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Orginal Article

Developing a model for measuring the spatial disability level of cities within the framework of barrier-free pedestrian accessibility: the case of Kırklareli City centre

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Abstract: The problem of disability is directly related to the physical barriers encountered in urban spaces. Pedestrian accessibility performance is a notable urban quality indicator. Universal design principles and barrier-free design standards are important in making urban spaces usable for everyone. However, projects in this context generally cover specific areas of cities. Bringing an entire city into compliance with barrier-free design standards requires high cost and time. Therefore, determining the spatial disability level of the urban texture and planning project stages constitute a critical process for local governments. This study proposes a model to measure the pedestrian accessibility performance of medium-sized cities with relatively walkable distances within the framework of spatial barriers and to identify priority intervention points. In this context, Kırklareli city centre was selected as a case study area. According to the model developed with the support of GIS, the "ideal accessibility network" is determined for the citizens, and the performance level is calculated by identifying the spatial barriers on this network. The model was developed using components that can be applied to any city and tested in a sample urban environment. This conceptual model contributes to urban science and local government policy by providing a monitoring mechanism for spatial disability that can be constantly tracked by citizens, and by supplying an information base for projects to be developed by local governments. It is hoped that this study will popularise pedestrian-oriented spatial design and control in cities where walkability is postponed due to the focus on wheeled vehicle mobility and where spatial barriers are felt only by disabled individuals.

Keywords: spatial disability, ideal accessibility network, barrier-free design, pedestrian accessibility, Kırklareli

1. Introduction

The components that determine the level of spatial use are generally related to people's "anatomical, sensory, and mental" state. The level of spatial use—resulting from the interaction between health conditions, personal factors, and environmental factors—varies profoundly. Thus, reviewing the available literature on disability may be helpful to quickly grasp the level of physical space use. It is worth highlighting that the issue of disability and the level of spatial use are directly related. Although wheelchair users and other "typical" groups, such as the hearing or visually impaired, are the first to come to mind when discussing disability, people with disabilities are actually very diverse and heterogeneous [1, pp. 1–5]. Therefore, it is important to evaluate the different conditions of individuals at the spatial level and to develop an approach based on the elements that require attention within the framework of the problems and abilities identified. Given the increase in the dynamism of urban life, it is necessary to ensure that users in cities—especially disadvantaged groups, including the elderly and the disabled—can adapt. In this process, the problematic "disabled city," with insufficient infrastructure and insensitive superstructure, where public space is neglected due to the increasing appeal of private spaces, proves to be a more important place in people's lives. In this respect, a particular cross-section that the study focuses on is the issue of unhindered-accessible transportation in the city and walkability at the human scale. An urban space that offers sufficient pedestrian flow is one of the factors that determine the efficiency and quality of urban transportation as well as the mobility of the users [2, pp. 1–3]. Therefore, walkability proves to be one of the important criteria for a liveable and sustainable urban space [3–5].

The aim of this study is to develop and test a model in the city centre of Kırklareli that reveals the level of spatial disability in terms of the ideal accessibility network in settlements, based on the continuous accessibility of pedestrians in cities. Therefore, the objectives of the study are as follows:

- To quantitatively reveal the relationship between disability and urban space in the eyes of local governments and society, thus raising awareness and creating opportunities for control.
- To provide a tool to help local governments address the issue across the city. This will provide a basis for accurate identification of the problem and phased implementation to save both time and money.
- To provide a mathematical basis for incorporating "disability" into the urban planning process.
- To provide a basis and working model for legislation to be developed in the spatial design and planning process.

The study developed a new method for measuring spatial disability. This method, described in detail in the corresponding section, essentially consists of three steps: (1) identifying the ideal accessibility network, (2) calculating the level of spatial disability, and (3) assessing intervention priority. In brief, the ideal network forming the main pedestrian routes in Kırklareli city centre was identified, and the level of spatial disability on this network was measured. As a result of the study, the ideal walking level and spatial disability were compared, and the routes that should be prioritised for intervention were determined.

Further evaluations will be conducted to examine the adaptability of the control system formulated in the study to different cities and to disseminate the control system throughout the country. Currently, accessibility standards and checklists at the building and urban design scales have been developed in the available literature. However, the guidance provided by urban planning legislation is quite limited, and there is no established basis for identifying the implementation process in urban spaces. This study aims to provide local governments with a Guide and Evaluation Tool that can be used in the implementation process.

2. Literature review

2.1. Disability and the new proposal concept of spatial disability

Physical, sensory, and mental abilities vary from person to person and change as individuals age. While some people have difficulty climbing slopes, others can only walk limited distances or may struggle with turning. Some may need to use mobility devices such as crutches or walkers, while others may need to stop frequently to regain strength or catch their breath [6, p. 91]. Disability is considered any physical or mental disorder that significantly limits one or more of an individual's basic life activities. Disability includes not only people in wheelchairs but also those with other mobility problems due to diseases such as polio or rheumatism, people with low vision, people with speech or hearing impairments, people with Alzheimer's and Down syndrome, and caregivers who provide therapy or support to individuals with disabilities [7, p. 5]. Disadvantaged individuals make up 15% of the world's population and 13% of Turkey's population, making them the world's largest minority [1,8].

Research on the spatial, sociological, and economic aspects of disability began in the USA, Japan, and Europe in the 1960s and gained prominence in 1975 with the United Nations General Assembly's "Declaration of the Rights of Persons with Disabilities." The development of the "universal design concept and principles" between 1987 and 1997 further intensified the focus on solution methods. During this period, disability rights and spatial design standards were formulated in many countries, including the USA, UK, Australia, Canada, and Northern Europe. The United Nations International Convention on the Rights of Persons with Disabilities in 2006 marked a turning point in this process [9]. With 175 countries ratifying the convention and optional protocols, work on the subject has accelerated.

In medicine, disability is defined as “the inability of a person to do the things that he/she needs to do on their own in their personal or social life, as a result of any inherited or later defect in their physical or mental abilities” [9, p. 1]. However, in many other scientific fields, disability is defined by the "social" model rather than the "medical" model, accepting that individuals are actually incapacitated by society [10,11]. Accordingly, disability is an umbrella term used for physical disabilities and activity limitations, referring to the hardships between the individual and contextual factors (environmental and personal factors) [1, p. 4]. Since the 1980s, disability has been addressed as a social issue rather than a medical condition because “disability” refers not only to the identity attributed to a group but also to the oppression experienced in society or a social environment [12, p. 3, 13, p. 190]. In this context, "disability" is the result of the interaction between people and their environment, and it is not related to people's incapabilities [14, p. 181, 15]. Disability can be considered the reflection of the environment in which individuals are restricted to live, rather than an inherent quality of an individual [13, p. 191, 16].

2.1.1. Conceptual framework for spatial disability

The conceptual content and literature review of spatial disability, developed as a new concept in the study, is explained below.

Disability increases significantly with age. The increase in urbanisation rates, in parallel with the rise in average life expectancy and aging rates, are significant trends of our times, attaching critical importance to the decades ahead of humanity [17,18]. Given these emerging trends, the number of individuals with disabilities will increase in densely populated cities in the near future. Currently, this outlook is often evaluated in the fields of technology and design. In the current cross-sectionality of design-based science fields, "Universal Design" is accepted as the most inclusive approach offered as a solution to isolation by design [7, p. 2, 19, 20, p. 444, 21]. The products, structures, and settlements achieved with the universal design approach enable all users to benefit, ensuring that the disabled, elderly, children, and others with special conditions are not excluded from urban life. Designers play a key role in eliminating the barriers faced by people with all kinds of physical or cognitive disabilities and ensuring their integration into the environment [7, p. 3]. Disability and the level of spatial use are directly related to each other. In this respect, planners and designers need to shape settlements by paying due attention to the profile of the users in cities.

According to the relevant literature, potential users in urban spaces are evaluated in four categories based on their disadvantages [22, 23, pp. 19–20, 24, p. 491, 25, pp. 12–13, 6, pp. 140–143, 26, p. 10].

1. Individuals with physical disabilities

Lack of movement: Individuals with systemic diseases, disabilities, or those who rely on a vehicle and/or accompanying person (e.g., individuals with partial and/or temporary disabilities, the elderly, children, etc.).

Mobility difficulties: Individuals who carry a load, accompany another individual, are overweight, are pregnant, etc.

