Kocaeli University

Kocaeli Journal of Science and Engineering

http://dergipark.org.tr/kojose

Towards a New Walking Evaluation Approach: Power of Surveys and Route-based Evaluations in GIS Environment

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Article Info

Research paper

Received : *October 04, 2021*
Accepted : *February 18, 2022*

Keywords

Pedestrian
Campus
Survey
Walking
Walkability
GIS

Abstract

Walking is a critical mode to be encouraged in sustainable urban mobility plans (SUMPs). However, the lack of analysis methodology is making it challenging to detect walkability aspects necessary to develop better policies. Middle East Technical University (METU) Campus was designed with a pedestrian-friendly layout which has been threatened recently by different factors (i.e. enlargement of the campus, changing traffic volumes, etc.). This necessitated further investigation of walking and walkability in the campus, which was the main scope of the most recent survey, designed to investigate a) pedestrian perspective and b) walking limits on campus. While the former was investigated via traditional questions, the latter was sought after via map-based 1844 routes from 623 participating students. Besides the descriptive statistics performed by the responses to the traditional evaluation questions, the route-based data resulted in enriched analyses, proving the power of the latter in evaluating walkability, which has a spatial variation by nature. Consideration of both traditional survey approaches accompanied by the route-based investigations enabled the development of a more comprehensive understanding of walkability of the study area, which should be used in the evaluation of pedestrian mobility in urban pedestrian analysis zones, i.e. city centers, metro station capture zones, campuses, etc.

1. Introduction

Walking is one of the main modes of transport which had an effect on many different areas such as health, sustainability, and planning. Two key concepts, “walking (activity)” and “walkability (quality of walking)”, are required [1]to understand this transportation mode and support it as a part of our sustainable urban development plans. Walkability is identified as “walking- friendly” [2], which is supported by the good-quality walking environment (density, capacity, directness, etc.), identification and comparison of the conditions with different assessment techniques (reviewing, auditing, and rating). More recently, especially within the European Union (EU) region, local governments are encouraged to analyze and promote more sustainable modes (walking, biking) and develop their sustainable urban mobility plans (SUMP), which are in process for Konya and Eskişehir, and being contracted out for other metropolitan cities such as İzmir, Ankara, etc. However, it is critical to developing an evaluation method to assess the current level of walkability as well as walking preferences of the pedestrians to develop policy tools encouraging it further, which requires consideration of both walking network infrastructure as well as pedestrian mobility data, analyzed in an engineering perspective. This paper focuses on assessment of both the traditional survey technique and GIS-based route evaluation option to support development of new pedestrian mobility evaluations in the future.

Within the scope of this study, both the conceptual and route-based walkability assessments were performed to compare the strength and weaknesses of both data collection methods. While the responses to the traditional survey questions enabled the statistical evaluation of sufficiency and the importance of selected walkway

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features, the route-based data provided spatial distribution of the most used walkway segments. Gender differences in walking behavior are sought through both data types. Using the latter, it is possible to evaluate zone/building-based walkability [5]. Finally, a list of recommendations is provided to further improve walkability data collection and evaluation techniques, which may contribute to the further understanding and encouragement of walking not only on METU campus but other campuses and urban regions.

The case study is based on various walking and walkability evaluations performed for the Middle East Technical University (METU) Campus. The campus serves a population of approximately 30,000 people and was originally designed as a "walking-friendly" layout with a Central Pedestrian Alley (CPA) connecting all the academic buildings (old campus buildings) in the academic loop with no motorized traffic exposure (Figure 1). The continuation of the walkway among the recreational and dormitory regions made walking a major mode on the campus, but the expansion of the campus-built area (new campus buildings) over the years overturned this dominancy. Also, despite the existence of two metro stations at the northern border of the campus (at A1 and A2 entrances), the long walking distance (almost 2km to the nearest academic buildings) has been forcing campus users to use motorized modes more. Previous efforts on different pedestrian mobility data collection and estimation of Pedestrian Level of Service (PLOS) [3, 4] were further followed by a detailed survey conducted aiming to evaluate METU campus walking patterns among students, as well as in-campus transportation. In addition to traditional questions evaluating the key walkability factors discussed in the literature, a map-based inquiry regarding walking routes from departments to the most common destinations was included.

