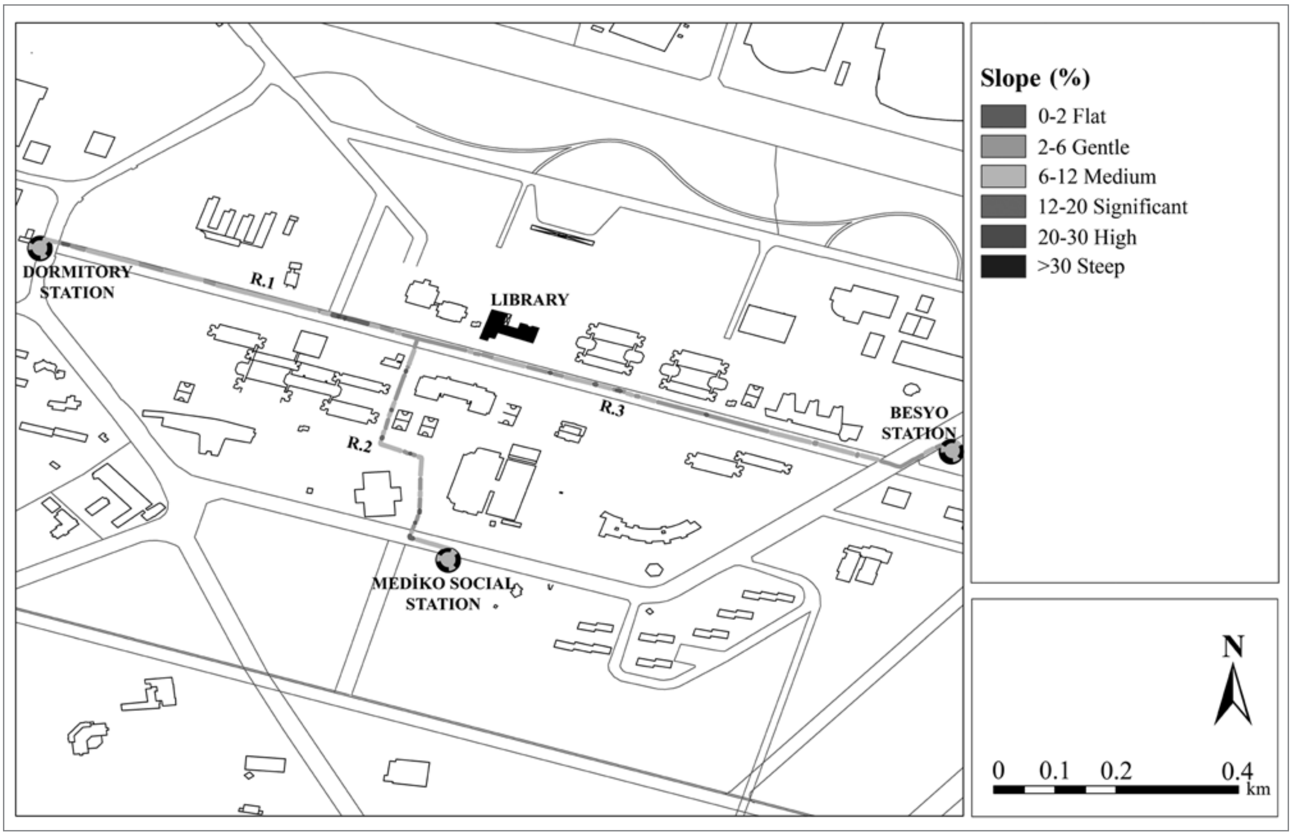

Figure 8: Slope map of the site, including the three routes on the campus (illustration: Hatice Kocaaslan).

Table 4: Length of each slope range on the three routes of the study.

Slope, %	Route 1, m (%)	Route 2, m (%)	Route 3, m (%)
0–2	13 (2.1)	29 (5.7)	19 (3)
2–6	203 (34.3)	241 (47.7)	332 (52.7)
6–12	323 (54.6)	211 (41.7)	174 (43.4)
12–20	43 (7.3)	25 (4.9)	6 (1)
20–30	9 (1.6)	0	0
> 30	0	0	0
Length (m)	592	506	630

Table 5: Evaluation of three routes in terms of the mobility criteria determined in the study.

Route	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	+	–	–	+	+	+	+	+	+	+
2	+	+	+	+	+	–	–	–	+	+
3	+	–	–	+	+	+	+	+	+	–

Notes: + = suitable; – = unsuitable.

taken and then assessed in terms of the ten criteria identified in the research. For instance, each path was checked for parameters related to paving, ramps, lights, and so on. The results of the visual analysis are presented in Table 5.

According to the on-site analyses based on the mobility criteria, Route 1 has two negative aspects and Route 2 and Route 3 have three negative aspects each. Table 6 presents the negative aspects found for each route.

As shown in Table 5, criteria 2 and 3 of Route 1; criteria 6, 7, and 8 of Route 2; and criteria 2, 3, and 10 of Route 3 were found inadequate for SWMI mobility. After determining the negative criteria for each route through on-site analyses, the

Table 6: Visual assessment of alternatives for mobility criteria through on-site analyses.

Route	Criterion	Negative aspect	Importance
1	C2	Handrails on stairs, but not on ramps.	5
	C3	Paving is worn, broken, cracked, or unconnected.	2
2	C6	Directions and signboards are inadequate.	7
	C7	Lighting is dim and insufficient.	8
	C8	There is a ramp to the trolleybus stop, but no safe passage or pavement at the stop.	4
3	C2	Handrails on stairs, but not on ramps.	5
	C3	Stones on the paving may cause problems for wheelchairs.	2
	C10	Pavement plants are improperly located.	9

results were compared considering the weight of the criteria already identified in this study.

