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VISUALIZATION OF BARRIERS TO WALK: TRANSFORMING INTERVIEW RESPONSES TO WALKABILITY EVALUATION PATHS (WEPS)

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INTRODUCTION

Walking is an active mode of transportation that plays a critical role in sustainable mobility and climate change mitigation (Brand et al., 2022). However, promoting walking remains a challenge due to the complex interplay of factors that influence walking decisions, ranging from the built environment characteristics to individuals' trip purposes. To implement effective sustainable transportation policies, it is essential to understand the underlying conditions and factors that either enable or hinder walking.

While various methods exist to evaluate walkability, only a limited number of studies provide quantitative assessments of walking decisions and pedestrian infrastructure (Shatu and Yigitcanlar, 2018). Traditional tools such as the Pedestrian Level of Service (PLOS) have attempted to quantify walkability through attributes like path quality and safety (Bloomberg and Burden, 2006; Christopoulou and Pitsiava-Latinopoulou, 2012; Asadi-Shekari et al., 2014). These tools have since evolved into more inclusive concepts like the Quality of Level of Service (QLOS), incorporating factors such as aesthetics and user comfort (Talavera-Garcia and Soria-Lara, 2015). Comparative studies of PLOS/QLOS frameworks (e.g., Tan et al., 2007; Christopoulou, 2012) have provided methodological insights and, in the case of the METU Campus, produced numerical evaluations that led to the categorization of walkability factors into five key dimensions: traffic, safety/comfort, land use, infrastructure, and user/trip characteristics (Karatas and Tuydes-Yaman, 2016; Tuydes-Yaman and Karatas, 2017).

However, while these studies have effectively catalogued influencing factors, they often fall short in capturing the interrelations among these variables or how they collectively shape walking decisions, positively or negatively (Tuydes-Yaman and Karatas, 2017; Tuydes-Yaman et al., 2018). For example, a lack of sidewalk maintenance can become a critical deterrent when combined with harsh winter conditions, and insufficient

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lighting along walkways may simultaneously create visibility problems and raise safety concerns, especially at night.

Addressing this gap, this study introduces a novel methodology aimed at detecting and visualizing the interdependencies among walkability factors and their impacts on pedestrian behaviour. This study aims to model walking decisions by proposing a mathematical approach based on graph theory that relies on the factors (nodes) visited in a traveler's mind and their relations (links) in an imaginary network. To support this approach, a catalogue of walkability factors was created based on people's responses to walking decisions and barriers gathered via a semi-structured interview with open-ended questions. Participant responses were digitized and processed using Python code, enabling the creation of walkability evaluation paths (WEPs) for every traveler. These paths were then visualised using Geographic Information Systems (GIS) to create a walkability factor relation map: a graphical representation highlighting the key deterrents to walking and the connections between them. This approach allows not only the identification of the most influential barriers but also enables comparative mapping across user groups, such as males versus females or students versus personnel, providing a behavioural dimension to the spatial analysis.

The primary contribution of this study lies in its development of a flexible, interdisciplinary method to mathematically represent and visualise walking barriers. Unlike existing tools, the WEP-WFC framework incorporates user perceptions into a graph-based model, revealing how multiple factors interact cognitively during walking decisions. The novelty of this method is twofold: i) it translates subjective interview data into quantifiable, spatially explicit networks of barriers, and ii) it creates a transferable and adaptable tool for evaluating walkability beyond static physical conditions. Furthermore, this method is generalisable to other large-scale campuses, institutional sites, or enclosed urban areas that exhibit diverse land use, elevation, and mobility infrastructure. The structure of the WFC is adaptable to local contexts, making it possible to replicate the methodology across different geographies with cultural or infrastructural variations, while maintaining a common analytical backbone under five major categories (i. Traffic, ii. Safety/Comfort, iii. Land Use, iv. Infrastructure and v. User/Trip).

METU provides a highly dynamic and complex setting for walkability analysis. Its combination of well-planned pedestrian corridors, such as The Alley, and organically developed, under-connected peripheral zones reflects challenges faced by many university campuses worldwide. The co-existence of diverse land uses, natural terrain variation, and uneven population densities contributes to varied pedestrian experiences across the campus. Additionally, multiple access points, including the metro, bus, and minibus systems, offer a unique opportunity to examine interactions between public transportation and pedestrian movement within a semi-enclosed environment. This spatial diversity, coupled with varied user behaviours and needs, enhances the relevance and applicability of the WEP method. By modelling walkability not just through physical parameters but also through the lived experiences and behavioural insights of pedestrians, this study provides a more holistic understanding of walkability. It contributes to both campus-scale mobility planning and broader sustainable transport initiatives, offering a scalable and user-driven methodology for improving pedestrian accessibility in complex urban environments.

LITERATURE REVIEW

Factors Affecting Walkability

The impact of the built environment on walking is influenced by land use characteristics, trip purposes, and walking infrastructure (Frank et al., 2010; Özbil, 2013; Yang, 2015). In terms of land use characteristics, land-mix use, accessibility, street connectivity, infrastructure quality, neighborhood aesthetics, and traffic conditions were discussed (i.e. Frank et al., 2010; Yang, 2015). Utilitarian walking (walking as a transportation mode with a trip purpose) was strongly associated with proximity to services and a land use but not too much with neighborhood aesthetics and safety, while recreational walking (walking as a physical activity) was positively associated with neighborhood aesthetics and safety (Yang, 2015). Increasing the quality of walking infrastructure and providing a safe environment regarding traffic conditions were considered actions that can lead to increased walkability and preference toward access to facilities by walking (Hine, 1996).

Studies on walking behavior have primarily explored how various factors influence individual preferences. For instance, research by Timperio et al. (2004), Koh and Wong (2013), and Lee and Dean (2018) has highlighted significant factors such as walking distance, security concerns, crash risk, slopes, rain shelters, road crossings, detours, and crowding in residential and industrial areas. Ramakreshnan et al. (2020) emphasized building proximity, walking purpose, connectivity, accessibility, land use, and safety as key motivations for walking.Specific factors like traffic lights, pedestrian crossings, and sports facilities have been found to impact walking and cycling behaviors in children (Timperio et al., 2004). Studies focusing on university students, such as those by Lu et al. (2017), have examined how the campus environment characteristics influence walking behavior. Variations in density, walking distance, and land use have been noted between utilitarian and recreational walking, with the social environment, safety, and individual factors like health and motivation playing significant roles (Lee and Dean, 2018). Additionally, Borst et al. (2008) highlighted that the cleanliness of streets, their aesthetic appeal, and the availability of activities contribute to the perceived attractiveness of street walking among older adults. These studies collectively underscore the multifaceted nature of factors influencing walking behavior across different demographic groups and contexts.

Barriers to walking have been classified into three main categories: (i) opportunity barriers, such as the lack of recreational facilities and limited diversity of destinations within walking distance; (ii) access/distance barriers, including low accessibility to walking and recreational facilities; and (iii) safety barriers, which involve concerns about crime, traffic crashes, or personal injury related to the built environment (Wang et al., 2016). These barriers vary depending on the type of walking (utilitarian or recreational) and individual socio-demographic characteristics such as age, gender, and auto-ownership (Clack and Scott, 2016). Females, senior citizens, and individuals with a higher body mass index tend to report the highest number of walking barriers, whereas young adults, parents, and those with a driver’s license or a bus pass report fewer barriers.

Among these, time constraints and safety concerns emerge as particularly significant for specific subgroups (Wang et al., 2016). In particular, increased physical limitations can intensify safety-related concerns, especially among women, further restricting their walking mobility due to heightened perceptions of personal risk (Schmucki, 2012; Pollard and Wagnild, 2017). Additionally, context-specific factors can create localized barriers; for example, a recent study from Türkiye reported that the presence of stray dogs in the urban areas of Mardin posed safety concerns for schoolchildren, highlighting the role of region-specific challenges and the need for effective animal population control policies (Karadas and Dag, 2025).

Recent advancements in walkability research have introduced sensor-based and machine learning methodologies that offer more dynamic and individualised assessments of walking environments. Nirjhar et al. (2023) demonstrated the potential of wearable physiological and accelerometry sensors to detect pedestrians' in-the-moment responses to the built environment, using machine learning to estimate perceived walkability with improved accuracy over traditional measures. Similarly, Kim (2020) applied inertial measurement units (IMUs) on elderly participants to quantify gait stability across different walking environments using the MaxLE metric, enabling a continuous diagnostic perspective on walkability. Ng et al. (2022) further enhanced the objective evaluation through a gait-based classification system using accelerometers and support vector machines, effectively identifying irregular sidewalk conditions. Beyond wearable technology, Yang et al. (2024) offered a comprehensive overview of how big data and machine learning have reshaped walkability research, identifying applications in street classification, behavioral modelling, and generative urban design. These emerging approaches highlight a shift towards personalised, data-rich, and scalable methodologies that complement traditional audit and survey techniques.

Walkability on University Campuses

Given that university campuses are often self-contained environments with a diverse pedestrian population, walkability studies in campus settings provide unique insights. A growing body of research has examined how built environment features affect student mobility, health, and perceptions of walkability. Studies such as Keat et al. (2016) and Harun et al. (2020) highlighted the gap between policy and user experience. Despite traffic calming measures, students at the Universiti Malaya reported poor perceptions of walkability due to limited user-friendly elements and a lack of shading or street connectivity. A factor analysis was conducted to extract four key walkability dimensions, comfort, connectivity, safety, and accessibility, emphasising their role in shaping both movement and social interaction (Harun et al., 2020). In another study, smartphone usage altered students' walking perceptions: smartphone walkers prioritised route safety and surface quality, while others favoured directness and aesthetic experiences (Lee et al., 2020). Ramakreshnan et al. (2020) identified street connectivity, pedestrian infrastructure, and land-use proximity as dominant built environment factors in Malaysia, influenced by students' income and daily walking habits.