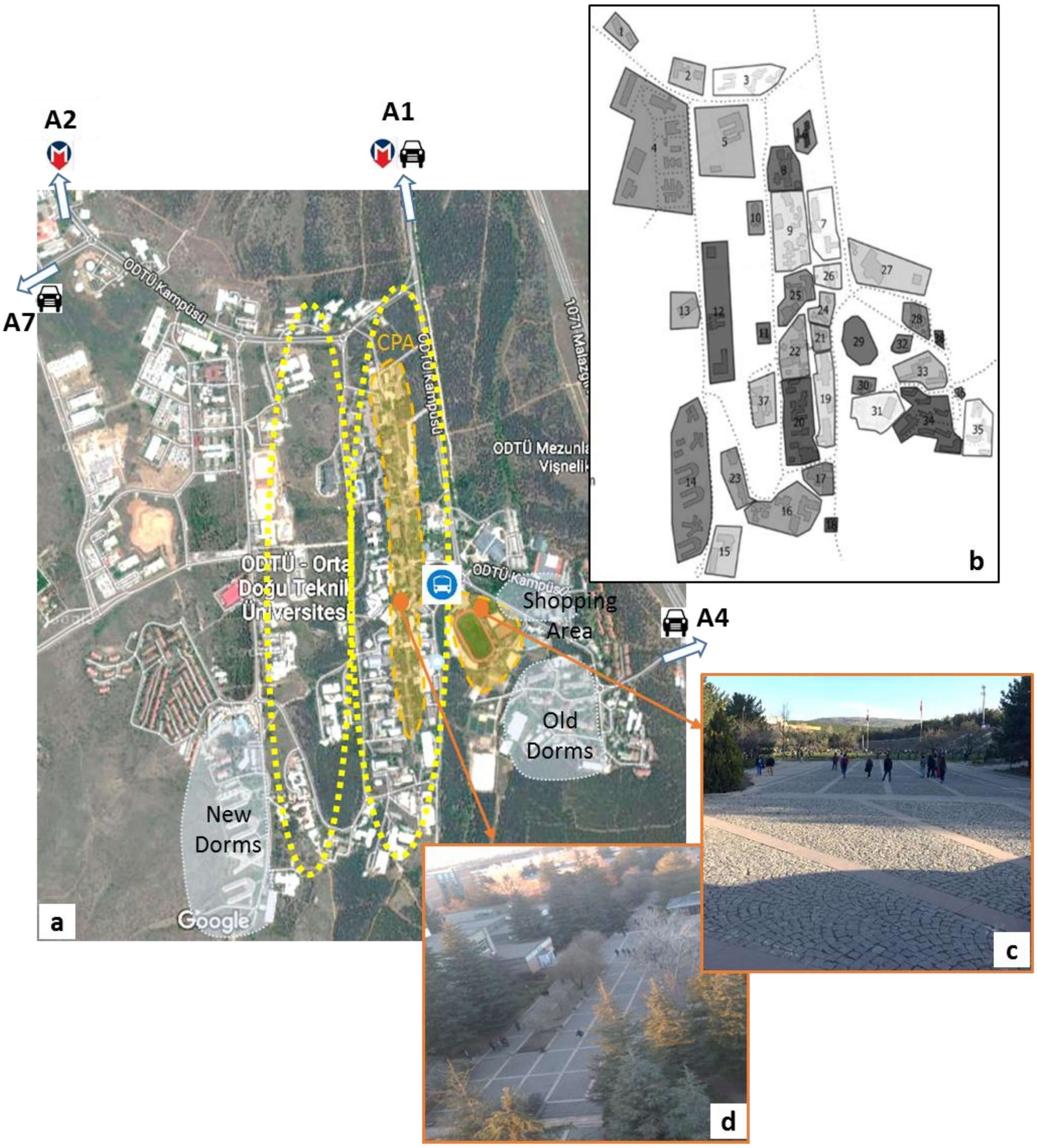

Figure 1. a) METU Campus layout b) Department-based walkability analysis zones c) Walkways around the stadium d) Central Pedestrian Alley serving the first academic loop.

2. Literature Review

The indicators of “pedestrian-friendly design” were investigated, for which three major aspects of walkability were defined as connectivity, quality of road network, proximity, etc [6]. In urban planning, the promotion of sustainable urban neighborhoods was discussed in association with walkability [7]. Results showed that wider walkway width, free barrier walkways, and more shaded walkways could encourage pedestrians to walk. With a planning focus, Blecic et. al. [8] presented the urban design support tool on pedestrian accessibility and walkability of places, which generates urban design, besides the evaluation process. As a recent perspective, Dovey and Pafka [9] focused on the concept of walkability as a combination of three key factors; density, functional mix, and access; but this concept should not be based on actual walking levels. In the study walkability is directly connected to the physical environment and facilities.

Shorter and simpler walkability evaluation tools have also been proposed by different researchers, such as a simple checklist by selecting some local destination points [10]. Scottish Walkability Assessment Tool which is an auditing-based tool, was designed to assess walkability according to functional elements (walking surface and permeability), safety (personal and traffic), aesthetic (streetscape, architecture, views), and destinations (“parking, land use mix, services, public transport, parks”) [11]. Pedestrian Environment Index (PEI) was used to measure pedestrian friendliness in Chicago [12]. In the index available data for planners was used combining four components: i) land-use diversity, ii) population density, iii) commercial density, and iv) intersection density. The methodology investigated the areas for each sub-traffic analysis zone and component at a level and produced a comparative evaluation between zones. A comprehensive index for path walkability assessment (PWA) was developed based on pedestrian decision-tree-making (DTM) with 92 variables under 3 layers [13]. Model converts qualitative data to a walk score for shopping and retail walking in Taman University, but applicable to any region in the world. Synthetic Index of Walkability of public spaces (ISWAT) proposed a multi-criteria analysis and space syntax technique to determine walkability for different purposes [14]. The model determines scores for each indicator for 4 main categories (quality, movement potential, presence of anchor places, and distance from services and amenities) and summed up a value of ISWAT, which defines the walkability rating according to pre-defined intervals. A recent study combined street design measurement with thermal comfort under The Street Walkability and Thermal Comfort Index (SWTCI), combining a questionnaire survey (measure 21 street design indicators), observations (evaluate pedestrian comfort indicators), and in situ measurements (include weather information) [15]. The method revealed the highest SWTCHI score when thermal perception is neutral, lowest when the thermal sensation is warm. An open-source website, “Walk Score®”, had a patented system that analyzed hundreds of possible walking routes for the given addresses to nearby amenities and awarded points accordingly [16]. While amenities within a 5-minute walk were given maximum points, the point awarding decreases for the distances up to 30-minute walk. Any location that has 50 or fewer points was determined as “car-dependent”. The neighborhood where METU Campus is located was rated as a score of 29 points (car-dependent), while METU campus (mostly the housing units with many catering options) were rated as 80 points (very walkable) and METU library was rated as 86 points (very walkable).

2.1. Walking Behavior Analysis via Surveys

A series of studies in Putrajaya, Malaysia, focused on different aspects of walking behavior and pedestrian perception [17, 18, 19]. Three walking behavior features (speed, direction, and experience) were studied in urban and rural regions, which revealed very small differences. In the follow-up survey, walking times (from home to the nearest community facilities) were asked to pedestrians to understand their perception and among the socio-demographic variables, household income and gender were found to have a small effect. In the evaluation of walking experience from “safety and security” and “convenience and attractiveness” perspectives, important aspects included the street lightenings, street crossing signals, safety during walking in the nighttime, volume of traffic and traffic speed along a nearby street, tree existence, and awning, environment attractiveness/ building articulation, cleanness, street furniture for resting, etc. In Wuhu, China, based on the street characteristics (length, location, and width) and pedestrian behavior characteristics (trip purpose, travel time information, trip frequency, etc.) Liu et. al. [20] suggested improving the quality and increasing the attraction of walking by a combined design (with business activity, landscape, circulation, transit services, and beyond). For a regional coastal Australian city, Humpel et al. [21] conducted a survey focusing on the relation between environmental attributes and different purposes of walking behavior (defined as “general neighborhood walking”, “walking for exercise”, “walking for pleasure” and “walking to get to and from places”). Weather, aesthetics, accessibility, and location were associated with neighborhood walking; safety and accessibility were important in walking for pleasure, while weather and aesthetics were found to be associated with walking for exercise. In the San Francisco Bay Area, a "perception-based composite walkability index" was developed by three different surveys [22]. Among 42 "Path Walkability Indicators" defined (related with curb-to-curb roadways, pedestrian crossings, buffer zones, sidewalks and their facilities, street scale and enclosure, closer buildings, and their properties) 22 of them were used in the final formula. Investigated London Travel Demand Survey (LTDS) and Health Survey for England (HSfE) were applied to get predictors of walking variables with their direct effect on physical activity [23]. Small differences were highlighted in the results between the ethnic groups, age, and car ownership. Effect of street-level greenery investigated in Hong Kong, revealing high relation, and associated with total walking times [24]. In the study two-layer model was developed considering both associations of greenspaces and odds of walking and sensitivity analysis between greenspaces and total walking time. Li et.al. [25] focused on exploring the impact of perceptions and attitudes on walking in the historical neighborhood. Results reveal different perceptions and attitudes according to income, age, and employment status, and had a significant effect on walking frequency. Young, employed, and higher-income people walk less than the others. At Ohio State University a web-based survey was conducted to examine transportation choices of individuals conducted by getting information about mode choice and the factors affecting the choice [26]. In another study by Lee and Shepley [27], the aim was to examine how students evaluate the walking path and route characteristics when they are distracted by using the phone. The study used Analytical Hierarchy Process (AHP) method and results indicated that "Smartphone walkers" found the safety and quality of routes more important, while walkers without phones considered the shortest distance and positive walking experience to be important factors in their route choices.