2. Individuals with sensory disabilities
   - Visual impairment: Individuals with partial or complete lack of vision.
   - Hearing impairment: Individuals who are partially or completely deaf.
   - Lack of perception: Individuals with perception problems due to various reasons (e.g., fatigue, unfamiliarity, etc.).
3. Individuals experiencing mental disadvantages
   - Mental problems: Individuals with a mental illness who can act with support when necessary.
   - Communication problems: Individuals with a psychological illness who have special needs and rely on various tools, etc.
   - Problems associated with fear: Individuals who prefer to withdraw from the urban space due to factors such as gender, terror, accidents, traffic congestion, assault, etc.
4. Potentially disadvantaged individuals

Designers should be aware of this diversity when formulating design ideas [6, p. 90]. However, in the second half of the 20th century, cities were developed and shaped with a planning approach that prioritised motor vehicles. Transportation policies focused on private car ownership, combined with rapid urbanisation dynamics, led to the rapid expansion of cities with uncontrolled construction densities. This also resulted in increased environmental pollution, social and economic inequalities, and diseases that threaten public health [27, p. 5]. Given the increasing dynamism of urban life, it is necessary to ensure that city users—especially disadvantaged groups including the elderly and the disabled—can adapt. In this process, the appeal of private spaces increases, public spaces are neglected, and cities expand over increasing distances with car-oriented transportation networks. The problem of "spatial disability," which emerges from insufficient infrastructure and insensitive superstructure built without respect for the human physique and human scale, takes on greater importance in human life. Spatial barriers are elements that pause or hinder the fluency of pedestrian mobility in a city. The most important common point for the four user groups is that settlements can be experienced effectively as pedestrians, highlighting the necessity to strengthen physical activity opportunities. To encourage physical activity, it is essential to consider "unhindered movement" as a standard. “Unhindered movement” is the capacity of people of all ages and abilities to walk in an uninterrupted and barrier-free space [4, p. 235]. It is important to provide all the design features required for safe and unhindered walking for all pedestrians, including disadvantaged groups. Complementing the public space network with equipment and service areas for the needs of pedestrians (such as street furniture, toilets, breastfeeding areas, pedestrian crossings, and direction signs) affects the quality of the pedestrian network [28].

Smooth and unhindered pedestrian movement encourages walkability and physical activity. Accordingly, diverse land uses and a green environment encourage walking, whereas heavy traffic makes people feel unsafe [29, p. 1]. Increasing the attractiveness of public spaces and effectively and safely connecting them to other important urban functions promotes physical activity [30, p. 1557]. It is important that sidewalks are accessible, direct, connected, safe, comfortable, climate-sensitive, integrated with public transportation, and well-maintained for all pedestrian groups [31, p. 2]. The smoothness of the pavement is crucial for encouraging pedestrian movement; otherwise, steep streets, muddy roads, cracks and holes, and uneven pavements can deteriorate the urban experience [32, p. 2]. A walkable road network can be achieved through connectivity, integration with other modes of transport, diverse land uses, social and traffic safety, pavement quality (width, landscaping, road quality, lighting), spatial definition, and visually appealing street designs [28, p. 248, 33].

For the purposes of the quantitative evaluation in this study, it is important to determine the elements that create the spatial disability problem. Typically, natural or artificial elements disrupt the minimum dimensions on pedestrian axes [34, p. 75]. Achieving diverse land use and ensuring ideal walking distances (400 m) to urban functions encourage walkability; however, arrangements that fail to meet these criteria can be considered spatial barriers. Spatial issues that prevent walking can be classified as follows [35, p. 281, 36, pp. 3–4]: long distances to/from work and public buildings, exposure to climatic conditions, individual disabilities, fear and safety concerns, poor pavement quality, monotonous walking routes, and traffic insecurity. The barriers encountered in urban spaces are detailed as follows [37, p. 1139]:

- barriers in the use of transportation (pedestrian, vehicle, public transportation) spaces,
- barriers associated with the interaction of pedestrians with other people and vehicles (intersections with other people, bicycle paths, parked vehicles, etc.),
- barriers associated with the lack of information in terms of spatial use (elements that provide information, signs, use of colour, etc. when deciding on direction),
- barriers caused by the neglect of climatic events (rain, fog, snow),
- barriers caused by the neglect of the physical and perceptual qualities of individuals,
- barriers caused by the built environment (paving, road network, walkways, constructions, etc.).

Factors limiting accessibility, especially in Turkish cities, are summarised as follows [38, p. 31]:

- inadequate paving - uneven or slippery surfaces,

- infrastructure works without proper security measures,
- sidewalks that are too high or too narrow,
- inadequate ramps,
- improper intersections (unsafe pedestrian crossings),
- lack of signs and warning signs, unlit streets,
- urban furniture that is not fit for use (telephones and telephone booths, benches, etc.),
- transportation systems and vehicles that are unable to serve due to the absence of audio and visual stimuli.

In the literature on disability and accidents, it is noted that in addition to physical risks, the social, economic, and psychological effects of space also come to the fore. In line with these effects, disabled people's perception of traffic, the potential danger of the routes chosen to avoid risks, and changes in walking speeds also increase accidents. Therefore, the difference in spatial perception for disabled people due to physical risks increases spatial disability. However, the lack of perceptual supportive measures in addition to physical improvements in transportation policies causes design solutions to be limited [39, pp. 9–11].

Spatial barriers have organisational, perceptual, and physical components. Currently, the focus is primarily on physical obstacles, and solutions often involve fragmented interventions. To address this issue, standards for barrier-free design have been developed, evaluation charts have been created, and potential regulations have been explored [40]. However, the first requirement is a city plan in which barrier-free design standards are applied or adapted. In this respect, the initial target should be to plan cities that do not rely on obstacles, including private vehicles, special places, transportation networks, terrain conditions, etc. Just as the incapabilities that cause individuals to experience physical and cognitive issues, the "disabled city" has features that lead to the failure of various functional areas and the connections between them, resulting in numerous physical and social problems. According to the literature, people prefer compact settlements where they can consume less energy, reach the highest number of functions in the least amount of time, and have a high sense of security. In this respect, basic elements such as materials, transportation quality, dimensions that can be controlled by plans, accessibility network, public space network, and functional distribution play a critical role in the spatial disability quality of settlements. It is also recommended to prepare mobility maps in addition to the design and planning studies. Monitoring comparisons and/or improvements before and after design projects is important [41]. In this context, spatial disability has been discussed under the following headings throughout the analytical process carried out within the scope of the study [36–38, 42]:

- insufficient width-space-height: enabling movement volume,
- problematic surface qualities: making the movement surface adequate in terms of elevation, layout, and material,
- lack of orientation and warnings: supporting the direction of movement,
- low level of accessibility and transportation quality: reaching every point easily (public transportation, signalling, pedestrian priority),
- low spatial quality and appeal: increasing the time spent in urban space,
- inefficient locations of urban functions: choosing convenient locations for the most frequently used functions.

Given that this study focuses on the control of physical space, the emphasis is kept on the spatial dimension of the city when examining the concept of a disabled city. A spatially barrier-free city is a settlement compatible with universal design principles that offer equal use for all. The motivation of this study is to organise smooth mobility by examining the "spatial disability" character of the city, rather than highlighting the need for simultaneous arrangement of every place in a settlement.

2.2. Disability-accessibility relationship and analytical method evaluations

When the literature is examined, it is apparent that there are both quantitative and qualitative studies to measure pedestrian accessibility, with ratings formulated to indicate the inadequacies and usage levels in the space [43, 44]. For the purposes of this study, the following evaluations were made for studies that develop a mathematical perspective on accessibility:

- (Asadi-Shekari et al., 2013) [14] proposed a model to measure and evaluate the urban pedestrian accessibility of people with disabilities. In their study, spatial disability was generally evaluated under the title of lack of physical movement, and it was addressed particularly in terms of channel spaces such as ramps, signalisation, pavement qualities, and intersection points. Components such as traffic speed, barriers, traffic lanes, crossing distances, social spaces, landscape elements, pavement infrastructure elements, urban furniture, pavements (width, material, etc.), signalling elements, and slope were considered the main factors affecting the mobility of individuals with disabilities. Each street line was evaluated according to the scoring and existing standards developed in line with these components, revealing the accessibility potential of the streets for disabled individuals. According to the results of the model, lines with a score between 80-100 were identified as the most suitable for disabled individuals, while lines with a score between 0-20 were identified as the least suitable.
- (Makri & Folkesson, 1999) [45] developed a GIS-based accessibility measurement and evaluation model proposal. They discussed land use types and location as the main components, both in terms of being influenced by and having an influence on accessibility (potential route creation effects). Average city-wide distance and trip duration to trade and service centres were evaluated along with the potential of existing roads to offer access for pedestrians, cyclists, and vehicle users.
- (Colorado Pástor et al., 2020) [46] discussed the urban accessibility of people with disabilities with a particular focus on public transportation systems. In their study, which evaluates safety and comfort, they considered components such as the existing public transportation system, climatic factors, compliance with ergonomic design principles (ramps, stops, etc.), presence of smart transportation systems, and transportation duration. Their study was shaped by the experiences of target users, and they drew conclusions focused on standards.
- (Páez et al., 2012) [47] stated that components such as the location and presence of trade functions, land use preferences of users, travel tendencies of users (maximum travel distance and duration, types of transportation used, etc.), and the location and presence of transfer stations are the deciding factors of accessibility. The information obtained regarding users' travel tendencies from surveys was evaluated according to the Cumulative Opportunity measurement model.
- (Ertuğay, 2018) [48] evaluated accessibility in terms of physical barriers (walls, stairs, inadequate urban furniture, items that may prevent access [e.g., trees, garbage cans, etc.]) and transitional elements (ramps, elevators, etc.). In their study area, each of these components was evaluated using GIS applications on a 1x1 metre grid and scored according to the degree of accessibility.