Other works have assessed walkability as a support mechanism for physical activity (King et al., 2020; Zhang et al., 2024), with studies reporting that more than 85% of surveyed students perceived the campus design to encourage active movement. Labin (2024) introduced walkability typologies (convenient, tolerable, weary) based on infrastructure and services, while Liao et al. (2022) and Liao and Zhu (2025) explored how positive walking experiences relate to perceived walkability and mental well-being, underlining the mediating role of walking attitudes.

In diverse global contexts, such as Iraq (Raswol, 2020), Jordan (Yakhlef and Tarawneh, 2025), China (Zhang et al., 2020), and Spain (Lizarraga et al., 2022), researchers have investigated how infrastructure deficits, safety concerns, layout complexity, and environmental quality shape walking preferences on campus. These studies point to recurring themes: the importance of pedestrian infrastructure, safety from vehicles, environmental comfort (e.g. shading, seating), and inclusive design. Recent findings from Ramlee et al. (2024) at the Universiti Malaysia Kelantan further emphasise that student walking decisions are heavily influenced by safety, cyclist infrastructure, and access to amenities.

In summary, these campus-based studies reveal that campus walkability is shaped by an interplay of objective (infrastructure, design) and subjective (perception, behavioural) factors, which must be carefully considered to promote sustainable, inclusive, and healthy mobility in higher education environments. They highlight how even within confined and planned environments like university campuses, walkability cannot be assumed; it must be continuously evaluated, maintained, and improved. Importantly, they validate the need for inclusive and context-sensitive methods, such as the Walkability Evaluation Paths (WEPs) proposed in this study, to capture the nuanced and often overlooked barriers experienced by different user groups.

METHODOLOGY

This study focused on detecting and visualizing walking barriers regarding walking decisions, collected via a semi-structured interview with open-ended questions (see Supp. Figure 1). First, responses to the interview questions were digitized and indexed according to the predefined Walkability Factor Catalogue (WFC), which was later used to form paths for each response of each participant. Finally, the combination of all the paths from all the responses was mapped together to create Walkability Factor Relation Maps in GIS. The details of the major steps are discussed in the following sections.

Walkability Evaluation Interview

Traditional pedestrian volume surveys or pedestrian route analyses do not reveal much about the factors affecting walking in a region. To develop a comprehensive and effective walkability survey, it is necessary to capture the variety and intercorrelation of factors influencing walkability. This requires obtaining users' opinions through open-ended questions specific to the walking mode and environment in the study region. Thus, a face-to-face semi-structured interview was designed as a preliminary step for a future survey. The interview, approved by the METU Research Ethics Committee (the reference number of 2017-FEN-002 by 08/02/2017), was conducted with 50 randomly selected participants, including 30 students and 20 academic and administrative personnel. Participants agreed to have their responses recorded, which were transcribed verbatim to identify various parameters. Interviews continued until no new walkability-related factors or perspectives emerged, indicating that the saturation point had been reached. This approach ensured that the key dimensions of walking behaviour and barriers were captured without unnecessarily expanding the sample. While the composition did not include all user types (e.g. visitors, individuals with disabilities, or non-university employees), the intent of this phase was to explore the diversity of responses and guide the development of a future survey.

The interview included questions regarding:

a) socio-demographic information (i.e., age, gender, income, education, automobile ownership),

b) walking behavior and walkability preferences.

The interviews conducted at the METU study included the following walkability-related questions seeking information regarding the walking behavior of the participants on campus as well as at off-campus locations:

Q1-Q5: Situations and conditions that affect general walking patterns and decisions/Preference of walking with a group versus alone and the reasons/ Most frequently walked origin-destinations and preferred routes/Factors affecting walking route choice/Factors affecting walking decision; positive/ negative factors affecting walking behavior.

Q6-Q9: Routes not preferred on the campus and the reasons/ Evaluation of the Alley (infrastructure, network and aesthetics)/Evaluation of campus safety (while walking)/Overall evaluation of campus walking infrastructure (walkways, stairs, crosswalks, etc.)

Q10-Q11: Recommendations for a safer/more comfortable walking and traffic environment on campus.

Walkability Factor Catalogue (WFC) Creation

Expressing walkability factors can vary among travelers, yet it is crucial to establish a reserved catalogue index words to represent the main issues mathematically. This necessitates compiling the primary concerns identified in the walkability literature first. For this purpose, all parameters and categorizations used in walkability and pedestrian LOS literature were examined and summarized as a table (Karatas and Tuydes-Yaman, 2018). Accordingly, the walkability framework was created using five major categories including i) Traffic, ii) Safety/Comfort, iii) Land Use, iv) Infrastructure and v) User/Trip. In this study, the existing literature was further reviewed to select key topics for creating main subcategories, forming the initial draft of the WFC. An expanded and comprehensive catalogue was prepared by adding to the general framework with possible subcategories obtained from the literature by adding the factors obtained from the open-ended interview questions culminating in its final form depicted in Supp. Figure 2. However, in order for this catalog system to be visualized digitally and interpreted numerically, each factor must be digitized, taking into account the category and subcategory included. Since it was desired to preserve information at three levels for each factor, categories were coded starting with hundreds and going downwards. For example, under the Traffic category (indexed as 100s), factors were grouped under the Pedestrian Traffic (10) subcategory which included the individual factor of low pedestrian volume (1) which would have a WFC value of (111).

The literature review found overlaps between factors typically associated with Land Use (300s) and Infrastructure (400s). To ensure unique indexing in the proposed WFC system, physical features (e.g., width, surface materials) were classified under Infrastructure, while general concepts (e.g., density, network familiarity, aesthetics) were classified under Land Use. To address local walkability aspects specific to METU Campus, a Campus Regions subcategory (390) was created within Land Use, including factors like The Alley (395), remote campus locations (398), and the Campus Core (396). Additionally, within the Safety/Comfort category (200), stray dogs (235) was separately catalogued, as this is a commonly mentioned factor discouraging walking on campus..

Walkability Evaluation Path (WEP) Creation

As seen in the WFC (Supp. Fig 2), factors were coded with numerical values without specifying them as positive or negative. In its simplest form, a path is created by writing the numerical values of the factors in the sentences that the participants form about a certain subject from their answers to any question, in order. However, the actual effect of a factor was determined by its mention in a positive or negative statement. These statements were mathematically coded into four types within the interview: i) barrier paths (S10), ii) recommendation paths (S20), iii) preference paths (positive (S30) and negative (S31)), and iv) no-judgement comment paths (S0). (Note: This study focused on evaluating statements about barriers to walking (S10). While recommendations, preferences, and general comments were not analyzed, the same approach can be used if needed. If multiple statements were given in response, each was indexed separately according to the set rules summarized below:

For each participant i and interview question j, check if there is a response R_i^j,

Step 1: Using the WFC, index the factors referred to in the response.

Step 2: For each statement that has at least one factor, create an evaluation path *k*,

Action 1: Start with the statement type $S_i^{j,k}$ from the options of (S0, S10, S20, S30, S31)

Action 2: Form an ordered list of factors raised in the response $\{N_0^{i,j}; N_1^{i,j} .. N_m^{i,j}\}$,

Action 3: Create a WEP in the form of $\{S_k^{i,j}; N_0^{i,j}; N_1^{i,j}; N_2^{i,j}; \ldots N_m^{i,j}\}$.

Special Case 1 (Segmentation): If a participant makes a joint statement about two factors combined with or/and in the sentence, the combined statement should be divided into two simple ones represented by individual WEPs accordingly.

Special Case 2 (Augmentation): If a participant makes a general comment first and then complements it with a special case, a general WEP is created first, then repeated to include the special case as well.

To evaluate the methodology in its simplest form, the sentence I do not walk in The Alley, because the stairs are broken. was selected. By determining the codes of the factors in the sentence, it was converted to I do not walk in The Alley (395), because the stairs (484) are broken (451).. However, since there is no information at this stage for what purpose the factors are mentioned, the statement type is assigned by adding the code (S10)-barriers path according to Action 1 to the beginning of the sentence. Textual expressions are completely eliminated and numeric codes are stored as WEP in the form {S10:395;484;451}. The coded response as R1-WEP1 is later depicted in Figure 1. Similarly, when three participants provided the following responses to the question of walkability on The Alley (Q8):

$R_1^{1,8}$: I do not walk in The Alley, because the stairs are broken.

$R_2^{2,8}$: I do not walk in The Alley in hot weather or snow.

$R_3^{3,8}$: I do not walk in The Alley, especially in hot weather.

These responses were first indexed and later coded to create the WEPs as follows (see Figure 1):

Step 1: Indexing

$R_1^{1,8}$: I do not walk (S10) in The Alley (395), because the stairs (484) are broken (451).

$R_2^{2,8}$: I do not walk (S10) in The Alley (395) in hot weather (241) or snow (243).

$R_3^{3,8}$: I do not walk (S10) in The Alley (395), especially in hot weather (241).

Step 2: WEP Creation

$R_1^{1,8}$: I do not walk in The Alley, because the stairs are broken.