When the studies investigated in Turkey are evaluated, it was seen that there are several walking behavior related researches conducted in İstanbul, Ankara, İzmir, Adana, Edirne [28 - 34]. In a study conducted in Istanbul [28], it was seen that utilitarian and recreational walking were influenced by perceived neighborhood safety and busy places were stated as a good place for both types of walking. A study conducted in Bursa [33] examined the principal factors affecting walkability by a survey conducted with 200 participants and the results showed that the most important factors were traffic safety, crime security, and connectivity.

A recent study by Rashidi [35] focused on walkability in the METU Campus and uses different methods such as direct observation, archival studies spatial analyses, and surveys with 240 users in different walking paths, etc. The study focused on the safety and security issues regarding the physical features, sense of safety, and traffic safety of the university campus. Among the walking routes, uncomfortable and comfortable ones were detected based on the results of the survey study and it was indicated that female participants feel significantly less safe than male users at night-time walks; they think lighting is not sufficient.

2.2. GIS-based Walking and Walkability Analysis

Starting in the early 1990s, walking access to the transit systems and development measures were investigated with Geographic Information System (GIS) to gain insights into the measurement of the pedestrian access, the effect of the street configuration on the pedestrian access, and whether the walking distance influenced the transit mode choice [36]. There are an increasing number of studies and applications suggesting the use of walkability, especially to develop a walkability index. Pedestrian-environment areas were evaluated in GIS by three visualization and quantification techniques: "street network classification (quality)", "pedestrian catchment areas (proximity)" and "intersection intensity (connectivity)" [37]. In the study, TIGER data was used in the GIS-based Pedestrian Assessment Tool. The relationship between pedestrian access and transit preferences was studied at the district levels based on environmental attributes such as dwelling density, street connectivity, land-use mix, and net retail area and sociodemographic characteristics of pedestrians [38]. Walkability was studied considering proximity and connectivity characteristics with a spatial data set to define a GIS-based "Walkability Index" in Australia [39]. Also, additional the street level audits and participant responses Hajna et al. [40] studied by GIS to derive land use mix, street connectivity, and residential density. As an alternative way, Cubukcu et al. [41] used the GIS method to measure the street level walkability "Walk Score®" for developing countries. Izmir, Turkey was evaluated by this method under 6500 street segments, and calculated the walkability score based on betweenness, centrality - and accessibility scores derived from the street network and land use. More recently, Ellis et al. [42] employed the six connectivity measures ("intersection density", "link-node ratio", "pedestrian route directness", "pedshed", "metric reach" and "directional reach") using the Belfast footpath network, North Ireland. Results reflected that metric reach and intersection density have seemed like the best measures for connectivity.

GIS can also improve the analysis and the visualization of pedestrian activities. For the analysis of the change in walking behavior on a university campus due to the construction of additional 14 buildings, a "walking diary" included walk trip data (start and finish time, route, social content as in walk alone or with a group, and purpose) was conducted with users via a map-based survey [43]. When the data was mapped in the GIS environment and analyzed, results showed significant increases in walking distances. Sun et al. [44] studied the metro stations in Beijing, China to see the influence of the local environmental characteristics on walking behavior by the empirical data. In a survey about the walking trips beyond the metro station, the information on walking time from the station, destination, perceived environmental characteristics as well as objective built environmental measures, were coded in GIS with the walking routes to compare the perceived and measured built environment characteristics. Mean walking time from the stations was found as 8 minutes, and both perceived and measured travel times decreased with greater connectivity.

In a study conducted for Adana, Turkey [31], the level of serviceability of urban emergency shelters within maximum capacity, usability, sufficiency, and a certain walking time limit was evaluated by using spatial analysis techniques of GIS-Network Analyst and methodology was proposed. Another study [34] examined the walkability in terms of urban design principles in 5 cities of Turkey using a hybrid method (fuzzy logic, space syntax analysis, and GIS). The study showed that the spatial design of the Turkish cities mostly provides the needs of motor vehicles rather than pedestrians and the success level of walkability was found as very low.

3. Methodology

METU Campus and Transportation Survey was designed to have information on i) perception of sustainability and sustainable transportation, ii) travel characteristics regarding access to METU and in-campus transportation, and iii) perspectives on traffic safety. The questionnaire had five main sections (see Table 1), starting with socio-demographic data collection (Section A). Walking and walkability were evaluated in Section D, which had both the traditional questions (Part 2) as well as the map-based walking route collection (Part 3). The survey was conducted face-to-face with METU students in two rounds in the Fall and Spring semesters. To estimate building/zone-based walkability on campus, sampling was planned proportional to the departmental student populations aiming 5%-10% rate. Based on the preliminary evaluation, revisions were made in the second round in some parts of the survey, which are discussed in detail below.