- (Gamache et al., 2016) [49] evaluated the use and accessibility of individuals with disabilities to various components (e.g., parking areas, pedestrian areas [ramps, sidewalks, signalisation, intersection points], building entrances and exits, suitability of educational buildings, suitability of service buildings, and suitability of public toilets). According to the scoring system they developed, 0-50% points were identified as weak accessibility, and 50-100% as strong accessibility.
- (Ilahi & Axhausen, 2017) [50] stated that the deciding factors of accessibility are the presence of appealing functions, average travel cost for routes, and travel trends of users. They conducted land use surveys specific to existing street lines and performed surveys to obtain user travel trend information, and they comparatively examined and evaluated the findings with the Activity Based Model.
- (Marcheschi et al., 2020) [51] constructed a theoretical framework for the pedestrian accessibility of disabled individuals, combining the main concepts of environmental psychology and traffic planning. After conducting focus groups and literature reviews, they stated that disabled people depend on five components in pedestrian transportation in the urban environment: (1) physical environment (spatial conditions allowing for disabled access and transitions), (2) social environment (social support and the characteristics of society), (3) types of activities, (4) individual capabilities, and (5) basic sensory factors.
- (Church & Marston, 2003) [52] developed a model to measure the accessibility level of people with disabilities in the urban environment. They stated that, when it comes to disabled accessibility, the city lines should be evaluated in terms of length, proximity, gross interaction opportunity, potential to offer preference, and providing access to more than one use.
- (Pirie, 1979) [53] asserts that, since movement arises primarily from the need to flow from one point to another, the model built for accessibility in the urban environment should be evaluated in terms of activity and attractive functional points.
- (Shrestha, 2023) [54] used videographic and verbal questionnaires to holistically assess pedestrian waiting and crossing times and other obstacles. Survival analysis and hazard analysis statistical methods revealed that disabled pedestrians had to wait 3-6 seconds longer than non-disabled pedestrians. It was also found that the average crossing speed of blind pedestrians was 0.98 m/s, wheelchair users 0.88 m/s, physically disabled pedestrians 0.806 m/s, and crutch users 0.77 m/s. The presence of deformations in superstructure factors such as sidewalks, ramps, pedestrian bridges, and lack of warning signs were cited as factors that increase spatial disability.
- (Vale et al., 2017) [55] developed a disability-inclusive mathematical model to measure the level of pedestrian accessibility. The model is based on two main frameworks: place-based and individual accessibility. Place-based accessibility measures the accessibility of a place by considering the cost of getting from one place to another, while individual accessibility measures the accessibility of a place by considering the individual's special abilities and environmental requirements. Using the "accessibility disparity" analysis, the change in transportation costs between disabled and non-disabled individuals was calculated on a spatial scale.

The studies examined focus on two different approaches: the physical environment and land use/user trends. Only one of the studies considers the environmental reaction and perceptual tendencies of users within the scope of disability. This study differs from previous ones in its holistic evaluation of elements such as land use, user tendencies, and environmental-psychological factors. It is evident that the selected studies from the literature produced models with varying scopes for the scale of the study area. This study differs from previous examples in the literature by proposing a model that can be generalised and examined at various scales and locations.

Based on 1.1 and 1.2, the terminology and explanations developed specifically within the scope of the study were determined as follows:

- Spatial Disability Level: Refers to the current performance of the physical spatial structure of a settlement in terms of uninterrupted walkability.
- Spatial Intervention: Efforts made to remove the spatial barriers in a settlement.
- Ideal Accessibility Network: Indicates the connection group in which mobility between housing areas, amenities, and service areas in the entire settlement is the most functionally and physically efficient.
- In-Connection Obstacle: Refers to a physical obstacle that affects walkability on a specific connection.
- Connection Continuity: Refers to uninterrupted walkability along a connection, considering its cross-section as well as the presence of gateways and signalisation.
- Intervention Priority Scale: Indicates the order of all connections on the ideal accessibility network, ranging from the highest level of connection and the highest level of disability to the lowest level of connection and the lowest level of disability.

3. Study area and method

3.1. Study area

For the purpose of this study, Kırklareli city centre was chosen as the study area (Fig. 1). The main reasons for choosing Kırklareli, which has the characteristics of a medium-sized city (with a current population of approximately 90,000 people), are summarised below:

- Observations conducted in the city reveal that there are problems with the physical infrastructure in urban transportation lines (obstacles, interrupted access, streets without sidewalks, steep lines, etc.) (Fig. 2). Additionally, the findings of [56] indicate that the number of lines utilised by users in the entire urban area is limited, thus supporting the aforementioned observations.
- According to a report prepared by the Kırklareli Provincial General Assembly, in 2016, approximately 33,000 people with disabilities were living in the province (approximately 10% of the population at that time), and approximately 6,000 individuals with disabilities were living in the city centre (approximately 8% of the urban population at that time) [57][1]. On the other hand, when the strategic plan of the Municipality of Kırklareli for 2020-2024 is examined, it is evident that the policies for transportation are vehicular-access oriented rather than human-oriented, and the policies for disabled individuals do not go beyond social aid and service delivery. Therefore, in a settlement like Kırklareli city centre with a high potential for walkability, it is critical to identify the problems related to spatial disability and to produce solutions and policies accordingly.

[1] Currently, relevant ministries only provide statistical information on disabled individuals at the country level. Therefore, it was not possible to access up-to-date data for the province and the city center.

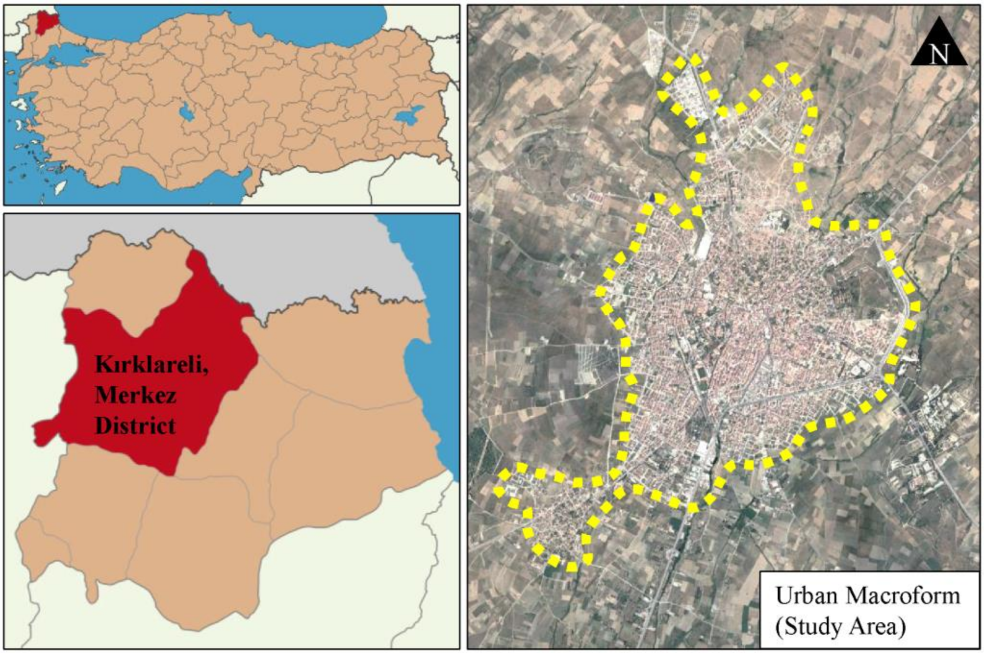

Fig. 1. Location of study area

Fig. 2. Photos of problematic roads in the study area

3.2. Methodology

In urban spaces, the universal goal is to create areas that are accessible to everyone and meet barrier-free design standards. However, while it is relatively easy to implement such measures in urban development zones and new design projects, there is no effective process for doing so in existing residential areas. In the implementation process within existing urban areas, it is crucial to accurately determine the project stages, specifically the identification of priority intervention areas. This study discusses this issue under two main titles: (1) Identification of ideal accessible networks, which involves identifying places with high pedestrian accessibility and providing sub-groups, and (2) Identification of spatial obstacles, which involves identifying places where priority intervention is required and determining the phasing plan. The methodology aims to enable the quantitative measurement of spatial disability performance to determine the level of "accessible" spaces in cities. The studies were carried out on urban networks, which are open spaces that connect all the nodes in the urban fabric. The methodology consists of three stages (Fig. 3):

1. Identification of the ideal accessibility network (six sub-assessments) *[see Subheading 3.2.1.]*,
2. Calculation of the level of spatial disability (five sub-assessments) *[see Subheading 3.2.2.]*,
3. Assessment of intervention priority *[see Subheading 3.2.3.]*

The details of each stage are provided below.