→ $WEP_1^{1,8,1}$: {S10:395;484;451}

$R_2^{2,8}$: I do not walk in The Alley in hot weather or snow. (Segmented)

I do not walk in The Alley in hot weather. → $WEP_2^{2,8,1}$: {S10:395;241}

I do not walk in The Alley in snow. → $WEP_2^{2,8,2}$: {S10:395;243}

$R_3^{3,8}$: I do not walk in The Alley, especially in hot weather. (Augmented)

I do not walk in The Alley. → $WEP_3^{3,8,1}$: {S10:395}

I do not walk in the Alley in hot weather. → $WEP_3^{3,8,2}$: {S10:395;241}

It is also helpful to monitor the first factor node in a WEP as the path generator node, such as (395) in the example below, which is mostly the main factor described with more details or interactions with other factors in the remaining part of the path.

In this simple and flexible approach, it is possible to represent the combination of any factors describing walkability evaluation. For a question regarding route choice preferences, it is possible to get infrastructural factors stated as barriers, or responses to the evaluation of walkway infrastructure may include WEPs connecting safety/comfort factors. For the three example responses above, it is possible to create three individual networks, but the final network showing all 5 WEPs can show 5 statements of barrier (S10) for walking in The Alley due to: i) broken stairs (484-451), ii) hot weather (241), and iii) winter/snow (243). Furthermore, the emphasis on hot weather can be seen in the link value of 2 between (395; 241) (Figure 1). Thus, the overlapping of all the WEPs on the WFC network leads to the detection of stronger factor relations.

Mapping Walkability Factor Relations in the GIS Environment

Instead of mapping each WEP individually for every participant, it is more meaningful to assign them to the conceptual WFC network using a graph theory analogy similar to vehicle traffic assignment. A Python-based code was used for this purpose: links connected to factors (nodes) in a WEP were treated as routes taken by a vehicle. Assigning all WEPs

Figure 1. Conceptual representation of WEP mapping created from three participant responses to the `barriers (S10) for walking in Te Alley.

to the network generates link flows (factor-to-factor relation frequencies), representing the total number of WEPs passing through any two factors. WEPs of a statement group are assigned separately, creating factor association matrices (M) where the frequency of consecutive occurrence of two factors, i and j, is recorded in the Mij entry. Row sums of an M matrix indicate the number of WEPs originating from selected factors, while column sums show WEPs leading to those factors. The M matrices are not necessarily symmetric, as walking evaluations may be directional, such as linking physical barriers to safety/comfort more often than the reverse. Visualizing WEPs and the resulting factor relation frequencies is crucial for developing future walkability surveys and policies. This analysis helps to understand the complexity of factor relations and identify strong patterns in WEPs. However, it does not fully support creating comparison maps (e.g., walkability factors of males versus females) since random mapping features may produce different networks even for the same factor association matrix, M, in other trials.

Visualization of the WFC in the GIS environment can be done as an imaginary network of factor nodes laid out randomly in the subcategory regions of the selected five category zones. While the main category zones are colored separately (Traffic-100: green, safety/comfort-200: red, Land use -300: blue, infrastructure- 400: orange, and user/trip characteristics-500: purple), subcategories (i.e. 110 for pedestrian traffic, 130 for vehicular traffic, 210 for perceived comfort etc.) are shown as smaller polygons in which the related factors are represented with nodes. This thematic display of categories and subcategories facilitates the depiction of the complex WEPs that crosses over multiple categories. Fixing the network topology for various WEP maps strengthened the visualization of the complex WEP structures and differences across participant groups or statement types.

Study Area for Walking Evaluation

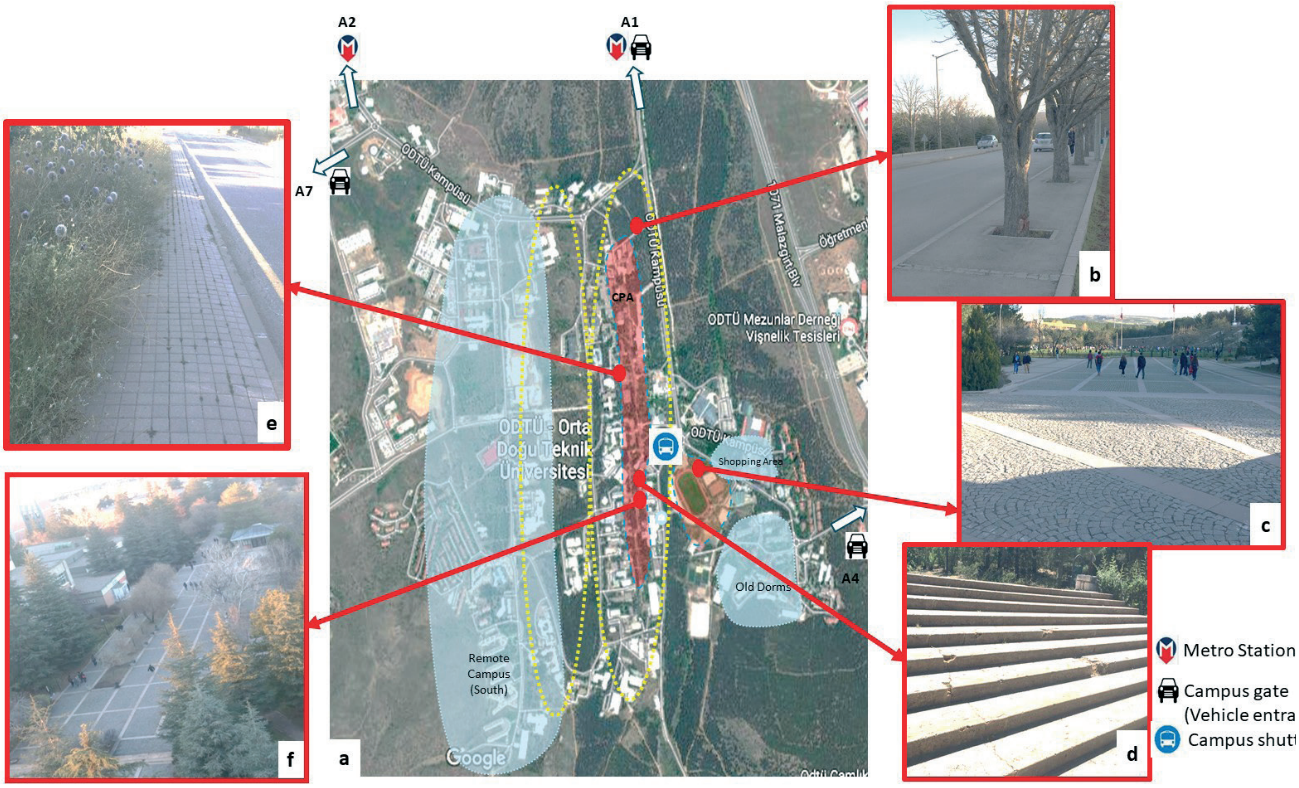
The METU Campus is located approximately 7 km from the city center of Ankara, Turkey. The campus spans an area of 4,500 hectares, including 3,043 hectares of forest and around 400 hectares allocated for academic buildings, residential facilities, and social infrastructure. This extensive and ecologically integrated layout creates both opportunities and challenges for pedestrian mobility across the campus. The primary entrance gates (A1 and A2) are situated along the Eskişehir Highway and are directly connected to the city's metro system via two metro stations, ODTÜ Metro Station

(A1 Gate) and Bilkent Metro Station (A2 Gate), providing convenient and sustainable access to the campus. In addition to the metro, the campus is served by municipal EGO (public) buses, private buses, minibuses (dolmuş), and taxis (METU, 2024).

As of 2024, METU accommodates a student population of approximately 23,395, alongside 1,802 academic staff and 2,337 administrative personnel. The campus also hosts over 8,000 daily users, with dormitories offering 7,691 beds across 2,859 rooms (METU, 2025). Originally designed for compactness and walkability, the campus is organized around a central pedestrian alley known as The Alley, which connects major academic units, administrative buildings, and social spaces (Figure 2). This pedestrian deck is largely free from motorised traffic and was intended to promote walking as the primary mode of movement. However, recent expansions into the southern and western parts of the campus have posed new challenges for walkability. These areas are characterised by lower connectivity, longer travel distances, and fewer social or commercial facilities.

In previous studies on pedestrian flow and comfort levels at 83 campus locations (Tuydes-Yaman et al., 2015; Karataş and Tuydes-Yaman, 2016), the results showed that although The Alley has a high infrastructural capacity, its usability is restricted by design features such as trees planted in the middle of walkways, which limit the effective sidewalk width. A qualitative study by Froughisaeid (2018) revealed that students residing in the western dormitories often feel isolated and unsafe, particularly in areas with poor lighting and insufficient signage. Several shortcuts, especially those connecting the west dorms to central departments, were identified as locations with reduced surveillance and limited pedestrian infrastructure. These studies emphasize critical variations in walkability perceptions and physical conditions across different parts of the campus.

Figure 2. a) METU campus layout, b) sidewalk with tree obstruction, c) walkway around the stadium, d) broken stairs serving the first academic loop, e) sidewalk with weeds, and f) The Alley.



RESULTS AND DISCUSSION

Participant Profile

A socio-demographic analysis of participant profiles revealed a balanced distribution across gender and income levels, as shown in Table 1. Females made up 46% of the sample, while males comprised 54%. Reflecting the campus population, 60% of interviewees were students, with the remainder being academic and administrative personnel. Income distribution was as expected: 33.3% of students reported incomes between $143 and $285, while 30% earned less than $143. Over 60% of personnel reported monthly incomes exceeding $714. This ensured diverse income representation in the analysis of results. In terms of age, the majority of participants were between 18 and 24 years old, which corresponds with the high share of students in the sample. Educational attainment also reflected this demographic profile: most participants had completed high school, consistent with their current student status. Among the participants, six held bachelor's degrees, six held master's degrees, and thirteen had completed doctoral studies.