Table 1. 1Summary of the Survey Study

Survey Sections	*Round 1*	*Round 2*
A) Socio-demographic information	-Age, gender, income, on-/off-campus residence, registered department at METU, private car ownership, METU parking permit ownership	*-Remained as same-*
B) Perception of "sustainability/ sustainable transportation"	Technical definition, classes taken, related actions, METU Campus perception	---
C) Access to METU campus	*Not Included in this study*	*Not Included in this study*
D) In-campus transportation	**Part 1: Frequently used modes** (frequency and origin-destination) **Part 2:** Assessment of walking conditions on: - sufficiency of walkway infrastructure and walking environment -the importance of proposed infrastructure improvements **Part 3:** Map-based walking routes from departments to stated destinations	**Part 1:** *Remained as same* **Part 2:** Assessment of walking conditions -sufficiency of walkway infrastructure and walking environment **Part 3:** *Remained as same*
Survey Dates	November-December 2014	May 2015
Sample Size	307 participants	316 participants

3.1. Participant Profile and In-Campus Mode Choice

The survey study was conducted in two rounds, which had almost equal sample sizes (see Table 2). Male and females were represented almost equally to be able to study the possible gender effects. Equal distribution among different classes was considered to catch academic schedule differences. Note: Proportionality between the students residing in the city, and the dormitories was maintained according to the campus proportionality (about 1/3 of the total population lives on the campus).

Analysis of the responses to the Part 1 question in Section D, showed that 67.9% of the students preferred walking as their first choice in in-campus trips, followed by in-campus shuttle services preferred by 11.3%. Among the second-best choice, students reported in-campus shuttles (29.6%) and hitchhiking (27.0%) while walking was preferred by 22.5% of the students.

Table 2. Participant Profile for METU Campus and Transportation Survey- Student Perspective

	Round 1 (N=307)			Round 2 (N=316)		
	N	F	(%)	N	F	(%)
Gender						
Male	(307)	153	49.8	(315)	149	47.3
Female		154	50.2		166	52.7
Housing Location						
On-campus	(306)	115	37.5	(315)	120	38.1
Off-campus		191	62.4		195	61.9
Class						
Prep School	(307)	18	5.9	(316)	20	6.3
1st year		45	14.7		39	12.3
2nd year		79	25.7		73	23.2
3rd year		70	22.8		107	33.9
4th year		73	23.8		64	20.3
Graduate		20	6.5		15	4.8

3.2. Student Perception on Sustainable Transportation

The participants were not technically familiar with the concept of sustainability in general and did not take any lessons on the subject. Yet, they commented that the concepts frequently found in the literature (alternative energy sources, transportation, global warming, energy saving, biodiversity, etc.) should be discussed under sustainability. The sustainable transportation was expected to have positive economic, environmental, and social contribution against major problems such as traffic, air pollution, noise, global warming, depletion of natural resources. Bicycle roads, environmentally friendly vehicles, high pedestrian access, ITS, high-quality public transportation were evaluated as very important sustainable transportation options. Evaluating METU Campus according to sustainable transportation vision, they concluded that campus was partially sufficient via in-campus ring services, personnel ring services, paratransit mode, walking areas, and vehicular roads, but, insufficient in terms of bicycle infrastructure and parking lots.

3.3. Traditional Survey Questions regarding Walkability

Part 1 (of Section D) focused on detection of major modes of in-campus transportation; a question was sought after the perspective of students on the sufficiency of walking environment/infrastructure based on selected 9 factors (i.e., quality of pavement, continuity, etc.). The following question required the rating of the importance of the proposed improvements on 20 factors regarding walkway infrastructure and walking environment (i.e., increasing the width of walkways, etc.) from “1 (not important)” to “4 (extremely important)”.

Responses to the sufficiency question included trivial answers; furthermore, a simple choice of “sufficient/insufficient” did not reveal much about students’ perception and some respondents wanted to rate the level of it. Stated levels of importance of certain features only validated the existing literature without contributing much. In the second round, these questions were replaced by a question seeking ratings of the sufficiency of 20 factors.

3.4. Walking Route Data Collection

The map-based route collection part had the exact question: “What are the destinations that you generally WALK from YOUR DEPARTMENT? Please indicate the route do you commonly take on the map and how much time it takes”. The responses were drawn and noted on the METU map provided in the questionnaire by the pollster (see Figure 2a). While recording the route, the origin was selected as the department of the student, while the destination was selected as the building/zone (cafeteria, dormitory region, etc.) declared by the student on the map.

For each route, students' perceived time of walking was also recorded to be used for further studies.

The study area was divided into 38 zones by considering a major walking alley, the closeness of departments, and common behaviors of participants as seen in Figure 1b. While nearby buildings (i.e. Food Engineering and the Petroleum and Natural Gas Engineering buildings) are collected under the same zone (Zone 21), some buildings were shifted to another zone (Zone 10), if divided by vehicular roads or are not within walking perimeter of another one.

3.5. Digitization in GIS Environment

The stated walking routes were digitized in the GIS environment using a base map with all vehicular and pedestrian roads (sidewalks and pedestrian alleys) and buildings (see Figure 2b). Pedestrian roads were defined with links and nodes, where different entrances of large buildings were designated with different nodes to digitize routes more precisely. All routes were digitized individually by selecting every link one by one using the base map merged in a separate layer in Quantum GIS environment and saved as a shapefile (see Figure 2b). To validate the data, topological checks were performed; errors, such as unsnapped lines and nodes, were corrected automatically by the auto snapping tool of ESRI ArcGIS software. The manual overdrawn parts of the routes showing the destination zone roughly were not digitized, as they did not carry any specific information about the destination but were extended merely for taking notes (such as the name of the region). The digitalization process produced data for a total of 1844 routes from 623 participants.

Figure 2. Walking route example of a respondent a) as coded in the survey b) digitized in GIS.

4. Evaluation of Perception of Walkability

4.1. Student Perception of Walkability Environment in METU Campus

Responses to traditional questions were analyzed in IBM SPSS Statistic V23 software. Descriptive statistics of Round 1 (see Table 3) revealed that more than half of the students found the walking infrastructure mostly enough, whereas almost 40% found it insufficient. A large majority had reported consensus on insufficiencies for lightning, safety precautions, and arrangements for disabled users. Rating of the importance of 20 selected factors revealed responses parallel to the findings in the literature: Walkway capacity, continuity, and width were identified as partially important features, while the improvements for sheltering against weather conditions, shortcuts, arrangement for disabled users, infrastructure, and lightning were found highly important. The existence of sidewalks on both sides of the road and the sidewalk widths were extremely important, as in the literature, as well as a decrease in man-made obstacles (i.e. signs, electric poles). However, any improvement to decrease in trees on sidewalks was not found necessary, most likely due to the long-lasting tradition of tree planting on the METU campus. 50% of the participants stated the importance of designing walkways for disabled persons as well as the avoidance of vehicle-pedestrian exposure with natural or man-made buffers.