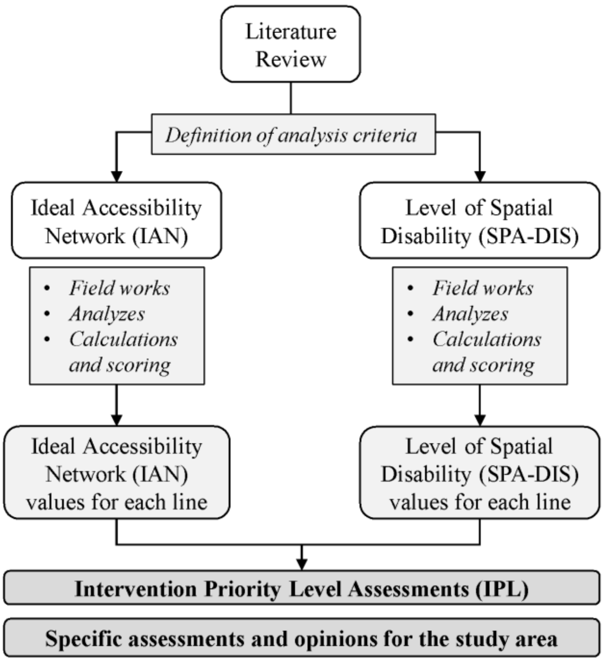

Fig. 3. General study method diagram

3.2.1. Ideal Accessibility Network (IAN Level) Method

The Ideal Accessibility Network (IAN) analysis is based on the principles of pedestrian accessibility and aims to identify the most frequently used individual links and the network these links form in a district. Six settlement-specific sub-analyses are synthesised to achieve this. The parameters for these analyses are listed under the following main titles:

A. **Land Use Attractiveness Coefficient:** An attractiveness coefficient was assigned to the land use types based on socioeconomic and political context. In accordance with the relevant literature [58, pp. 758–759, 59, pp. 2–5, 60, 61], the coefficient scale was designed to include retail/service (highest), recreation, public services, and industrial/manufacturing (lowest). Residential areas were excluded from the analysis because they would produce relatively the least movement. The average coefficient of attractiveness of the functions on each of the axial lines was calculated.

B. **Qualified Lines:** For this analysis, [56] was taken as the primary reference. The lines that are culturally, historically, and perceptually important for the users in the city were addressed in terms of their effects on directing the flow of users.

C. **Landmarks (Buildings and Open Spaces):** In relation to the analysis of the qualified lines, a survey[2] was conducted to determine the reference locations that guide the flow of users. In the survey, users were also asked questions about optimum comfortable walking distances, and this value (r: 335 metres) was taken as the basis for the basic accessibility distance.

D. **Axial Characteristics of Network (Connectivity):** The Space Syntax Theory suggests that it is necessary to analyse the syntax features of the space to describe the spatial form quantitatively and analytically. The theory argues that the intelligibility of the urban fabric can be measured by analysing the relationship between how the spatial construct appears from the individual parts of the network and its place in the whole network [62]. This approach is defined as the "distribution of spatial integration." When the analysis techniques of the Spatial Syntax Theory were further studied, the concept of "configuration," which is a relational feature, emerged. Configuration defines the characteristic and relational orders of the urban network structure. According to these characteristics, the entirety of the urban network is considered as the "network pattern of axial lines" that intersect and connect with each other. The focus of the method is the axial maps that are created by processing the lines in the urban network that linearly cut through a certain area and have visual integrity. When it comes to producing axial lines with visual integrity and linearity, it is possible to say that sensory access, one of the main factors that affect movements and flows in behavioural psychology, is also addressed [63]. Within the scope of this study, connectivity analysis, one of the main axial line analyses, was used. Connectivity analysis measures the number of spaces that connect to a certain space of origin. The "connectivity" value is used to express the strength of the connections between the lines in the urban network [62, p. 103]. Connectivity refers to the strongest, longest lines in space, indicating the points where accessibility is the highest. High connectivity values indicate strong connections, while low connectivity values indicate isolated areas and low accessibility. The formula below is used to calculate connectivity (Eq 1) (Ci: connectivity value of a hypothetical starting i line, Tk: total number of k lines connected to the i line):

[2] The survey was conducted with 420 respondents, representing a sample size of 5% at a 95% confidence interval.

$$C_i = \sum_{i=1}^{k} T_k \tag{1}$$

E. Accordingly, the connectivity value of each road line (axial lines in terms of Space Syntax) was calculated using the open-source DepthMapX 0.80 software.

F. **Slope:** Within the scope of the study, a slope analysis was also prepared. In the literature, it is asserted that the slope of a street is among the main factors that affect the flow of users in terms of comfort of movement. Streets with a slope of more than 6% lead users to prefer other streets [64,65].

G. **Transfer Hubs:** The study examines whether additional modes exist on axial routes. Consistent with the literature, the spatial orientation of users is also influenced by the presence of transfer hubs, such as bus stops [66,67,46,68]. In this context, the lines that provide access to transfer hubs were identified, and they were evaluated together with the optimum access diameters calculated with the outcomes of the survey.

Min-max normalization (0: the lowest, 10: the highest) was applied to bring the outcomes of the analysis to a common denominator, thus enabling comparative evaluations. The ideal accessibility score of each line was calculated with the arithmetic sum of each value. The IAN Score ranges between 0 (the lowest) and 60 (the highest). Additionally, as a result of the calculations, the ideal accessible lines were divided into five levels (1: high quality to 5: low quality). The formula for calculations is as follows (Eq. 2) ($IANP_i$: IAN Score of each axial line, A-B-C-D-E-F_{value}: the individual value of each analysis):

$$IANP_i = \sum_{0 \le value \le 10} A_{value} + B_{value} + C_{value} + D_{value} + E_{value} + F_{value} \tag{2}$$

3.2.2. SPA-DIS Level Method (Level of Spatial Disability)

The level of spatial disability of a settlement determines its walkability performance, residents' accessibility preferences, and the mobility potential of people with disabilities. Measuring the level of spatial disability can provide an informative and guiding method for planning and implementation processes in local governments. By revealing the level of spatial disability for each street and comparing it with the initially determined accessibility hierarchy, it may be possible to formulate the phasing of implementation and identify priority areas. It is important to note that any intervention on highly accessible streets will have a greater impact on reducing spatial disability according to the method. The study identified 'links/connections' and 'nodes' as the basic analysis units (Fig. 4).

There were four types of analyses and additional criteria for the assessment of spatial disability. Link scores were obtained for each of the four analyses. Based on the analyses performed according to the four parameters, performance levels were determined as percentages, and the overall value was determined by the arithmetic sum of the four performance scores (see Table 1). When calculating the SPA-DIS Level, three additional evaluation criteria were considered, in contrast to the calculation of the IAN:

- **Scoring the units (nodes-links) according to the relevant analysis parameter:** With the analysis of each parameter, the scores for all the connections on the accessibility network were calculated. It was observed that connections with the highest score are the most problematic in terms of spatial disability, while connections with the lowest score are the least problematic.

Fig. 4. Representative network diagram (link-node)

- **Evaluating connections by level:** The principle adopted in this study is to prioritise interventions in the most used top-level connections. Any improvements made on a first-tier connection according to the ideal accessibility network would have a greater effect on the total score. Therefore, an inversely proportional additional coefficient evaluation was developed where 5 points were assigned for 1st level lines, and 1 point was assigned for 5th level lines.
- **Calculating the parameter performance level:** After calculating the score that reflects the current situation with any of the analyses, the maximum score that the same analysis can achieve under ideal conditions was calculated, and the performance level (as a percentage) was determined by comparing the current situation to the ideal situation. Given that some of the analyses involved more than one evaluation stage, the arithmetic average of the sub-analyses was taken to calculate the performance levels.

The parameters determined in accordance with the relevant literature for these analyses are as follows[3]:

A. **Link Continuity Analysis (Analysis A):** In this analysis, two separate sub-components were used: continuity (N) at intersections (junctions) of the accessibility network, and continuity (L) at connecting lines. The score “1” was assigned when there were solutions such as signalisation and pedestrian crossings that provide unhindered passage and facilitate flow at intersections; otherwise, the score “0” was assigned. For connection lines, it was analysed whether the road was wide enough for pedestrians to cross (if the lines were less than 7 metres wide, the score “0” was assigned to the associated connections, and the score “1” was assigned if the lines were over 7 metres[4]). As a result of the calculations, percentage values were obtained (Table 2, Fig. 5).