Walkability Evaluation Results

The WEP generation algorithm described above produced 243 paths, including augmentation and segmentation cases (Table 2) with barrier descriptions. To examine the factors in the barrier paths, the detailed table

	Total	**Male**	**Female**	**Student**	**Personnel**
Total	**50**	**23**	**27**	**30**	**20**
Campus User Status					
Student	30	14	11	-	-
Personnel (Aca. &Admin.)	20	9	16	-	-
Having Driving License (Yes)	**39**	20	19	21	18
Car ownership in the household (Yes)	**28**	14	14	16	12
Income ($)					
0-143	9	6	3	9	0
143-285	12	5	7	10	2
285-500	10	5	5	5	5
500-714	5	1	4	4	1
714+	14	6	8	2	12
Age					
18-24	21	9	12	20	1
25-29	11	6	5	10	1
30-35	7	2	5	7	0
36-49	5	3	2	5	0
50+	6	3	3	6	0
Education Level					
Primary School	1	0	1	0	1
High School	24	14	10	20	4
Bachelors'	6	0	6	3	3
Masters'	6	4	2	5	1
Doctorate	13	5	8	0	13

Table 1. Participant profile

was divided into two parts: the frequency of the factor as a path generator/starter (Table 2a) and the frequency of a factor regardless of order (Table 2b), along with frequency distributions according to participant profiles. Female participants accounted for 140 of the total paths, and students accounted for 145 WEPs, indicating more activity and/or criticism from these groups.

Within the 243 barrier paths, 28 were generated by The Alley, with remote campus locations (391) and stray dogs (235) also identified as starting factors explaining local walkability aspects of the METU campus. Sidewalks (482), a common walking infrastructure factor mentioned in the literature, were also significant WEP generators. The top five factors as major WEP generators were consistently repeated across gender and status. Notably, walkway slope was not specified by any male participant, and handicapped users were not specified by any female participant as WEP generators (**Table 2a**). Similarly, the A4 gate region was not specified as a WEP generator by any personnel.

The frequencies of all factors cited in a WEP, regardless of order, are summarized in Table 2b, including statement frequencies according to participant profiles. The four most frequently mentioned barriers were primarily cited by females and students. The stray dog problem was the top factor (f=56), mainly raised by students (*f*=38) and females (*f*=31). Stone surface material was another common barrier (f=36), mostly mentioned by students (*f*=21) and females (*f*=22). Sidewalk issues were frequently noted by participants in a more balanced manner (*f*=43).

Factors such as remote campus regions, fear, walkway slope, A1 gate region, and rainy weather were more frequently mentioned by female and student participants. Sidewalk width and handicapped users were mostly expressed by males, while fall season and female walkers were mostly cited by females. Additionally, sidewalk width, nighttime trips, trip season, animal attacks, ice on the surface, and health problems were predominantly mentioned by students.

The interrelation between categories for successive factors in all WEP sequences (similar to an origin-destination algorithm) is summarized in Table 3. The highest frequencies of links were observed among factors within the Infrastructure category (400s) with 124 links, and the Safety/Comfort category (200s) with 74 links. Despite this, factors in the Traffic (100s), Land Use (300s), and User/Trip (500s) categories showed more inter-dimensional relations, especially with Infrastructure and Safety/Comfort, highlighting the dominance of these two categories.

Visual Evaluation of Barriers to Walk

The generated 243 barrier paths were visualized in the GIS environment (Figure 3a) according to the Factor Association Matrix (M). The complexity of the map indicates various mechanisms discouraging walking: thicker links mostly emanating from the S10 node (center node for barrier paths) and reaching factors in the Land Use and Infrastructure categories suggest attributes negatively affecting walking decisions. To ignore minor associations, which may arise from personal differences or precise factor descriptions within subcategories, the following approaches can be taken:

a) Re-define the WEP relations in an aggregated WFC network where only subcategory nodes represent all factors within them (e.g., 210 representing all factors 210-219) as shown in Figure 3b.

a) **Number of Paths According to Major WEP Generators (StartNode_Factor)**

Code	Factor Name	Total	Male	Female	Student	Personnel
Total		**243**	**103**	**140**	**145**	**98**
395	Alley Region	**28**	10	**18**	**16**	12
235	Stray Dog	**22**	8	**14**	**13**	9
482	Sidewalk	**18**	7	**11**	7	**11**
391	Remote Campus	**14**	6	8	**12**	2
415	Surf. Material-Stone	**12**	7	5	**8**	4
551	Night-time Trips	8	4	4	5	3
518	Work Attire Walk	7	5	2	4	3
397	A4 Gate Region	5	3	2	**5**	0
463	Walkway Slope	5	0	**5**	3	2
542	Handicapped	5	**5**	0	2	3
---	Others*	**119**	**48**	**71**	**70**	**49**

b) **Number of Occurrence in Barrier Paths**

Code	Factor Name	Total	Male	Female	Student	Personnel
Total		**819**	**389**	**430**	**513**	**306**
235	Stray Dog	**56**	**25**	**31**	**38**	**18**
482	Sidewalk	**43**	**21**	**22**	**23**	**20**
415	Surf. Material-Stone	**36**	**14**	**22**	**21**	**15**
395	Alley Region	**32**	**12**	**20**	**19**	**13**
461	Sidewalk Width	**25**	**17**	8	**19**	6
391	Remote Campus	**24**	9	**15**	**18**	6
243	Winter/Snow	**18**	9	9	9	9
450	Maintenance Problems	**16**	8	8	7	9
551	Night-time Trips	**16**	7	9	**12**	4
212	Scared	**15**	5	**10**	**10**	5
463	Walkway Slope	**15**	4	**11**	**12**	3
553	Trip Season	**14**	7	7	**11**	3
135	PT Vehicles	**13**	6	7	8	5
292	Fall	**13**	3	**10**	8	5
237	Security Concern	**11**	4	**7**	4	**7**
393	A1 Gate Region	**11**	4	**7**	**9**	2
484	Stairs	**11**	**7**	4	5	6
518	Work attire walk	**11**	6	5	6	5
542	Handicapped	**11**	**10**	1	6	5
242	Rain	**10**	3	**7**	**7**	3
294	Animal Attack	**10**	6	4	**8**	2
444	Surface Condition-Ice	**10**	4	6	**7**	3
517	Female walkers	**10**	3	7	6	4
543	Health Problems	**10**	6	4	**9**	1
---	Others*	**378**	189	189	**231**	147

** Others: Work attire walk, Security Concern, Close to motorized traffic, Animal Attack, Shortcuts in the Network, Snow Plowing, Load/Luggage, Erosion Brokenness, Walking Environment-Smell, Hot Weather, Trees on Sidewalks, Walkway Height, Slippery Surface, Ped-vs-Ped Conflict, Walk Alone or as a Group, etc.*

Table 2. Walkability Factor: a) path starting, and b) occurrence frequencies of WEPs.

b) Subdivide the WEPs into smaller groups based on the first node (factor) of the WEPs (e.g., Traffic Category-100 covering all WEPs starting with traffic-related factors while discussing barriers to walk) as shown in Figures 3c-5g.

c) Analyze the WEPs of different participant subgroups (e.g., males versus females and students versus personnel) as shown in Figure 4.

The relation of subcategories is in the same direction with all barrier paths and aggregated version; however, the map became more understandable. Major subcategories of BPs for aggregated map can be listed below;

Category	100s	200s	300s	400s	500s	Total
Traffic (100s)	2	9	3	5	3	22
Safety/Comfort (200s)	3	**74**	17	**29**	**21**	**144**
Land Use (300s)	7	**31**	13	**44**	12	107
Infrastructure (400s)	5	**40**	18	**124**	24	**211**
User/Trip (500s)	7	**32**	6	**24**	**23**	92
Total	24	**186**	57	**226**	83	576

Table 3. Link frequencies of subcategories for: Barrier Paths (S10).

- Vehicle (130) and control (160) under traffic category,
- Perceived comfort (210), safety (230), crashes (290), weather (240) and conflict/exposure (220) under the Safety/Comfort category,
- Campus regions (390), walking network (340) and walking environment (380) under the Land Use category,
- Walkways (410), walkway type (480), surface condition (440), walkway design aspects (460) and maintenance (450) under the Infrastructure category,
- Trip time (550), pedestrian (510), physical condition (540) and trip (520) under the User/Trip Characteristics category.