Table 3. Sidewalk design evaluations and possible improvements for METU Campus walkways by students (Survey Questions–Round 1)

Q1) Sufficiency of walking areas	**N**	**Insufficient (%)**	**Sufficient (%)**
a) Pavement Quality	(302)	40.4 %	**58.0 %**
b) Continuity	(302)	32.2 %	**66.1 %**
c) Width	(305)	40.7 %	**58.6 %**
d) Shortcuts	(305)	32.2 %	**67.1 %**
e) Shading	(300)	46.3 %	**51.5 %**
f) Safe Lightning	(303)	**64.2 %**	34.5 %
g) Planned according to the disabled person	(301)	**88.6 %**	9.4 %
h) Other safety precautions (Stragglers, vehicle conflicts)	(302)	**79.8 %**	18.6 %
i)Marked crosswalks	(295)	34.2 %	**61.9 %**

Q2) Importance of proposed infrastructure improvements	**N**	**Not Important**	**Slightly Important**	**Moderately Important**	**Extremely Important**
a) Walkways on Campus should be;					
a1) increased	(297)	14.7 %	**29.0 %**	**36.5 %**	16.6 %
a2) continuous	(302)	10.7 %	**24.4 %**	**44.6 %**	18.6 %
a3) widened	(304)	16.0 %	**27.0 %**	**36.5 %**	19.5 %
a4) sheltered against weather	(304)	7.2 %	12.1 %	**40.7 %**	**39.1 %**
a5) sheltered against the sun	(302)	10.7 %	22.8 %	**34.2 %**	**30.6 %**
a6) shortcuts	(305)	3.3 %	16.0 %	**38.1 %**	**42.0 %**
a7) designed for disabled	(300)	8.5 %	8.8 %	**32.6 %**	**47.9 %**
a8) improved in desing&material	(305)	7.5 %	20.5 %	**39.4 %**	**31.9 %**
a9) better lit	(297)	6.2 %	18.6 %	**36.2 %**	**35.8 %**
b) Sidewalks on Campus should be;					
b1) at both sides of the road	(304)	5.9 %	9.4 %	**42.7 %**	**41.0 %**
b2) widened	(305)	8.1 %	21.8 %	**37.1 %**	**32.2 %**
b3) cut by fewer obstacles	(304)	17.3 %	**32.2 %**	**30.0 %**	19.5 %
b4) obstructed less by trees	(305)	**52.1 %**	**20.2 %**	16.0 %	11.0 %
b5) designed for disabled user	(298)	7.5 %	6.5 %	**32.9 %**	**50.2 %**
b6) less exposed to vehicles	(303)	10.4 %	19.5 %	**32.9 %**	**35.8 %**
c) Marked Crosswalks on Campus should be;					
c1) increased	(305)	7.8 %	22.1 %	**42.3 %**	**27.0 %**
c2) designed with a refuge	(299)	12.7 %	**28.7 %**	**37.5 %**	18.6 %
c3) equipped with traffic lights	(300)	15.3 %	**29.0 %**	**36.5 %**	16.9 %
d) Speed limit decreased	(303)	13.7 %	22.8 %	**33.6 %**	**28.7 %**
e) Illegal parking e avoided	(302)	7.5 %	15.6 %	**32.6 %**	**42.7 %**

As for safety precautions, crosswalks, presence of a median, and traffic lights seemed important to students, who also found a decrease in the speed limit in the campus important. Descriptive statistics of Round 2 (see Table 4) were parallel to the sufficiency evaluations in Round 1, walking infrastructure seemed mostly enough, but lightning, safety precautions, and arrangement for disabled users seemed problematic. Also, sheltering of the walkways against weather conditions and sun effect seemed nearly insufficient. When the evaluation of the selected 20 factors was compared based on the responses between the first and second rounds, mainly focusing on their importance and sufficiency, it was observed that what students stated important in the first round were also those that were found insufficient in the second one. These features included the items such as sheltering against weather and sun effects, having shortcuts, lightning, etc. Because students were randomly selected at both rounds, this showed a consistency in the evaluation of factors affecting walkability in the perceptions among students.

Table 4. Sidewalk design evaluations for METU Campus walkways by students (Survey Questions – Round 2)

Sufficiency of the walking environment	N	Totally Insufficient	Insufficient	Moderately Sufficient	Sufficient
a) Walkways in terms of					
a1) existing capacity/network	(311)	4.5 %	14.8 %	**48.2 %**	**32.5 %**
a2) continuity	(316)	6.0 %	21.8 %	**45.3 %**	**26.9 %**
a3) width	(314)	6.1 %	28.3 %	**41.1 %**	**24.5 %**
a4) sheltering against weather	(**315**)	**30.8 %**	**44.4 %**	18.4 %	6.3 %
a5) sheltering against sun effects	(314)	24.8 %	**33.4 %**	**28.3 %**	13.4 %
a6) having shortcuts	(311)	8.4 %	**25.4 %**	**43.1 %**	23.2 %
a7) planning for disabled use	(**314**)	**54.1 %**	**34.4 %**	8.0 %	3.5 %
a8) pavement quality	(314)	25.2 %	**38.9 %**	**29.9 %**	6.1 %
a9) lightening	(316)	17.4 %	**36.4 %**	**37.3 %**	8.9 %
a10) safety against stragglers	(**313**)	**52.7 %**	**27.8 %**	14.1 %	5.4 %
b) Sidewalks in terms of,					
b1) existence at both sides	(315)	9.8 %	**36.2 %**	**39.4 %**	14.6 %
b2) width	(315)	12.4 %	**35.6 %**	**40.3 %**	11.7 %
b3) less disruption by obstacles	(316)	14.6 %	**32.9 %**	**40.2 %**	12.3 %
b4) less disturbance by trees	(313)	16.6 %	**28.4 %**	**33.9 %**	21.1 %
b5) avoiding vehicular conflicts	(312)	16.3 %	**37.2 %**	**35.6 %**	10.9 %
c) Crosswalks in terms of,					
c1) number	(311)	7.1 %	**37.6 %**	**45.7 %**	9.6 %
c2) having refuge	(312)	7.7 %	**31.4 %**	**46.2 %**	14.7 %
c3) having traffic lights	(314)	11.5 %	**39.2 %**	**35.4 %**	14.0 %
d) Speed limits on roads	(311)	8.7 %	**28.9 %**	**46.9 %**	15.4 %
e) Avoiding parking affectis the pedestrian flow	(314)	10.5 %	**34.4 %**	**43.3 %**	11.8 %

