


Article

Perceived Walkability and Respective Urban Determinants: Insights from Bologna and Porto

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Abstract: Walking is undoubtedly a sustainable and healthy mode of transport. However, the decision to walk is influenced by many built environment and streetscape attributes. Specifically, the term walkability is used to describe the extent to which the urban environment is pedestrian-friendly, usually by quantifying multiple built environment attributes at the neighbourhood scale. The present study adopts a qualitative approach to evaluate perceived walkability. Based on a questionnaire ($n = 1438$) administered in the cities of Bologna and Porto, this paper analyses how respondents perceived and evaluated 19 built environment and streetscape attributes. An Exploratory Factor Analysis was carried out to examine the correlations between the various attributes and to identify the underlying walkability determinants. The analysis indicated that 13 attributes were highly correlated, resulting in four determinants: (i) urban ambiance, which includes land use and street design attributes, such as land use mix, enclosure, transparency, and architectural and landscape diversity; (ii) pedestrian infrastructure, which is related to sidewalk conditions; (iii) street connectivity and proximity to community facilities; and iv) access to other modes of transport. In turn, traffic safety and security were not correlated with perceived walkability in both cities. These findings suggest that specific urban design and pedestrian infrastructure attributes should be highly considered when formulating policies aiming to create more pedestrian-friendly cities, as well as in walkability studies and when developing walkability scores and indexes.

Keywords: perceived walkability; built environment; streetscape design; factor analysis; walking



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1. Introduction

Walking is the most common and natural form of moving and an enjoyable, sustainable, and healthy mode of transport, namely for short urban trips. The overall environmental and health benefits of walking have been extensively analysed and discussed in the literature [1–3]. Due to these benefits, many studies have been conducted to analyse how the built environment affects travel behaviour and the overall walking experience [4,5]. The extent to which the built environment is pedestrian-friendly and enables walking is broadly defined as walkability [6]. The concept of walkability only started to be used in transport and planning studies in the early 2000s, but rapidly became a widely used concept in sustainable mobility and other disciplines. Nonetheless, the term is rarely defined in English dictionaries [7], and the concept associated with walkability remains vague and unclear [8]. In part, this is related to the different subject areas that included walking and walkability in their research field, such as transport, urban planning, health, and environmental sciences.

For these reasons, the ways to assess walkability are strongly changeable regarding the attributes, the methods, and the scale of analysis used.

Walkability assessments have been mostly based on quantitative evaluations in the form of indexes or metrics that measure a changeable number of built environment attributes [9]. One of these first referential methods was the so-called “3D layout” proposed by Cervero and Kockelman [10]. They found that density, land-use diversity, and pedestrian-oriented designs reduce automobile trips and encourage active travel. Later, Ewing and Cervero [11] added destination accessibility and distance to transit (“5D layout”) to have a greater overview of the influence of built environment features on walking. Other referential methods were the GIS-based walkability indexes of Frank et al. [12,13], which included land use mix, street connectivity, residential density, and retail floor area. Acting as a predictor of walking and physical activity, these composite indexes have been extensively replicated and have inspired many other indexes [6,14]. The Walk Score is another example of a quantitative index used for assessing walkability [15]. The Walk Score uses distance to amenities, block length, and intersection density to estimate walkability.

Walkability research has resulted in increased precision in measuring-built environment influences of walking [16], namely due to the growing availability of spatial data along with the use of GIS tools [17]. For Andrews et al. [18], the widespread use of quantitative approaches is a “neo-environmental determinism”, which assumes a deterministic relationship between the environment measured by specific attributes and walking. However, these objective measures often do not include important qualitative features such as the aesthetics of the landscape, the sense of safety, and the pleasure of walking. In this context, Jensen et al. [19] also emphasised that walkability indexes usually overlook streetscape features, such as the characteristics of sidewalks, which are associated with perceived walkability [20]. Selecting an appropriate scale of analysis to accurately represent daily activities, such as walking trips, also remains a topic of discussion [21]. Scales of analysis vary greatly from country to country depending on the characteristics of cities, while buffers often used in walkability studies based on Euclidian distances from specific points may be poorly suited to describing walking. This leads to another problem which consists of replicating indexes developed for specific areas. As shown by Shashank and Schuurman [21], the application of specific methods may result in different walkability scores for the same city. Various urban morphologies, data in different formats and from different spatial units could make replications less effective in describing walkability.