Major subcategories emerging from the center are easily visible, but further description of barriers created intense coupled relations even if it does not originate from the center some of which can be seen between the main categories. These major coupled relations are as follows;

- Campus regions (390) and walkways (410),
- Walkway design aspects (460) and walkway type (480),
- Safety (230) and crashes (290),
- Pedestrian physical condition (540) and walkway design aspects (460),
- Walkway type (480) and pedestrian physical condition (540),
- Safety (230) and campus regions (390),
- Road furniture/roadside elements (130) and trip characteristics (520),
- Perceived comfort (210) and safety (230),
- Crashes (290) and campus regions (390),
- Campus regions (390) and surface condition (440)

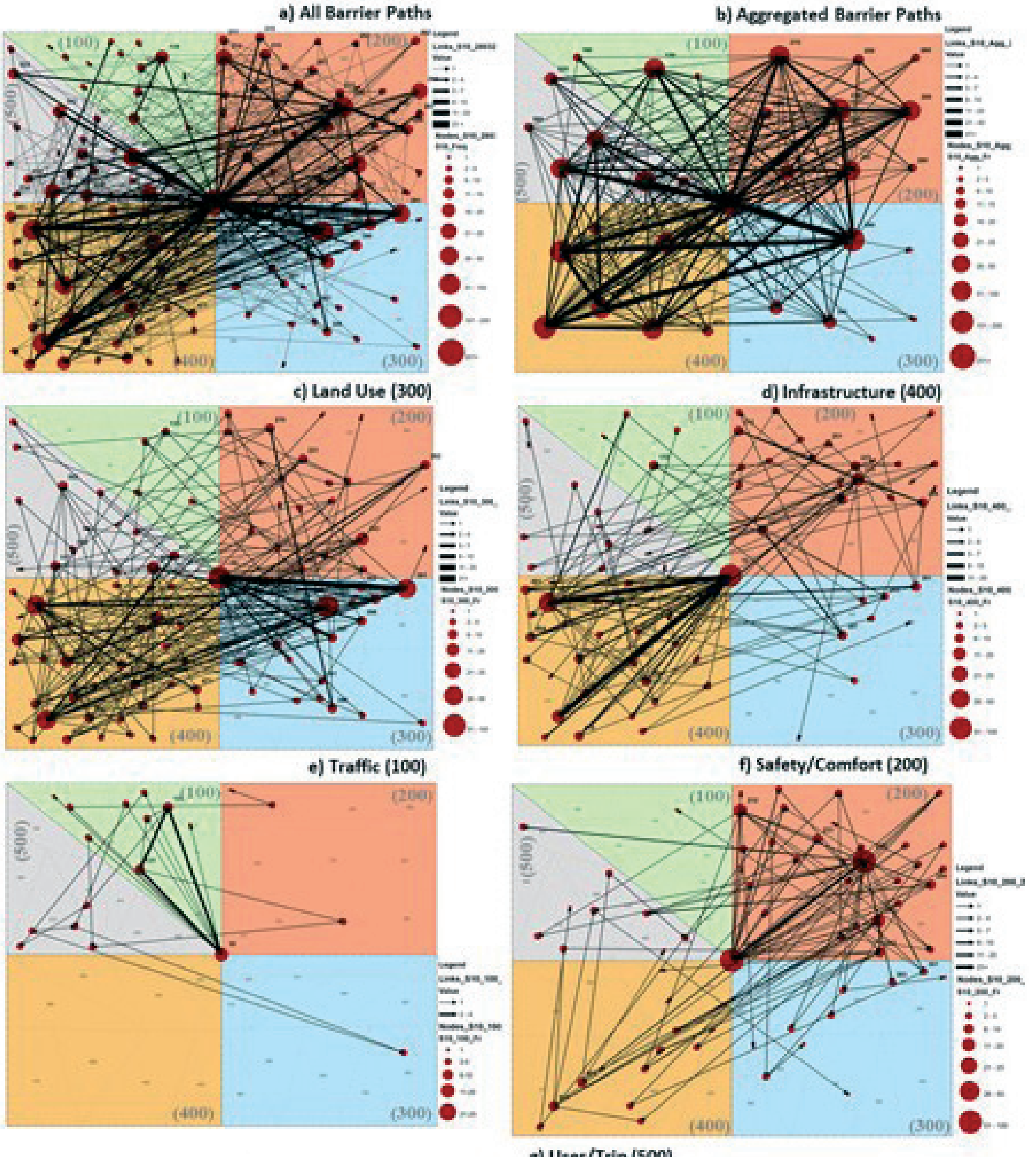
Land Use focused WEPs reveal a complex and more correlated map, which, as noted earlier, may be triggered by vagueness of factor definitions in this category (Figure 3c). Land Use factors are highly correlated with the factors in the infrastructure category. It showed a strong emphasis on specific regions, such as remote campus (391) and Alley (395) regions, which were associated with the stone surface material (415) and all the walkways (482). However, the A4 Gate region (397) was problematic due to the steep slope (463), and the A1 Gate region (393) was discouraging in terms of sidewalk existence (411) and condition (410), as well as vehicular traffic conflict (221). In the Infrastructure-based paths, relations mostly occurred in-category factors followed by the factors under safety/comfort category (Figure 3d). A strong relation was detected between S10 and the sidewalk (482), followed by the stone surface (415). The width (461) represents the narrow sidewalk design problem on the campus, snow plowing (456), especially in stairs (484). Besides, walkway height (462), slope (463) and surface material (418) or being unpaved (446) were repeated frequently.

As the WEPs starting with factors regarding Traffic were very limited and simple in association, barriers mostly related within their own category (vehicle volume-131 and commercial vehicles-135), with some being tied to the factors of User/Trip Characteristics category (Figure 3e). The WEPs started with a factor under Safety/Comfort are mostly related to many factors within their own category, and some of them even associate these factors with the factors of the infrastructure category (Figure 3f). This map shows a very strong emphasis on stray dogs (235) which was mentioned more than 20 times; this was scaring people (212) and creating a fear of attack (294), especially in the remote locations of the campus (391). Besides, selfishness/reckless behavior of other road users (215) and perceived safety problems (231) especially on sidewalks (482), as well as winter- snow (243) created safety concerns due to ice (444) and stairs (484).

The WEPs that start with a User/Trip factor usually show relations in the same category; repeated correlations are seen to stray dog (235) and falling crashes (292) in Safety/Comfort category and sidewalk (482), width (461), stone surface (415) and maintenance (450) in Infrastructure category (Figure 3g). The most frequently repeated barriers for this map are night-time trips (551), time limitation (518), work attire (517), load-carrying situations (530), handicapped people (542), the health status of the pedestrian (543).

While males and females generally highlight similar factors and relations between factors; the frequencies established by females are stronger when compared to males suggesting more similar responses among female participants (Figures 4a and 4b). Both males and females repeatedly stated barriers about the remote campus regions (391), Alley (395), sidewalks (482), walkway widths (461), stone pavement (415) and stray dogs (235). The differences observed between females and males are seen in the coupled factor relations. For example, while males emphasize a strong relation between sidewalks (482) and walkway widths (461) and between perceived safety problems (231) and animal attack (294), females reflect minor relationships. On the other hand, females establish frequently stated coupled factor relations between stone pavement (415) and harassment (295), between stray dogs (235) and night-time trips (551) and between remote campus regions (391) and animal attack (294), which are considered minor for males. These differences may reflect the heightened sensitivity of female participants to personal safety risks, particularly during evening hours or in less populated areas of campus. This highlights the influence of gender-based perceptions and experiences on walking behaviour and the need for planning interventions that are sensitive to such concerns.

When barrier paths for students and personnel are examined, it is seen that personnel are affected by fewer factors than students, and factor relations are also weaker (Figure 4c and 4d). The Alley (395), sidewalks (482), stone pavements (415) and stray dogs (235) are the major factors for both groups, however students also emphasize walkway widths (461), remote campus regions (391), A4 Gate region (397), winter/snow (243), scaredness (212), night-time trips (551), season (553) and handicapped people (542) as major barriers. Personnels reveals a strong coupled factor relation between walkway widths (461) and sidewalks (482) and between scaredness (212) and stray dogs (235), while students reveal strong relations between Alley (395) and stone pavements (415), and between stray dogs (235) and



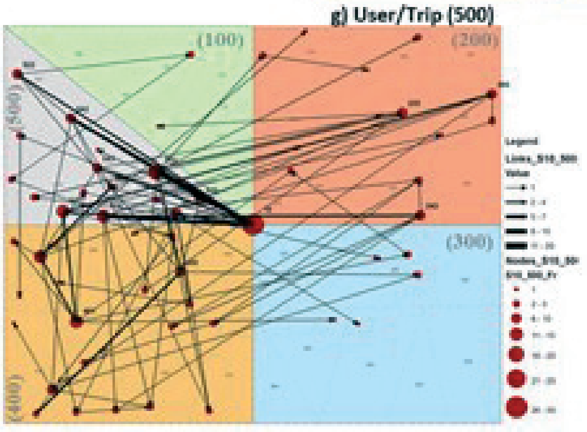


Figure 3. Maps of walking barrier paths a) with all factors, b) aggregated as subcategory level, starting with c) a Land Use factor, d) an Infrastructure factor, e) a Traffic factor, f) a Safety/Comfort factor, and g) a User/Trip related factor.

night-time trips (551) and walkway widths (461) and sidewalks (482) and between stray dogs (235) and animal attack (294). While these differences can be explained by the variability of user characteristics and intensity, the highly stated relation for the fear of stray dogs at night by students, which was not observed in the personnel thematic map, can be explained by the fact that personnel do not walk on campus at night, while many students live in the campus dorms which are mostly accessed by walking. This distinction likely stems from differences in daily routines and spatial exposure: students, particularly those living in dormitories, tend to navigate campus more frequently, at varied hours, and under diverse environmental conditions. Personnel, in contrast, are more likely to be daytime users with more structured routes and limited interaction with peripheral or poorly lit areas. These user-based differences in exposure and experience explain the more extensive and interconnected barrier patterns observed among students and the more concentrated patterns among personnel.