Traditional survey questions were investigated to capture the Gender perception difference, and significant results were shown in Table 5. According to the results of the chi-square test for the sufficiency of walking areas, there is a statistically significant difference between men and women for continuity, safe lightning, other safety precautions for stragglers/ vehicle conflicts ($p<.05$), and a highly significant difference for marked crosswalks ($p<.01$). When the evaluations were examined, while women put forward a much more negative point of view in negative situations, men evaluated positive situations at a higher level. Considering the importance of characteristics of campus walkways in terms of preferring walking, sheltered against the weather is evaluated statistically different ($p<.05$) according to gender, while sheltered against sun, designed for disabled, improved in design and material and better lighting are evaluated highly different ($p<.01$). When this difference is examined, it is seen that women consider all characteristics more important than men. Women evaluated the design of sidewalks suitable for the disabled as more important than men ($\chi^2(3, 300) = 14.49$, $p<0.01$). It is also seen that there is a significant difference between women and men in equipping the marked crosswalks with traffic lights ($\chi^2(3, 300) = 11.14$, $p<0.05$). In addition, a statistically high difference was observed in terms of reducing the speed limits on campus by gender ($\chi^2(3, 303) = 11.76$, $p<0.01$). Finally, the fact that walking paths have shortcuts was rated as more important by women.

Table 5. Chi-Square Analysis of the Survey Question by Gender Differences

ROUND 1						
Q1)	**N**	**Gender**	**Sufficient**		**Insufficient**	
b) Continuity*	(302)	Female	**61.8 %**		38.2 %	
		Male	**72.7 %**		27.3 %	
f) Safe Lightning *	(303)	Female	29.6 %		**70.4 %**	
		Male	40.4 %		**59.6 %**	
h) Other safety precautions (stragglers, vehicle conflicts)*	(302)	Female	14.4 %		**85.6 %**	
		Male	23.5 %		**76.5 %**	
i)Marked crosswalks **	(295)	Female	**55.7 %**		44.3 %	
		Male	**73.3 %**		26.7 %	
Q2)	**N**	**Gender**	**Not Important**	**Slightly Important**	**Moderately Important**	**Extremely Important**
Walkways on Campus should be,						
a4) sheltered against weather	(304)	Female	3.9 %	11.8 %	**37.9 %**	**46.4 %**
		Male	10.6 %	12.6 %	**44.4 %**	**32.5 %**
a5) sheltered against sun**	(302)	Female	6.0 %	19.9 %	**35.8 %**	**38.4 %**
		Male	15.9 %	**26.5 %**	**33.8 %**	23.8 %
a7) designed for disabled**	(300)	Female	2.7 %	9.4 %	**32.9 %**	**55.0 %**
		Male	14.6 %	8.6 %	**33.8 %**	**43.0 %**
a8) improved in design and material**	(305)	Female	3.9 %	16.3 %	**39.9 %**	**39.9 %**
		Male	11.2 %	**25.0 %**	**38.8 %**	24.3 %
a9) better lit**	(297)	Female	2.7 %	14.7 %	**35.3 %**	**47.3 %**
		Male	10.2 %	23.8 %	**39.5 %**	**26.5 %**
Sidewalks should be,						
b5) planned for disabled us**	(298)	Female	2.0 %	6.0 %	**32.5 %**	**59.6 %**
		Male	13.6 %	7.5 %	**35.4 %**	**43.5 %**
Marked Crosswalks should be						
c3) equipped with traffic lights*	(300)	Female	11.3 %	**24.7 %**	**44.7 %**	19.3 %
		Male	20.0 %	**34.7 %**	**30.0 %**	15.3 %
In campus speed limit should decrease**	(303)	Female	7.9 %	21.1 %	**39.5 %**	**31.6 %**
		Male	19.9 %	25.2 %	**28.5 %**	**26.5 %**
ROUND 2						
	N	**Gender**	**Totally Insufficient**	**Insufficient**	**Moderately Sufficient**	**Sufficient**
Walkways in terms of						
a6) having shortcuts*	(310)	Female	9.7 %	18.8 %	**42.3 %**	**24.2 %**
		Male	6.9 %	**33.1 %**	**38.6 %**	21.4 %

Note:* $p < .05$, ** $p < .01$

4.2. GIS-Based Evaluation of Usage of Walkway Infrastructure

Using the digitized routes and calculating their frequencies at link levels, an intensity map showing the most preferred pedestrian road segments was created in the GIS environment as shown in Figure 3. Frequency seemed to be very high levels at the main alley and spread to the expected attractive points such as the shopping area, recreational area, and dormitories. Walkways at the outer parts of the first loop seemed to have very low demand, especially at the new dormitory region (Zone 14).

4.3. Walkability of Campus Zones

To compare the walking behaviors of participants from different departments, 4 zones were selected which were located in different parts of the campus (see Figure 4).

- Zone 1 is located at the Northwest corner, far from central campus facilities and other departments (Figure 4a).
- Zone 6 is located at the northeast corner of the campus. It is in the alley and closer to the main attraction points such as the library, cafeteria, and shopping area (Figure 4b).
- Zone 21 is located on the southwest side of the campus. It is divided by a forest area through the campus center (Figure 4c).
- Zone 19 is located on the southeast side of the campus, which is also in the alley (Figure 4d).

The common destination points of all the paths departing from these zones were found are library (Zone 26), cafeteria (Zone24), and shopping area (Zone 28). The students also preferred walking through the alley in their routes more than sidewalks along the roads as seen in Figure3. As a difference, walking to the campus entrances A1 and A2 (which also has metro stations) were preferred by the students from the northern zones, while students at the departments in the southern zones rarely walked to these destinations. It was also possible to display the route differences between male and female students by simply dividing the routes and creating gender-based maps as shown in Figure 5. Even with this example, it was possible to point out the difference in the variety of destinations and lengths of pedestrian routes stemming from Zone 21. However, it is too soon to make any general comments on the matter without generating such maps for more buildings/zones.