[3] It was accepted that a low number of problems in these criteria would also lead to reduced spatial disability in an urban area. In this study, climatic factors were not considered when evaluating the duration for which a connection is experienced. The aim of the study was to analyse the minimum qualifications so that the analysis can be adapted to other settlements. Measures against climatic factors can be evaluated with design solutions under the initiative of local governments. However, in this study, the minimal analyses and analysis methods are explained to evaluate the level of spatial disability regardless of the location of the settlement.

[4] Given that, pursuant to the current development regulations in Turkey, the standard pedestrian path should be a minimum of 7 metres wide, this value is accepted as a benchmark.

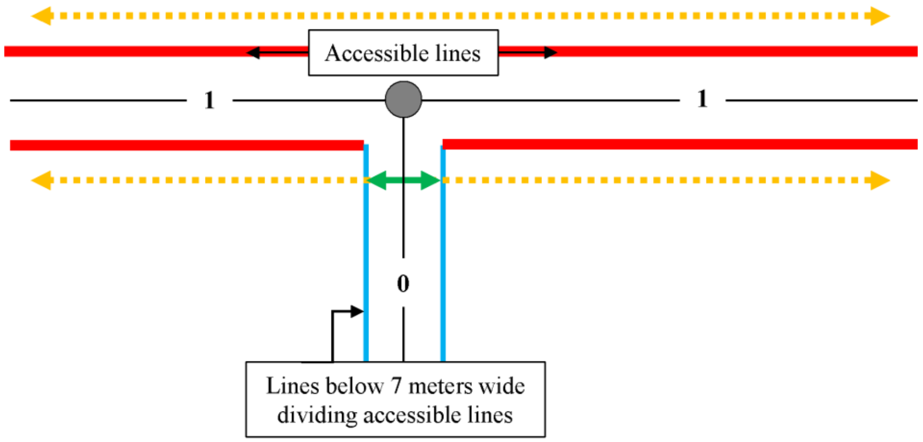

Fig. 5. Line continuity diagram when accessible lines divided by roads below 7 meters

B. **In-connection Spatial Disability Analysis (Analysis B):** The physical barriers that users encounter when using each connection that makes up the accessibility network were identified. Physical barriers include situations that arise as a result of the practices of local governments, apart from individual interventions. Spatial disability analysis in this context was addressed under two main categories and seven sub-categories in total.
- Spatial Barriers (negative factors that prevent the flow of movement) (B1): elevation differences, uneven ground conditions, situations that hinder the width of pedestrian movement, presence of dangerous elements, and disruption of perceptual continuity.
- Spatial Interventions (factors that support movement flow or are positive) (B2): presence of wayfinding elements (B2-1), and presence of urban furniture (elements for rest) (B2-2).

The scores were calculated by taking the arithmetic sum of the presence of each positive or negative factor (each factor was assigned 1 point). As a result of the calculations, the percentage values were obtained (Table 3).

C. **Topographic Character Analysis for Connections (Analysis C):** Lines with a slope of less than 6% according to the ideal accessibility network analysis were evaluated based on their levels (the presence of any factor was evaluated with 1 point). As a result of the calculations, the percentage values were obtained (Table 4).

D. **Connection Experience Duration Analysis (Analysis D):** Light is very important for an unhindered experience of a connection. It is crucial that each connection can be experienced comfortably in the evenings and at night without any obstacles to vision or issues affecting the sense of security. The analysis performed in this context was based on the lighting infrastructure in the entire accessibility network. Thirty-five metres was accepted as the reference value[5] for the distance between urban lighting elements. Lines with lighting elements that meet the reference value were identified as "perceptually safe" (the presence of the factor was evaluated with 1 point). As a result of the calculations, the percentage values were obtained (Table 5).

[5] The average distance for the study area was calculated based on [69].

The resulting percentage performance scores were obtained according to the coefficient values[6] determined for the analyses conducted under a total of four categories (see Table 1).

Table 1. SPA-DIS Level calculation stage

Analysis	Performance Value (%)	Coefficient	Final Value
Analysis A	a	1	1 x a
Analysis B	b	7	7 x b
Analysis C	c	1	1 x c
Analysis D	d	1	1 x d
	Total	10	X

Total Value: $X = 1a + 7b + 1c + 1d$

Final Value: $(X) = \frac{X}{10}$

The methodology used in this study differs significantly from those found in the available literature. The percentage of spatial disability is expressed and can be used to monitor changes resulting from individual spatial interventions at specific links. It can also be used to evaluate the relationship between spatial disability and the level of intervention in the accessibility network.

Table 2. Line continuity analysis (Analysis A) calculation stage

<table>
<tr><td>Continuity assessment on connecting lines (L) (Current Status)</td><td rowspan="4">L= (TSx100)/IS</td><td rowspan="8">Final Score (Analysis A) = (L+N)/2</td></tr>
<tr><td>Total Score (TS) = Sum (R(i) x Coeff.)
R(i): Result of analysis for each line</td></tr>
<tr><td>Continuity assessment on connecting lines (L) (Ideal Status)</td></tr>
<tr><td>Ideal Score (IS) = Sum (R(i) x Coeff.)
Ideal status: For the L category, the situation where all lines provide uninterrupted access.</td></tr>
<tr><td>Continuity assessment at intersections (N) (Current Status)</td><td rowspan="4">N = (TSx100)/IS</td></tr>
<tr><td>Total Score (TS) = Sum (R(i) x Coeff.)
R(i): Result of analysis for each node</td></tr>
<tr><td>Continuity assessment at intersections (N) (Ideal Status)</td></tr>
<tr><td>Ideal Score (IS) = Sum (R(i) x Coeff.)
R(i): Ideal result for each node
Ideal Status: For the N category, this refers to the situation where solutions (such as signalisation, pedestrian crossings, etc.) that provide uninterrupted access at all intersection points are available.</td></tr>
<tr><td colspan="3">Coeff.: Coefficient based on IAN Level (e.g., Coeff:5 for IAN Level: 1)
IAN level and coefficient are inversely proportional to each other.</td></tr>
</table>

[6] For stages A, C, and D, a solution for a single problem should be developed. However, in stage B, numerous solutions should be developed for 7 different problems. Therefore, the performance scores for analyses A, C, and D were calculated by multiplying by "1" as the coefficient, while the performance score for analysis B was calculated by multiplying by "7" as the coefficient.

Table 3. In-connection spatial disability analysis (Analysis B) calculation stage table

Barrier-free distance rating (B1) (Current Status)	B1= (TSx100)/IS		Final Score (Analysis B) = (B1+B2)/2
Total Score (TS) = Sum (MDB(i) x Coeff.) MDB(i): Mean distance between barriers for each line MDB(i) = (Line Length/Total Number of Barries) for each line			
Barrier-free distance rating (B1) (Ideal Status)			
Ideal Score (IS) = Sum (Le(i) x Coeff.) Le(i): Line length for each line (with the acceptance that each line is barrier-free)			
Presence of wayfinding elements (B2-1) (Current Status)	B2-1= (TSx100)/IS	B2 = (B2-1 + B2-2)/2	
Total Score (TS) = Sum (MDW(i) x Coeff.) MDW(i): Mean distance between wayfinding elements for each line			
Presence of wayfinding elements (B2-1) (Ideal Status)			
Ideal Score (IS) = Sum (MDW(i) x Coeff.) *Ideal status: For the B2-1 category, the situation where wayfinding elements are available on all lines.*			
Presence of urban furniture (elements designed for resting) (B2-2) (Current Status)	B2-2= (TSx100)/IS		
Total Score (TS) = Sum (MDU(i) x Coeff.) MDU(i): Mean distance between urban furniture for each line MDU(i) = (Line Length/Total Number of Urban Furniture) for each line			
Presence of urban furniture (elements designed for resting) (B2-2) (Ideal Status)			
Ideal Score (IS) = Sum (MDU(i) x Coeff.) (with the acceptance that each line has urban furniture) *Ideal Status: For the B2-2 category, this refers to the situation where elements for rest are provided every 80 metres on average. Yücel (2013) states that the distance between elements for rest should be 60 metres on average in areas with high pedestrian traffic and 100 metres in areas with low pedestrian traffic. For the purposes of this study, the average of these two values (80 metres) was used.*			
Coeff.: Coefficient based on IAN Level (e.g., Coeff:5 for IAN Level: 1) IAN level and coefficient are inversely proportional to each other.			

Table 4. Topographic character analysis for connections (Analysis C) calculation stage table

Slope of links (C) (Current Status)	Final Score (Analysis C) = (TSx100)/IS
Total Score (TS) = Sum (Sl x Coeff.) Sl: Number of lines with a slope below 6%	
Slope of links (C) (Ideal Status)	
Ideal Score (IS) = Sum (Tl x Coeff.) Tl: Total number of lines *Ideal states: Each line with a slope below %6*	
Coeff.: Coefficient based on IAN Level (e.g., Coeff:5 for IAN Level: 1) IAN level and coefficient are inversely proportional to each other.	