Discussion of the Results

This study focused on identifying and visualizing barriers influencing walkability and their interrelations based on statements from semi-structured walkability interviews. To establish a systematic approach applicable across different locations, a WFC was developed to numerically

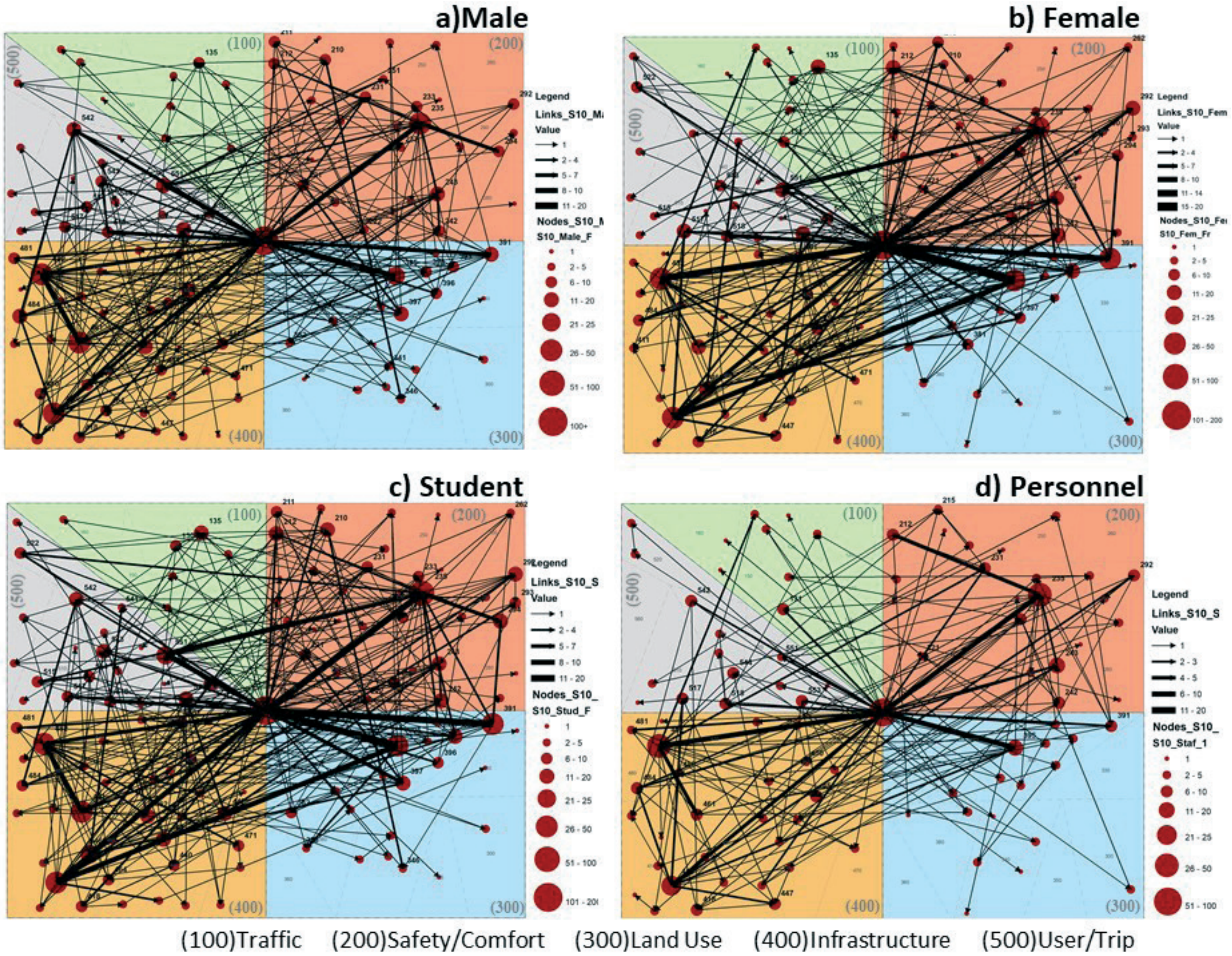


Figure 4. Walking Barrier Path maps for a) Males versus b) Females, c) Students versus d) Personnel.

code responses under five main categories (i. Traffic, ii. Safety/Comfort, iii. Land Use, iv. Infrastructure and v. User/Trip). Statements from 50 participants yielded 243 walkability evaluation paths (WEP) describing factors that create barriers to walking.

Statistical analysis of these paths revealed that the most commonly cited walking barriers were stray dogs, sidewalk width, and winter/snow conditions. Winter weather conditions, particularly snow and ice accumulation on sidewalks and stairs, were frequently mentioned as major barriers, especially in remote or sloped areas. Although weather was identified as a barrier category, further analysis of interview content revealed that walking behaviour also varies across seasons and times of day, particularly in relation to safety and comfort. Participants reported reduced willingness to walk during cold or icy conditions, and some noted that poor maintenance in winter compounded existing infrastructure issues. Additionally, night-time walking was associated with increased safety concerns, especially among female participants and students living in dormitories. These seasonal and temporal patterns suggest that barriers to walking are not static, they are influenced by environmental changes and daily routines.

Beyond commonly addressed issues in walkability literature, such as sidewalk design, maintenance, and weather, several localised factors were identified. Notably, the presence of stray dogs was reported as a major deterrent, particularly in less populated or dimly lit areas. Other behavioural and context-specific barriers, such as carrying heavy bags, wearing attire unsuitable for walking, or accompanying children or pets were also raised. These aspects are often overlooked in conventional planning and engineering frameworks but play a critical role in influencing walking decisions. GIS-based analysis of walking barriers illustrated clear interactions between different factor categories. Dispersion in WEP maps, characterized by numerous low-frequency links, indicated variability among individuals. However, aggregation at subcategory or dimensional levels highlighted more pronounced interactions between land use, infrastructure, and safety/comfort dimensions. Campus regions in the land use category (390s) were notably associated with maintenance in infrastructure (450s) and safety concerns in safety/comfort (230s).

The examination of walking barriers among subgroups, specifically male versus female and student versus personnel revealed further insights into differing walking behaviours. Females and students were more likely to report concerns about safety at night and discomfort in peripheral campus areas, pointing to differences in exposure and vulnerability due to residential status and daily schedules. This highlights the need for group-specific and time-sensitive planning strategies to ensure inclusive walkability improvements across campus.It should also be noted that this study primarily focused on barriers rather than facilitators of walking. While enabling factors were occasionally mentioned in participant responses, they were not systematically analysed. This is acknowledged as a limitation, and future research should explore motivational and environmental factors that encourage walking alongside barriers to provide a more balanced understanding of walkability.

Policy Implications and Practical Strategies

The findings of this study have several policy implications that may inform both campus-level interventions and broader urban mobility strategies.

First, seasonal hazards especially snow and ice require coordinated action between campus facilities and municipal services to ensure timely and prioritised maintenance of high-footfall pedestrian routes. This includes stairs, sloped paths, and dormitory access points. Besides, shade and greenery along walking routes should be prioritised to mitigate summer heat and promote a pleasant walking environment year-round.

Second, perceived safety concerns particularly at night emphasize the need for infrastructure improvements such as expanded lighting, visibility enhancements, and the integration of passive surveillance principles in urban design. These improvements should be targeted in remote and less active zones, identified through participatory mapping or GIS-based barrier visualisations.

Third, the presence of stray dogs and related fear responses reported by many participants calls for a humane and coordinated strategy involving both municipal authorities and campus organisations, aiming to manage populations while ensuring student safety. Fourth, institutional policies should consider creating safer, sheltered, and better-designed walking environments for students and staff who carry loads, walk during adverse weather, or have limited mobility. Improving the motorised access to peripheral locations via shuttle services or integrated public transit can enhance accessibility while supporting walking as a feeder mode.

Finally, by adopting the WFC-WEP approach in walkability evaluations, policymakers can build a clearer understanding of localised needs and user-specific vulnerabilities, creating a stronger foundation for inclusive decision-making aligned with SUMP goals and national mobility strategies. Last but not least, future walkability assessments at METU Campus could benefit from the integration of advanced technologies. The use of drone-based mapping and wearable sensors can support the identification of problematic locations with greater spatial precision and objectivity. When combined with machine learning and image analysis techniques, these tools can assist in the automatic detection of poorly maintained sidewalks, surface hazards, or inadequate lighting. Such approaches complement user-based methods like the WFC-WEP framework and can significantly enhance the richness and accuracy of data used for informed planning and decision-making.

CONCLUSIONS AND FURTHER RECOMMENDATIONS

Assessing walkability and understanding walking preferences poses challenges due to the complexity of decision-making processes influenced by various dimensions. Unlike motorized travel mode choice modeling, which relies on well-defined utility functions like travel time and cost, walking choice is influenced by latent variables such as safety and comfort that are not easily quantifiable. Therefore, identifying factors and their interrelationships is crucial for developing policies that promote walking and sustainable transportation.

This study proposed a novel approach that combines semi-structured interviews with a WFC to identify and visualise perceived barriers to walking. The resulting WEPs enabled a spatial and thematic understanding of walking deterrents through a GIS-based platform. Findings revealed the significance of both widely recognised walkability barriers (e.g., narrow sidewalks, surface conditions, winter maintenance) and localised concerns, such as the presence of stray dogs or discomfort related to attire, weather, or trip characteristics.

The approach demonstrated that walking behaviour and perceived barriers are not static. They vary by user group (e.g., students vs personnel), gender, and contextual factors such as time of day or season. For example, female participants and dormitory-residing students reported higher levels of concern related to night-time safety, icy conditions, and remote campus regions, underscoring the importance of exposure and vulnerability in shaping walking experience. Although facilitators of walking were occasionally mentioned, the study intentionally focused on visualising barriers. This limitation has been acknowledged and presents a valuable direction for future research.