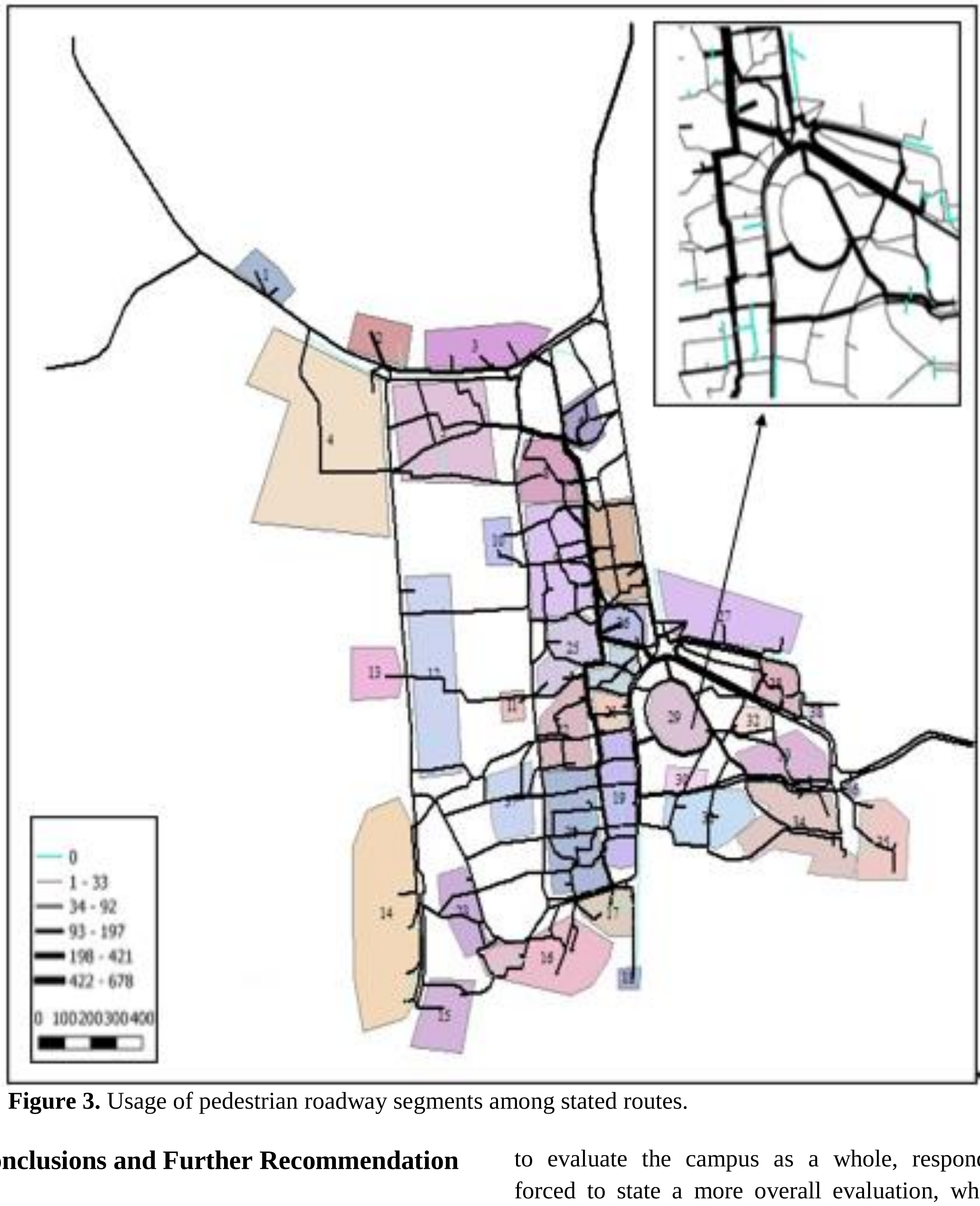

Figure 3. Usage of pedestrian roadway segments among stated routes.

5. Conclusions and Further Recommendation

This study showed the traditional questions assessing sufficiency or importance of various factors affecting walkability, were not capable of displaying the spatial distribution of their impact within a built environment. Also, unless asked specifically for a location, when asked to evaluate the campus as a whole, respondents were forced to state a more overall evaluation, whereas there were subregions with lower walkability levels. Also, when a question includes scales or choices (i.e. Sufficient/Insufficient or between 1 and 4) this does not produce insights per se. People do not differentiate the terms of sufficiency or importance and use them interchangeably, which produced trivial responses (i.e. very important or very enough).

Route-based walking data is stronger in terms of network usage and infrastructure, revealing information about personal choices (i.e. preference of sidewalks versus pedestrian alleys, sheltered regions versus unsheltered ones, etc.). The data collection period does not present a serious deficiency in terms of reflecting the walkability of the campus in general due to the general built environment remaining similar. When digitized in a GIS environment and supported with land use and network data (i.e. traffic volumes, roadway type, pavement type, etc.), walking routes lead to better modeling of walking behavior in a region. Furthermore, analysis of building/zone-based walking behaviors gave information about willingness to walk for different attraction points. A major drawback of route-based data collection is the additional time consumption due to manual digitization of stated routes, which can be improved if real-time GIS-based data collection tool should be developed.