Finally, the role that social and individual characteristics play in the different perceptions of spaces to walk, such as the socioeconomic status, social cohesion, community identity, race, age, gender, among others are often not taken into account [16,22,23]. All these variables could significantly affect people’s willingness to walk and, therefore, understanding the mechanisms by which the social environment influences walking remains limited [16]. This also explains that objective and perceived walkability do not always correlate in the same direction, and a neighbourhood with high objective walkability does not always correspond to a neighbourhood with high perceived walkability [17]. Moreover, as shown in some studies, people may not walk and socially interact more simply because they live in a walkable area, due to the complex nature of the relationships between walkability and the social environment [24,25].

Thus, research on walkability lacks qualitative studies, which according to Dörrzapf et al. [26] should be part of a new walkability concept and understanding. More specifically, there is a lack of studies on how citizens’ views favour or hinder the propensity to walk [27] and on how pedestrians perceive walkability [28]. In addition, as research has been mostly conducted at the neighbourhood level, there is a lack of studies evaluating both neighbourhood and micro-scale environmental factors when some forms of utilitarian walking are analysed [29].

Understanding how urban space influences citizens’ perceptions of walkability is critical to designing efficient pedestrian planning policies and guiding future research in this field. In this paper, we explore this topic by evaluating the influence of 19 built environment

and streetscape attributes on perceived walkability. The evaluation was carried out by performing a questionnaire ($n = 1438$) in the cities of Bologna (Italy) and Porto (Portugal) in the context of the research project called Smart Pedestrian Net. Respondents were asked to rate the importance of these attributes in walking using a five-point Likert scale. An Exploratory Factor Analysis (EFA) was the method selected to identify correlations between the attributes and to highlight the main determinants associated to walkability. To the best of our knowledge, this is the first study using a qualitative approach to analyse the way people perceive walkability in both cities.

2. Literature Review

Empirical research has shown that walking behaviour is affected by the way people perceive the walking environment [22]. The decision and satisfaction of walking are influenced by multiple built environment and streetscape attributes. One of the most widely used tools to assess individuals' perception of walkability is the Neighbourhood Environment Walkability Survey (NEWS) developed by Saelens et al. [30]. NEWS covers eight main walkability dimensions: residential density, land use mix, land use mix access, street connectivity, infrastructure for walking, traffic safety, security from crime, and aesthetics. In a recent review on the influence of built environment and streetscape attributes on walkability, Fonseca et al. [5] identified seven dimensions: land-use density, land-use diversity, accessibility, street network connectivity, pedestrian facilities and comfort, safety/security, and streetscape design. Accordingly, the influence of these built environment and streetscape dimensions on walking is briefly analysed below.

Land-use density and particularly residential density are crucial dimensions of the city and its built environment. High residential density means a larger number of people living in a given area, which potentially leads to an increase in walking activities. More people walking will encourage others to walk, increasing the interactions that take place between people [31]. In turn, traffic congestion tends to increase with population density, which could make walking more convenient rather than driving [32]. Areas with high residential density also tend to attract various amenities, which reduces travel distance and time, making walking trips more convenient. For these reasons, previous studies have shown that residential density is associated with more walking time and more active people [12,33,34].

Land-use diversity shows the extent to which there is a mix of land uses within an area. An area with a mix of land uses typically offers more non-residential destinations (services, shops, restaurants, etc.), which generally reduces the distances to travel and makes walking more convenient. Land-use diversity has often been evaluated by entropy indexes showing the degree to which an area has uniformly diverse land use through normalised scores, where 0 means a single-use and 1 an even distribution of a specific number of land uses [12,35]. Alternative ways of measuring diversity have included: (i) the number of local destinations in an area [36]; (ii) the percentage of specific land use in an area [14]; and (iii) the retail floor area, which indicates the amount of available space for parking reflecting a higher propensity to car usage [13]. The literature shows that mixed land uses are more conducive to walking and are associated with more active people [12,35].