Although this study is grounded in the context of the METU campus, its findings offer insights that resonate with broader global walkability research. Many of the identified barriers (such as winter-related safety risks, limited lighting in peripheral areas, or traffic safety problems) are challenges reported in other campus and urban studies worldwide. The proposed WEP method, supported by a structured and adaptable WFC (under five major categories i. Traffic, ii. Safety/Comfort, iii. Land Use, iv. Infrastructure and v. User/Trip), presents a transferable framework suitable for replication in different geographic and institutional settings. This contributes to international efforts in sustainable mobility, such as Sustainable Urban Mobility Plans (SUMPs), the Global Walkability Index (World Bank), and UN- Habitat's initiatives promoting inclusive and walkable environments.

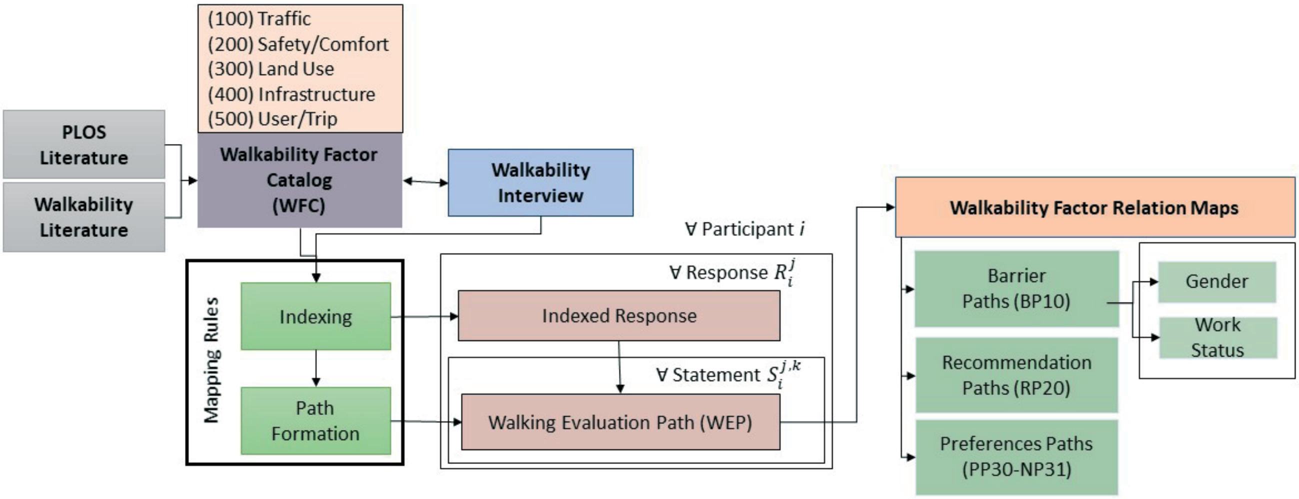
In practice, traditional surveys can assess walkability effectively if they are designed to capture both broad urban form elements (e.g., land use mix, infrastructure design, traffic levels) and context-specific variables (e.g., lighting, snow removal, stray animals). However, designing such surveys requires prior insight into which factors matter most in a given setting. In this regard, the method developed in this study offers a practical and replicable tool for identifying and prioritising walking barriers, and can serve as a preliminary stage for future survey design.

To improve walkability assessments and better understand latent and local influences on walking preferences, the following aspects are recommended:

- Clarify and define survey concepts through visual tools or examples, to ensure participant understanding and consistent interpretation.
- Use pilot interviews or focus groups (including online or automated transcription options) to extract a wide range of responses and map them onto a structured factor catalog.
- Incorporate seasonal and temporal variables in future studies to evaluate how walkability challenges shift across different weather conditions and times of day.
- Address subgroup differences explicitly in walkability evaluations to ensure that gender, age, education, mobility level, and user role (e.g., resident vs commuter) are reflected in policy design.
- Expand the WFC in future applications to include dimensions such as disability access, health status, purpose-specific walking (e.g., exercise, commuting), and psychological comfort.

- Explore parallel applications of this methodology for other sustainable travel modes, such as cycling, e-scooters, or last-mile transit, which share similar complexities in user perception.
- Scale up survey efforts to larger samples and apply decision-making tools such as Analytical Hierarchy Process or multi-criteria decision analysis to prioritise interventions.
- Employing Artificial Intelligence and Natural Language Processing tools in computer-based surveys to automatically categorise and analyse open-ended responses, enhancing scalability and interpretability.

Although the findings and conclusions reached in the study represent the walkability preferences of a small participant group, it was capable of catching factors/dimensions that were linked more often than others; more importantly in a systematic and visualized way, covering a part of the gap in the walkability literature. The finding of this study, would support the development of a more traditional survey regarding those factors, evaluated by more participants, even using quantitative approaches, supporting the reliability of future results. In the context of Sustainable Urban Mobility Plans and local campus planning, the proposed WEP approach provides a flexible, visual, and user-driven tool to inform walkability interventions. While this study focused primarily on visualising walking barriers, the broader framework can be adapted to explore both challenges and opportunities for walking in diverse urban environments.



Supp/ Figure 1: Framework of the Study

Supp. Figure 2: Walkability Factor Catalogue

REFERENCES

ASADI-SHEKARI, Z., MOEINADDINI, M., SHAH, M.Z. (2014) A Pedestrian Level of Service Method for Evaluating and Promoting Walking Facilities on Campus Streets, *Land Use Policy* (38) 175-193.

BLOOMBERG, M.R., BURDEN, A.M. (2006) *New York City Pedestrian Level of Service Study - Phase 1.* New York City Department of City Planning, Transportation Division.

BORST, H.C., MIEDEMA, H.M.E., DE VRIES, S.I., GRAHAM, J.M.A., VAN DONGEN, J.E.F. (2008) Relationships between Street Characteristics and Perceived Attractiveness for Walking Reported by Elderly People, *Journal of Environmental Psychology* 28(4) 353-61.

BRAND, C., DONS, E., ANAYA-BOIG, E., AVILA-PALENCIA, I., CLARK, A., DE NAZELLE, A., GASCON, M., GAUPP-BERGHAUSEN, M., GERIKE, R., GÖTSCHI, T., IACOROSSI, F. (2021) The Climate Change Mitigation Effects of Daily Active Travel in Cities, *Transportation Research Part D: Transport and Environment* (93) 102764.

CHRISTOPOULOU, P., PITSIAVA-LATINOPOULOU, M. (2012) Development of a Model for the Estimation of Pedestrian Level of Service in Greek Urban Areas, *Procedia - Social and Behavioral Sciences* (48) 1691-1701.

CLARK, A.F., SCOTT, D.M. (2016) Barriers to walking: An Investigation of Adults in Hamilton (Ontario, Canada), *International Journal of Environmental Research and Public Health* 13(2) 179.

FRANK, L., SALLIS, J., SAELENS, B., LEARY, L., CAIN, K., CONWAY, T., HESS, P. (2010) The Development of a Walkability Index: Application to the Neighborhood Quality of Life Study, *Journal of Sports Medicine* 44(13) 924-33.

HARUN, N.Z., NASHAR, A., BACHOK, S. (2020) Walkability Factors for a Campus Street, *Planning Malaysia* 18.

HINE, J. (1996) Pedestrian Travel Experiences: Assessing the Impact of Traffic on Behaviour and Perceptions of Safety Using an In-Depth Interview Technique, *Journal of Transport Geography*, 4(3): 179-99.

KARADAS, H., DAG, A. (2025) A Silent Threat to Children's School Road Safety in Türkiye: The Impact of Stray Dog Attacks, Acta Psychologica (256)105037.

KARATAS, P., TUYDES-YAMAN, H. (2016) A Pairwise Comparison of Different Pedestrian Level of Service (PLOS) Ratings [Poster presentation] *Transportation Research Board (TRB) 95th Annual Meeting*, Washington D.C., USA.

KARATAS, P., TUYDES-YAMAN, H. (2018) Variability in Sidewalk Pedestrian Level of Service Measures and Rating, *Journal of Urban Planning and Development* 144(4).

KAUFMAN, A. (2014) Using Natural Language Processing to Support Interview Analysis [Master's Thesis], Friedrich-Alexander University Erlangen-Nürnberg.

KEAT, L. K., YAACOB, N. M., HASHIM, N. R. (2016). Campus Walkability in Malaysian Public Universities: A Case-Study of Universiti Malaya, *Planning Malaysia* (5).

KIM, H. (2020) Wearable Sensor Data-Driven Walkability Assessment for Elderly People, *Sustainability* 12(10) 4041.

KING, S. B., KACZYNSKI, A. T., KNIGHT WILT, J., STOWE, E. W. (2020) Walkability 101: A Multi-Method Assessment of the Walkability at a University Campus, Sage open, 10(2).

KOH, P.P., WONG, Y.D. (2013) Comparing Pedestrians' Needs and Behaviors in Different Land Use Environments, *Journal of Transport Geography* (26) 43-50.

LABIN, A.E. (2024) Enhancing Students' Campus Walkability As a Sustainability Indicator, *Architecture and Engineering* 9(2) 3-16.

LEE, E., DEAN, J. (2018) Perceptions of Walkability and Determinants of Walking Behavior among Urban Seniors in Toronto, Canada, *Journal of Transport and Health* (9) 309-20.

LEE, J., SHEPLEY, M.M. (2020) College Campuses and Student Walkability: Assessing the Impact of Smartphone Use on Student Perception and Evaluation of Urban Campus Routes, *Sustainability* 12(23) 9986.