Table 6 shows that Route 1 has the fewest negative dimensions and is the optimum alternative for SWMIs. Routes 2 and 3 have no negative criteria in common. However, Route 2 is more accessible than Route 3 because the negative aspects of Route 3 are among the most important factors for people with mobility impairments compared to the negative dimensions for Route 2.

4 Discussion

This work presents the priority of significant characteristics of routes that should be considered when planning and designing spaces for persons with mobility impairments. According to the findings of the criteria valuation, the most important parameters for SWMIs are slope (C1) and paving (C2). By evaluating the three routes using the AHP, Route 1 (from the dormitory trolleybus stop to the library) ranked the highest. Regarding the on-site analyses, Route 1 was again the most preferable path. Visual evaluations of the sites showed that the negative aspects of Routes 2 and 3 exceed those of Route 1, which only has two negative issues (Table 5). However, a comparison of Routes 2 and 3 (with three physical problems each) showed that the weights of the positive dimensions for Route 2 exceeded the numerical values of the positive aspects for Route 3. On the other hand, Route 2 has fewer critical issues than Route 3. This is why Route 2 is the second-best route for SWMIs. This shows that an optimal route for accessible mobility of persons with mobility impairments needs comprehensive assessments and comparisons of all physical qualities of the possible routes.

Even though Route 1 is preferred by SWMIs and has fewer physical restrictions, it still has critical problems. The on-site analyses showed that Route 1 lacks appropriate paving and has no railings on the ramps. This is the main part of the campus pedestrian route, and it is used by a large number of students every day, which may have caused the paving to deteriorate.

The on-site analysis of Route 2 showed that the main problem is accessing the trolleybus station. There is no pavement for SWMIs to access the station, and they have to use the road to reach the station platform. Only one ramp connects the road to the trolleybus platform, and it seems unsafe for SWMIs. This is the main issue for Route 2, and solving it may make the route the most preferred one. With the longest length, Route 3 is the least preferred alternative for SWMIs. According to slope analysis, around 56% of this route suits people with mobility impairments. However, the on-site analysis showed that there is no guardrail on the ramps, the paving is broken, and shrubs are inappropriately located on the route.

Because it is impossible to eliminate all physical barriers on the routes, this work has tried to rank the most important physical qualities of the routes for SWMI mobility. The AHP is an appropriate method because it uses a systematic process for surveying elements that is clear to follow, and it provides analytical comparisons and numerical weights of route parameters based on experts' preferences. On-site analyses also confirmed the results obtained by the AHP method, which means the AHP model can correctly determine optimal routes for the mobility of persons with mobility impairments. The hierarchy model discussed in this study can be modified or changed depending on the research goals, target populations, and spatial characteristics of the alternative routes.

From the point of view of accessibility, various factors have been revealed through similar research, particularly in indoor environments (accessible entrance, elevators, and bathrooms) through the participation of wheelchair users (Simpson, 2005; Bizjak, 2022). This work surveyed outdoor obstacles and addressed individuals with diverse mobility impairments such as wheelchair users and those that have difficulty walking. This study evaluated only one destination; however, the same process can be applied to all routes on the campus and to urban networks as well. This can also be applied to other mobility factors such as safety, comfort, and pleasure. Here, the important issue that should be considered is to generate opportunities for individuals with mobility impairments to participate in this kind of project. As hypothesized, the findings of this study can help managers and designers use information about spatial arrangement and analysis to create spaces that are more suitable for people with mobility impairments. In addition, the data obtained can be useful in deciding where to locate navigation system services and facilities in future planning to achieve inclusiveness and sustainable development.

One difficulty faced during this research was contact with disabled students. This group of students does not seem to participate in campus social activities. One reason may be a lack of appropriate facilities and services to meet their requirements when they are outdoors. In Turkey, new guidelines and approaches have appeared to cover the accessibility needs of disabled individuals in open areas and urban regions.

Even though the efforts in this area are growing in Turkey, in practice they are preliminary and inadequate. Outdoor obstacles still exist and prevent disabled users from fully participating in education in particular. In other words, a usable navigation system has not been created to ensure accessibility for people with mobility impairment in Turkey. The university can act as a model of design and planning to lead a whole city and should necessarily meet the diverse needs of the students. Generally, to address the issue comprehensively, the university can contribute by:

- Increasing social awareness through ongoing conferences, workshops, courses, and relevant projects with the participation of various experts, especially planners and designers.
- Re-evaluating campuses' accessibility for safe and independent mobility of disabled people. A map or application with information about optimal routes on campus is necessary.
- Providing opportunities and incentive programs to gather disabled students, record their concerns, and facilitate their full participation in education and other social and cultural activities.

5 Conclusion

Unfortunately, the modern navigation systems and routing applications that are increasingly used by everyone do not consider the specific needs of disabled people. Mobility-impaired people also have the right to access a map or an application that determines the shortest distance, minimum barriers, fewest slopes, high-quality paving, and other physical qualities of routes. To do so, the contribution of disabled users in related research has been critical because they can better recognize obstacles and assess their living environment. It is also necessary to differentiate between types of barriers based on the diverse attributes of disabled individuals. Thus, there seriously needs to be an integrated planning approach considering the cooperation of all groups of disabled people in identifying the most fundamental physical criteria of routes for easy mobility. It seems like a time- and labour-intensive task to provide such a map with a large amount of data for each region of a city. However, with smaller open areas, a university campus can be a good starting point to apply such initiatives. Re-assessment of the navigation network based on the critical needs of students with disabilities should be considered in managing and arranging universities' open areas. The AHP method can be applied to recognize the importance level of criteria and evaluate existing routes to choose the most optimal ones.

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