Table 5. Connection experience duration analysis (Analysis D) calculation stage table

Lighting level of links (D) (Current Status)	Final Score (Analysis D) = (TSx100)/IS
Total Score (TS) = Sum (LPl x Coeff.) LPl: Number of lines without lighting problems	
Lighting level of links (D) (Ideal Status)	
Ideal Score (IS) = Sum (Tl x Coeff.) Tl: Total number of lines *Ideal Status: For the D category, this refers to the situation where lighting elements are used at least every 35 metres (see Footnote 5).*	
Coeff.: Coefficient based on IAN Level (e.g., Coeff:5 for IAN Level: 1) *IAN level and coefficient are inversely proportional to each other.*	

3.2.3. Intervention Priority Level (IPL) method

To achieve lower levels of spatial disability, the ideal process is to intervene simultaneously to make each link accessible. However, it may not be feasible to make all interventions at the same time without hindering current urban mobility. Therefore, local governments should intervene in phases to minimise the impact on urban mobility. The proposed system ranks all connections on the accessibility network based on their level of accessibility and spatial disability. The ranking starts from the connection with the highest level of accessibility and spatial disability and ends with the connection with the lowest level of accessibility and spatial disability.

The intervention priority score for each connection is calculated by multiplying the accessibility coefficient with the disability level score. Similarly, in the previous sections, we formulated an evaluation of additional coefficients that are inversely proportional, assigning a coefficient of '5' to 1st level routes and a coefficient of '1' to 5th level routes (Table 6). The results of this method are presented below.

Table 6. IPL Level calculation stage

Link	IAN Level	IAN Coefficient	SPA-DIS Level Score	Intervention Priority Level
n1	1	5	a	5 x a
n2	2	4	b	4 x b
n3	3	3	c	3 x c
n4	4	2	d	2 x b
.....	5	1	e	1 x a

Final Score: $IPL_n = IAN(C_n)\ x\ SPADIS(L_n)$
IPL_n: Intervention priority score for each n connections
$IAN(C_n)$: Accessibility network coefficient for each n connection.
$SPADIS(L_n)$: Disability level score for each n connections.

4. Findings and discussions

Within the scope of the study, the analyses specified in the methodology section were conducted. The findings obtained are explained below, in the same order as outlined in the Methodology section:

4.1. Ideal Accessibility Network (IAN Level) findings *[based on Subheading 3.2.1.]*

After conducting the analysis and calculations in the study area, it was observed that none of the connections achieved the ideal maximum value of 60 points. The highest value reached was 48 (refer to Table 7, Fig. 6, and Fig. 7). However, 21% of the total lines comprised the ideal accessibility network based on their scores and the configuration of the road pattern (see Fig. 7). In the study area, the slopes of the roads and the connectivity values of the existing road pattern were identified as the most influential factors for attaining ideal accessibility. Nevertheless, the uneven distribution and limited diversity of urban functions, the absence of structural/spatial reference points, and the lack of historically significant axes diminished the impact of these factors. This study classified the ideal accessibility lines into five levels based on their configuration, intersection forms, and the existing street hierarchy (ranging from 1: high quality to 5: low quality) (see Table 8). Tier 1 (high quality) connections constituted approximately 7% of all ideally accessible lines.

Table 7. IAN analysis results

Kırklareli city center			Analysis	Kırklareli city center		
IAN Score	Minimum	6		Minimum	Mean	Maximum
	Mean	22	Land Use Attractiveness Coefficient	0	2.35	10
	Maximum	48	Connectivity	0	6.69	10
Total Number of Lines		2846	Landmarks (Buildings and Open Spaces)	0	1.26	10
Ideal Accessible Line		608	Slope	0	7.3	10
Percent (%)		21	Transfer Points	0	3.66	10
			Qualified Lines	0	0.82	10

Table 8. Levels of ideal accessible lines and their frequencies

IAN Level	Frequency	Percent (%)
1	40	6.58
2	99	16.28
3	133	21.88
4	190	31.25
5	146	24.01
Total	608	100.00

To assess the accuracy of the values obtained from the ideal accessibility analysis, pedestrian counts were conducted on randomly selected streets, followed by a correlation test. The results indicated a moderate positive correlation (p: 0.672, Sigf: 0.009) between the IAN score and the average pedestrian count (Table 9). Hence, the ideal accessibility network demonstrates its suitability for spatial studies, given the consistency observed between the ideal accessibility network and the empirical data.

Table 9. Correlation test between pedestrian counts (2022) and the IAN score for selected streets

Street Name	Weekday Average	Weekend Average	Overall Average	IAN Score
Lojman Street	76	110	93	18
İstasyon Street	1099	927	1013	34
Emek Street	63	77	70	16
Şeref Street	253	206	230	32
100. Yıl Street	420	391	406	40
Mandıra Street	171	223	197	23
Fevzi Çakmak Avenue	798	1319	1059	36
Cami Şerifli Street	163	145	154	26
1. Fırın Street	122	111	117	26
2. Fevzi Çakmak Street	129	112	120	27
3. Fevzi Çakmak Street	102	101	102	24
Cumhuriyet Street	786	984	885	33
Dere Üstü Street	116	111	113	26
Mustafa Kemal Avenue	237	255	246	32

Correlations Test

	Overall Average	IAN Score
Pearson Correlation	1	0.672**
Sig. (2-tailed)		0.009
N	14	14

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

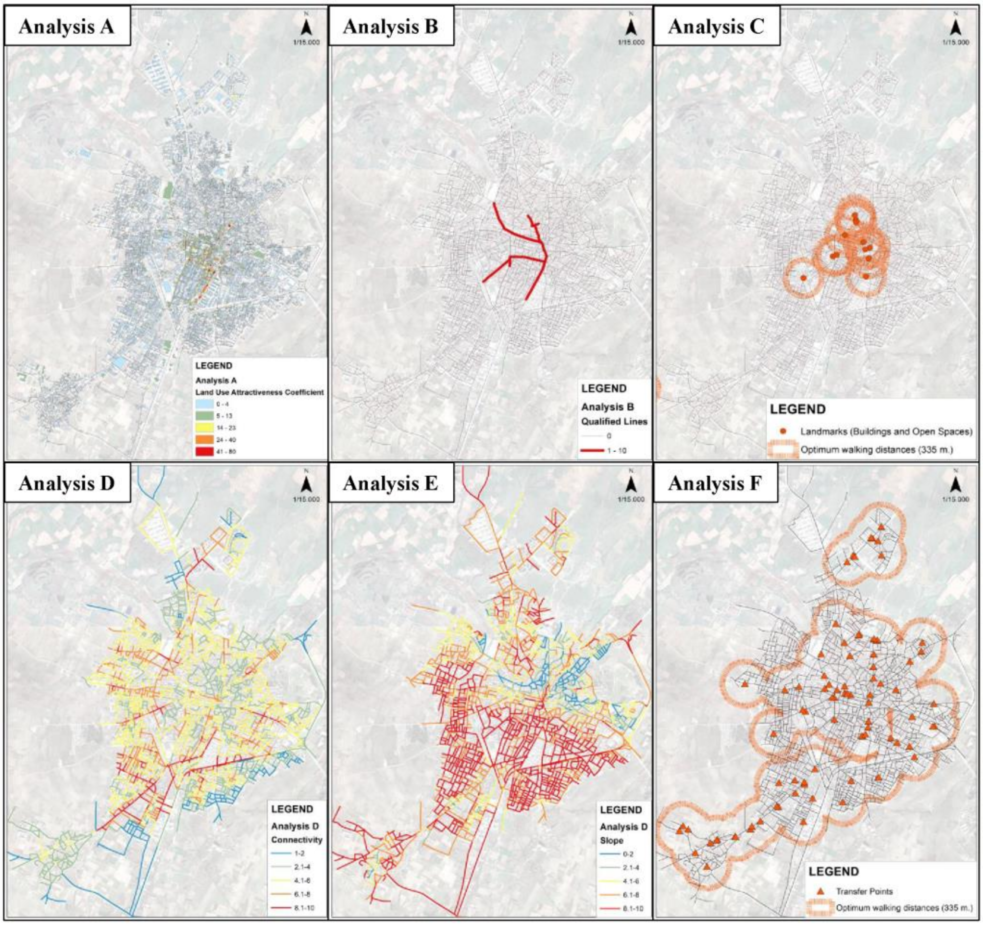

Fig. 6. IAN Level analysis (collective view)