LIAO, B., XU, Y., LI, X.,LI, J. (2022) Association between Campus Walkability and Affective Walking Experience, and the Mediating Role of Walking Attitude, *International Journal of Environmental Research and Public Health* 19(21) 14519.

LIAO, B., ZHU, J. (2025) Exploring the Causal Relationship between Campus Walkability and Affective Walking Experience: Evidence From 7 Major Tertiary Education Campuses in China, *Journal of Urban Management*.

LIDDY, E.D. (2001) Natural Language Processing, *Encyclopedia of Library and Information Science*, 2nd Ed. Marcel Decker, Inc., New York.

LIZÁRRAGA, C., MARTÍN-BLANCO, C., CASTILLO-PÉREZ, I., CHICA-OLMO, J. (2022) Do University Students' Security Perceptions Influence Their Walking Preferences and Their Walking Activity? A Case Study of Granada (Spain). *Sustainability* 14(3) 1880.

LU, Y., SARKAR, C., YE, Y., XIAO, Y. (2017) Using the Online Walking Journal to Explore the Relationship between Campus Environment and Walking Behavior. *Journal of Transport and Health* (5) 123-32.

NIRJHAR, E.H., KIM, J., WINSLOW, J.F., CHASPARI, T., AHN, C.R. (2023) Sensor-Based Detection of Individual Walkability Perception to Promote Healthy Communities, *Smart Health* (29) 100414.

NG, H.R., SOSSA, I., NAM, Y., YOUN, J.H. (2022) Machine Learning Approach for Automated Detection of Irregular Walking Surfaces for Walkability Assessment with Wearable Sensor, *Sensors* 23(1)193.

ÖZBIL, A. (2013) Modeling Walking Behavior in Cities based on Street Network and Land-Use Characteristics: The case of Istanbul, *METU Journal of the Faculty of Architecture* 30(2), 17-33

PARMAR, M., MATURI, B., MALLIK DUTT, J., PHATE, H. (2018) Sentiment Analysis on Interview Transcripts: An Application of NLP for Quantitative Analysis. *International Conference on Advances in Computing, Communications, and Informatics (ICACCI)*: 1063-8.

POLLARD, T.M., WAGNILD, J.M. (2017) Gender Differences in Walking (for Leisure, Transport and in Total) Across Adult Life: A Systematic Review, *BMC Public Health* (17) 1-11.

RAMAKRESHNAN, L., FONG, C.S., SULAIMAN, N.M., AGHAMOHAMMADI, N. (2020) Motivations and Built Environment Factors Associated With Campus Walkability in the Tropical Settings. *Science of the Total Environment*, (749) 141457.

RAMLEE, N., HAMID, N.H.A., OTHMANI, N. I., MOHAMAD, W.S.N.W., YEO, L.B., MOHAMED, S.A., RAMLEE, M.F. (2024) Encouraging Factors of Walkability Among Students in the Tropical Campus, In *BIO Web of Conferences* (131) 03002. EDP Sciences.

SCHMUCKI B. (2012) If I walked on My Own at Night I Stuck to Well Lit Areas: Gendered Spaces and Urban Transport in 20th Century Britain, *Res Transp Econom* (34) 74-85.

SHATU, F., YIGITCANLAR, T. (2018) Development and Validity of a Virtual Street Walkability Audit Tool for Pedestrian Route Choice Analysis SWATCH, *Journal of Transport Geography* (70) 148-60.

SU, S., ZHOU, H., XU, M., RU, H., WANG, W., WENG, M. (2019) Auditing Street Walkability and Associated Social Inequalities for Planning Implications, *Journal of Transport Geography* (74):62-76.

TALAVERA-GARCIA, R., SORIA-LARA, J.A. (2015) Q-PLOS Developing an Alternative Walking Index: A Method based on Urban Design Quality, *Cities*(45) 7-17.

TAN, D., WANG, W., LU, J., BIAN, Y. (2007) Research on Methods of Assessing Pedestrian Level of Service for Sidewalk, *Journal of Transportation Systems Engineering and Information Technology* 7(5) 74-9.

TIERNEY, P.J. (2012) A Qualitative Analysis Framework Using Natural Language Processing And Graph Theory, *The International Review of Research in Open and Distance Learning* 13(5) 173-89.

TIMPERIO, A., CRAWFORD, D., TELFORD, A., SALMON, J. (2004) Perceptions about the Local Neighborhood and Walking and Cycling among Children, *Preventive Medicine* 38(1) 39-47.

TUYDES-YAMAN, H., KARATAS, P. (2017) Evaluation of Walkability and Pedestrian Level of Service. In: KNOFLACHER, H., OCALIR-AKUNAL, E., eds. *Engineering Tools and Solutions for Sustainable Transportation*

YAKHLEF, M., TARAWNEH, D. (2025) Walkability Assessment for University Campuses in the MENA Region. Case of Applied Science Private University (ASU), Amman, Jordan, *Urban, Planning and Transport Research* 13(1) 2438619.

YANG, J., FRICKER, P., JUNG, A. (2024) From Intangible to Tangible: the Role of Big Data and Machine Learning in Walkability Studies, *Computers, Environment and Urban Systems* (109) 1-20.

ZHANG, Z., FISHER, T., FENG, G. (2020) Assessing the rationality and Walkability of Campus Layouts, *Sustainability* 12(23) 10116.

ZHANG, Z., SUN, T., FISHER, T., WANG, H. (2024). The Relationships between the Campus Built Environment and Walking Activity, *Scientific reports* 14(1) 20330.

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Anahtar Sözcükler: Yürüme; Yürünebilirlik; Engel; Grafiksel temsil; Davranış.

YÜRÜME ENGELLERİNİN GÖRSELLEŞTİRİLMESİ: GÖRÜŞME YANITLARININ YÜRÜNEBİLİRLİK DEĞERLENDİRME PATİKALARINA (WEP) DÖNÜŞTÜRÜLMESİ

Yürüme, sürdürülebilir ulaşım politikaları için hayati öneme sahiptir; ancak yürünebilirliği etkileyen faktörler altyapı, güvenlik ve konfor gibi çok boyutlu unsurları içerdiğinden karmaşık bir yapı sergiler. Bu etkileşimleri anlamak amacıyla, literatür ve görüşme verilerine dayalı kapsamlı bir Yürünebilirlik Faktör Kataloğu (WFC) geliştirilmiştir. Grafik kuramına (çizge teorisi) dayanan bir yaklaşımla, bireylerin zihinlerinde ziyaret edilen faktörleri (düğümler) ve bunlar arasındaki ilişkileri (bağlantılar) içeren hayali bir ağ üzerinde yürüme kararları modellenmiştir. Yarı yapılandırılmış görüşmelerden elde edilen yanıtlar sayısallaştırılmış ve işlenerek her birey için yürünebilirlik değerlendirme yolları (WEP) oluşturulmuştur. Bu yollar, Coğrafi Bilgi Sistemi (CBS) ortamında grafiksel olarak temsil edilmiş ve en önemli yürünebilirlik faktörleri ile bunlar arasındaki ilişkileri gösteren bir yürünebilirlik faktör ilişkisi haritası oluşturulmuştur.

Analizler sonucunda, altyapı sorunları (örneğin merdivenler ve kaldırım genişliği) ile kış koşulları gibi güvenlik/konfor sorunları, başlıca yürüme engelleri olarak öne çıkmıştır. Kış koşullarıyla birleşen bakım eksiklikleri özellikle belirleyici olmuştur. Cinsiyet ve kullanıcı grupları (öğrenciler ve personel) arasında farklılaşan engel ve tercih yapıları gözlemlenmiştir. Bu yenilikçi yaklaşım, disiplinlerarası bir bakış açısıyla karmaşık seyahat karar verme süreçlerini incelemek için basit ve mühendisliğe dönük bir araç geliştirmeyi hedeflemektedir. En önemli katkısı, yürüme engellerinin matematiksel olarak temsil edilmesi ve görselleştirilmesidir; böylece yürümenin artırılmasına yönelik politika ve müdahaleleri desteklemektedir. Esnek yapısı sayesinde, WFC küresel ölçekte de farklı lokasyonlar veya bölgeler için değerlendirme yapılmasına olanak sağlayan ortak bir yöntem sunmaktadır.

VISUALIZATION OF BARRIERS TO WALK: TRANSFORMING INTERVIEW RESPONSES TO WALKABILITY EVALUATION PATHS (WEPS)

Walking is essential for sustainable transportation policies, yet the factors influencing walkability are complex, encompassing dimensions like infrastructure, safety, and comfort. To understand these interactions, a comprehensive Walkability Factor Catalog (WFC) was developed using literature and interview data. A graph theory-based approach modeled walking decisions, connecting factors (nodes) visited in a traveler’s mind and their relationships (links) in an imaginary network. Responses from semi-structured interviews were digitized and processed, creating walkability evaluation paths for each traveler. These paths were graphically represented in a Geographical Information System, forming a walkability factor relation map that highlighted the most important walkability factors and their connections.The analysis identified major walkability barriers, including infrastructure issues like staircases and sidewalk widths, and safety/comfort concerns like winter conditions. Maintenance problems combined with winter conditions were notably significant. Differences in barriers and preferences were observed between genders and between students and personnel. This novel approach aims to develop a simple engineering tool to study the complex travel decision-making process from an interdisciplinary perspective. Its main contribution lies in the mathematical representation and visualization of walking barriers, supporting necessary policies and interventions to increase walking. The flexible nature of the WFC facilitates a common methodology for evaluations in various environments, globally.

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