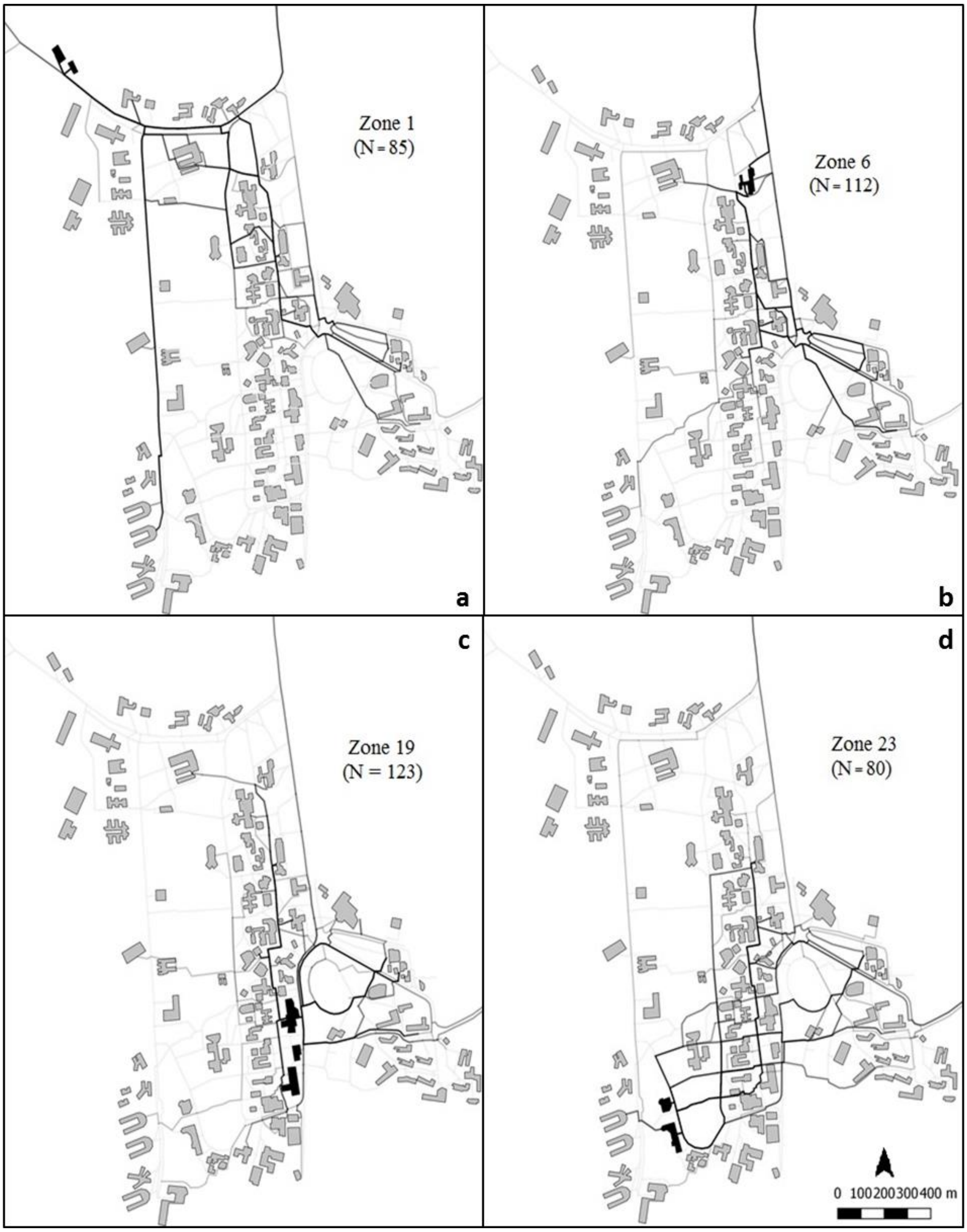

Figure 4. Zone-based stated walkway routes for a) Zone 1, b) Zone 6, c) Zone 19 and d) Zone 23

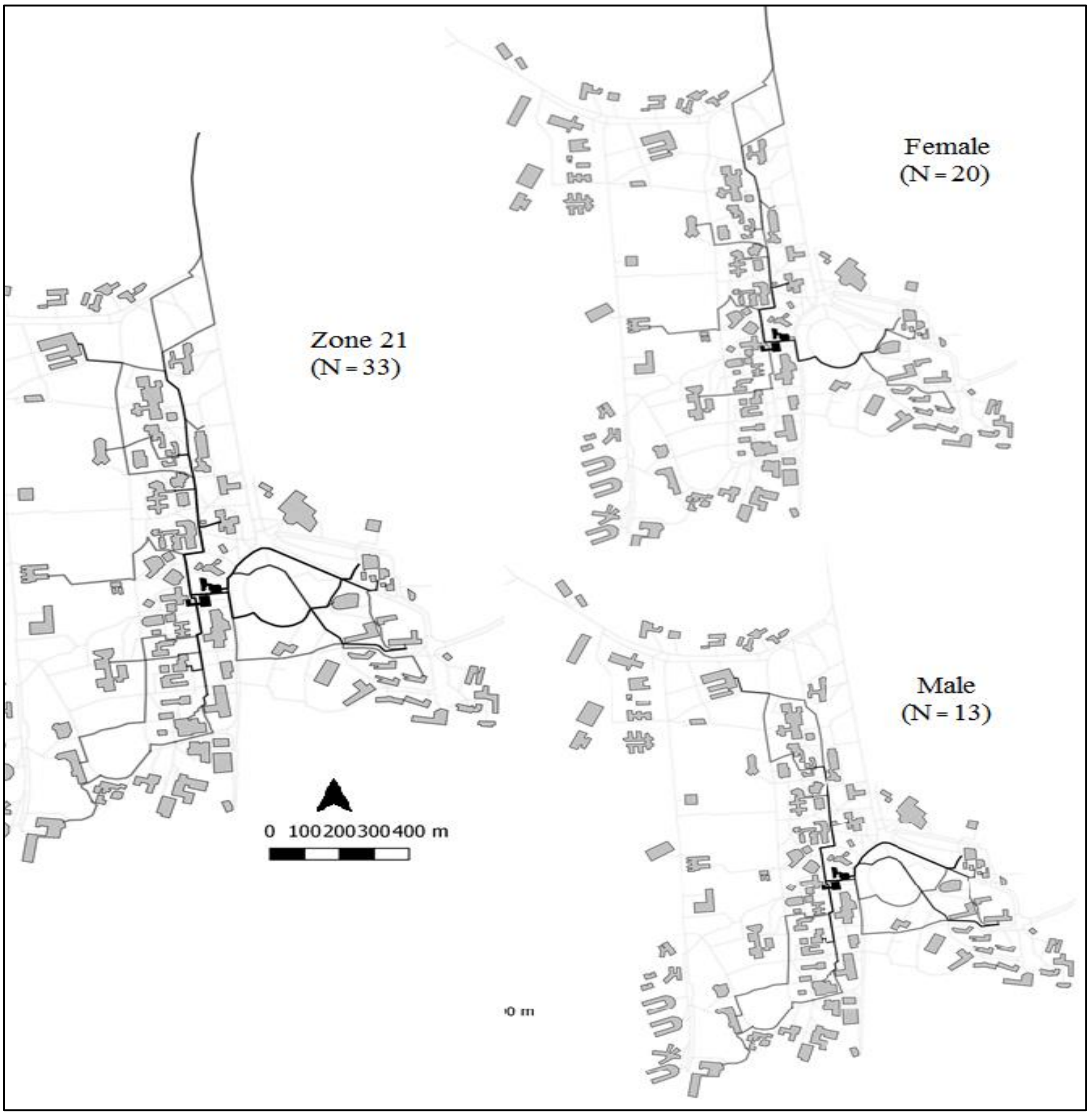

Figure 5. Zone-based stated walkway routes for a) Zone 1, b) Zone 6, c) Zone 19 and d) Zone 23

Acknowledgments

The survey used in this study was conducted by a group, consisting of graduate students from different departments. So, we would like to thank Başar Özbilen and EzgiKundakçı who are the invisible support team of this study.

Declaration of Ethical Standards

The author of this article declares that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Conflict of Interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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