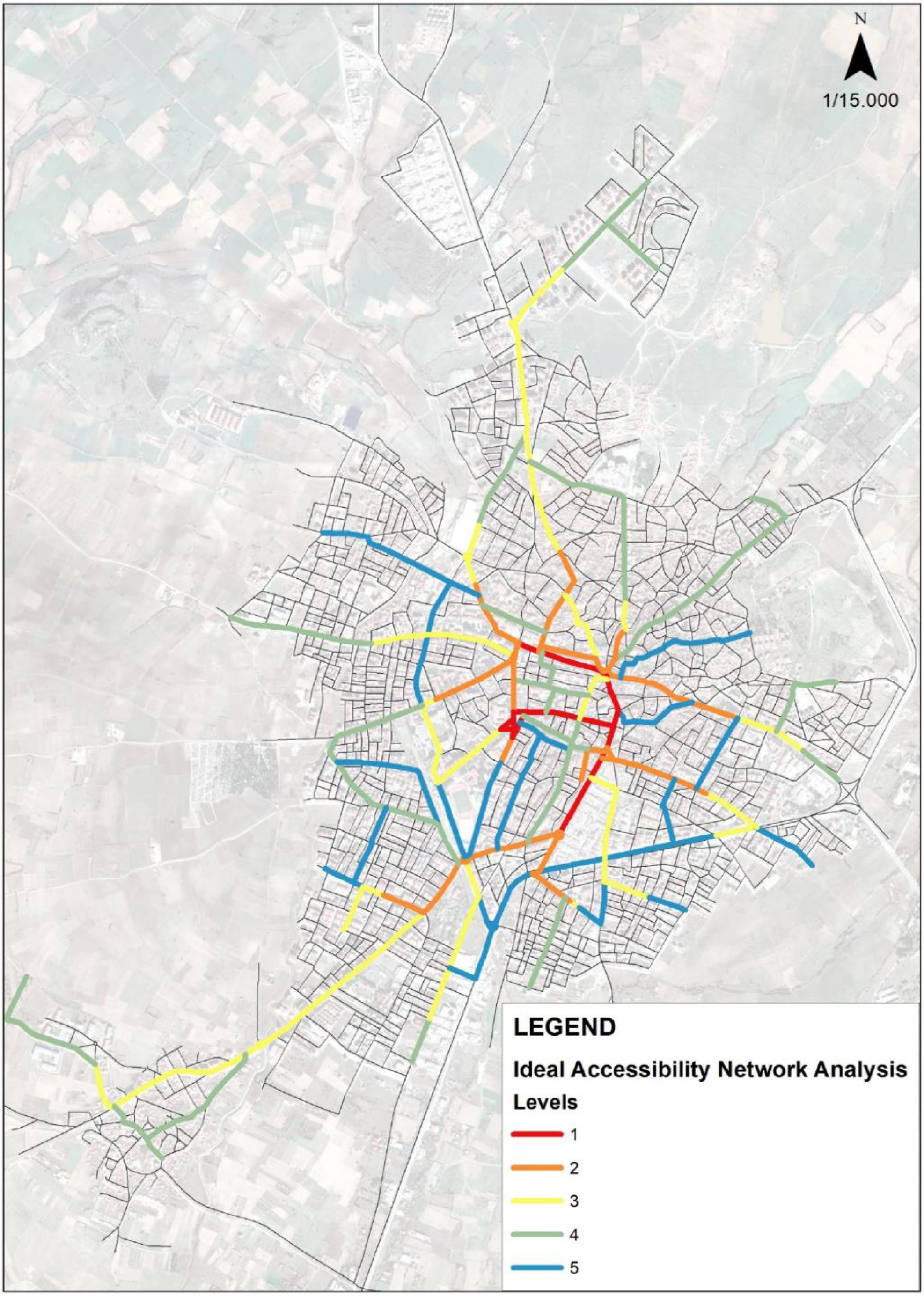

Fig. 7. Final IAN Level map

4.2. SPA-DIS Level Method (Level of Spatial Disability) findings [based on *Subheading 3.2.2.]*.

The analysis indicates that Kırklareli city center demonstrates a spatial disability performance level of 24%, indicating a 24% disability for each link. Focusing solely on Analysis-B *(In-connection Spatial Disability Analysis)*, it reveals that the city faces 79.5% spatial barriers. On average, a barrier appears every 7.44 meters, despite the ideal accessibility network stretching over 38 km. The study assessed connection performance within the settlement. It found that continuity performance between connections stood at 31%, while performance dependent on topographic character reached 88%. Nighttime experience performance of connections scored 43% (refer to Table 10, Fig. 8, and Fig. 9). Preliminary assessments highlight the most significant issues in the study area, including barriers in connections, nighttime experience performance, and continuity between connections. Analysis-C values are notably higher due to the relatively flat terrain in the study area.

Table 10. SPA-DIS level analysis results

Analysis		Result	Coefficient	Score
Analysis A	L	33.8%	1	30.90%
	N	28%		
	Mean	**30.9%**		
Analysis B	B1	0.12%	7	79.50%
	B2-1	22.64%		
	B2-2	22.52%		
	Mean	**11.35%**		
Analysis C	**C**	**88.76%**	1	88.76%
Analysis D	**D**	**42.34%**	1	42.34%
		Total	**10**	**241.50%**
		Final SPA-DIS Level Score	**24%**	

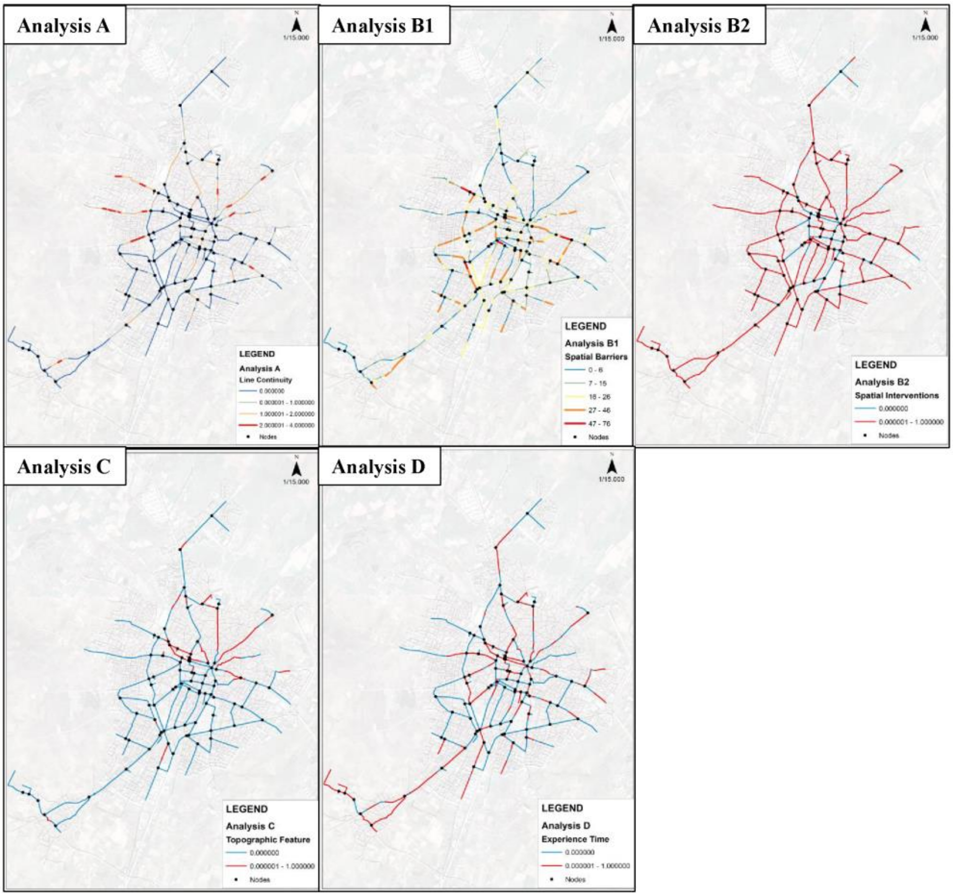

Fig. 8. SPA-DIS Level analysis (collective view)

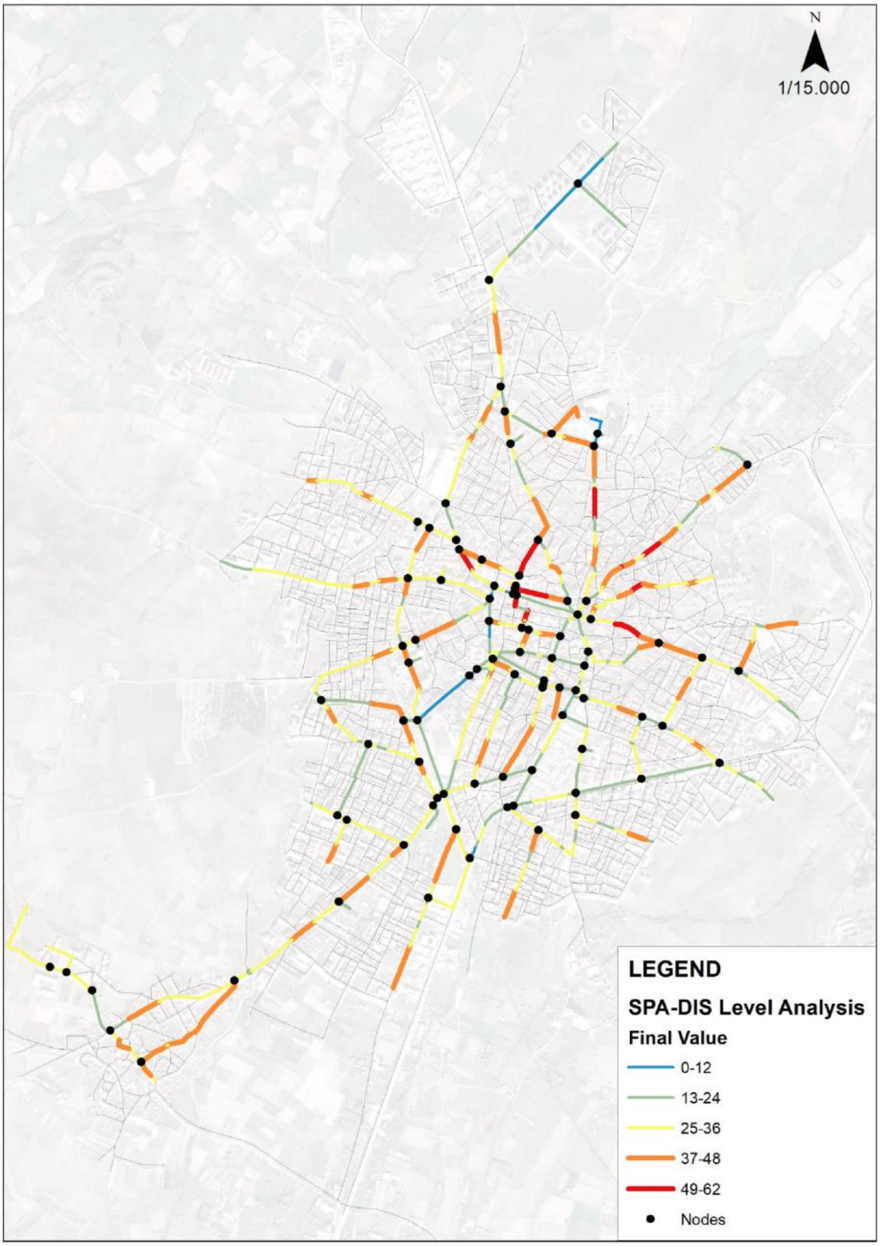

Fig. 9. Final SPA-DIS Level map

4.2. Intervention Priority Level (IPL) findings [*based on Subheading 3.2.3.*].

Using the methodology, intervention priority was computed to pinpoint the most crucial lines in the study area (refer to Fig. 10). A distinctive contribution of the study is the identification of sub-intervention zones within a road line, despite the top priority lines lacking spatial integrity.

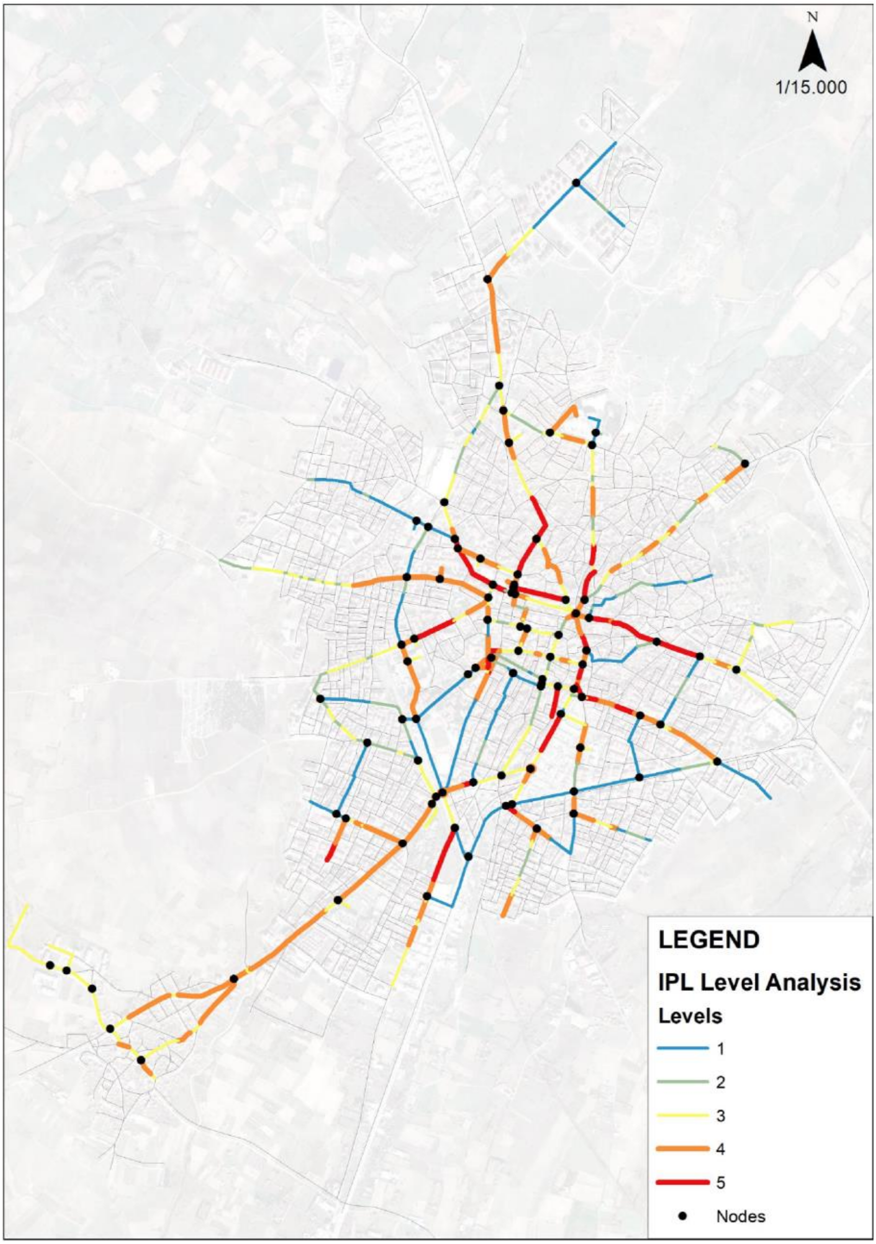

Fig. 10. Final IPL Level map

5. Conclusions

When designing, transforming, or rehabilitating cities, it is crucial to adopt design principles that consider all users. The practicality of public spaces serves as a measure of a city's public value. Therefore, uninterrupted walkability is an essential parameter. The aim of this study was to provide an unhindered and continuous experience of urban space, with a particular focus on uninterrupted walkability. Studies on accessibility have increased, especially since the adoption of the United Nations Convention on the Rights of Persons with Disabilities. In this context, studies on design standards have become widespread, and local governments have increased the implementation of accessible design standards. However, the current problematic construction in cities remains a significant challenge at this point. Barrier-free design standards are convenient to apply in new development areas or in urban areas where urban transformation projects are carried out. However, the adaptation of these standards in existing spaces is often hindered by various factors such as ownership, infrastructure, and economic feasibility. As a result, fragmented approaches to barrier-free design are common throughout cities. However, it is crucial to ensure that users can move freely throughout an entire urban area or its most frequently used areas.

To ensure a continuous experience, it's crucial to eliminate spatial barriers within a settlement. However, modifying existing city spaces to meet accessibility design criteria can be costly and challenging to implement all at once. Therefore, designers and practitioners require guidance. This study formulates these guidelines in three steps:

1. Analysing the ideal accessibility network, which holds the highest potential for use by every individual in the entire settlement (to reveal the spatial network that should be arranged at a minimum).
2. Identifying all obstacles on the ideal accessibility network and quantifying the settlement's performance with the adopted method (to reveal the extent of the problem and to monitor performance after interventions).
3. Overlaying the two analyses to determine the priority order of interventions (to identify where to start).

After conducting studies in the sample area and analyzing the data of Kırklareli city center, we determined the ideal accessibility network and then performed spatial disability analysis for each link in this network, calculating the spatial disability performance. The results revealed that the spatial disability performance level of Kırklareli city center is only 24%, relatively low for a medium-sized settlement. Finally, the connections forming the accessibility network were ranked according to the priority of intervention. If the local government intervenes according to the proposed priority ranking, the performance score will increase rapidly, and the local government will gain control over future implementations in the settlement. Adapting the calculation method to other cities is important as it allows for comparisons between different cities. Consequently, the data generated can be utilized to monitor the performance of settlements and assist in formulating appropriate budgets and investment programs. In a world where disability rates are increasing, individuals will have the opportunity to choose accessible cities in which to settle.

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