Accessibility is a complex and context-dependent concept that has been used to describe ease of access in terms of distance to attractions, but also as the expected utility derived from the number of accessible amenities (services, urban functions) from a given area [11,37]. In this study, accessibility reflects the walking distance to key destinations and public transport. Travel distance is critical for pedestrians because walking is a low-speed mode and requires more time and physical effort to reach distant destinations. For that reason, as the travelling distance increases, the probability of using motorised transport also increases [38]. Some authors argued that neighbourhood amenities, such as retail, stores, and services, should be provided within around 15-min walking or cycling distances [39]. Compact urban areas with mixed land uses are known for reducing travel distances, which increases the propensity to walk. Distance to public transport is also a critical attribute. There is evidence that the shorter the distances to stops, the higher the odds of walking

to catch a bus or a train [40]. The literature shows that people are usually willing to walk around 400 m to arrive at bus stops and 800 m to arrive at rail stations [40,41].

Street connectivity can be understood as the directness and availability of alternative routes between destinations. More interconnected streets provide more potential routes for walking, which reduces distances between origins and destinations and makes walking more convenient [40]. Street connectivity has been described by a considerable number of different attributes such as intersection density, street density, cul-de-sac density, average block length, median block length, connected node ratio, link node ratio, among others. From these, intersection density, usually calculated as the number of intersections of three or more links in an area, has been the most widely used attribute to describe street connectivity [5]. Areas providing high intersection density have been correlated with more walking activity and physical activity [12,42].

Pedestrian facilities are infrastructure provided to enhance the comfort and safety of pedestrians. They include infrastructure such as sidewalks, crosswalks, underpasses and overpasses, street furniture, and traffic calming devices, among others. In general, research has shown that well-designed and maintained pedestrian facilities encourage walking and promote higher levels of pedestrian travel. Sidewalks are the basic pedestrian facility, but attractive sidewalks depend on various features. Previous research has shown that the presence of wide, well-maintained, and clean sidewalks encourages pedestrian activity [43,44]. The presence of street furniture helps to create more pleasant sidewalks, providing for example settings for resting, but the presence of obstacles, such as parked cars on sidewalks, reduces the area available for walking and discourages people from walking [4,43]. Street trees provide various benefits at the sidewalk level (shading, cooling, UV protection, traffic safety, and enclosure, among others). For these reasons, street trees have been positively associated with healthy pedestrian routes [45]. Slopes have a significant influence on walking since they affect the travel speed and the effort required for walking [45]. Sloped sidewalks (>5%) are generally considered unattractive for walking [46].

Traffic safety means that pedestrians should be protected from motorised traffic [15], while security means that pedestrians should be protected from crime and incivilities [47]. As pedestrians are vulnerable road users, traffic safety is a critical issue. Some of the most commonly used attributes to describe traffic safety include traffic speed, traffic volume, the number of traffic lanes, among others. It has been shown that high traffic volume is a barrier to walking [14,48], the risk of accidents was associated with less physical activity [49], and pedestrians prefer quiet streets with low traffic speeds and volumes [43] and streets with few lanes to cross [50]. In turn, public security has been reported as a strong deterrent to walking [47,51], particularly in regions characterised by urban violence [4,47]. Security has been measured by considering various attributes, such as street lighting, buildings with broken windows and graffiti, homicide rates, police officers/stations, volume of pedestrians, among others [5]. It has been shown that graffiti, few shops, and vacant buildings increase the perception of insecurity [51], while the presence of street lighting, surveillance systems and police officers enhance the perception of security [4].

Streetscape design reflects the extent to which pedestrian spaces are attractive and functional for walking. Streetscape design is related to street-level features, such as the presence of attractive pedestrian facilities and furniture [5]. The literature shows that street design features have an overall positive impact on walking [52,53] and that they have been positively associated with walking and physical activity [54]. The attributes most commonly used to assess streetscape design include: (i) human scale, reflecting how buildings and spaces are scaled to human size and needs [53]; (ii) enclosure, showing how enclosed by vertical elements the spaces are, creating a room-like effect [52]; (iii) complexity, indicating the visual richness of a place, in terms of buildings shapes, styles, colours, street furniture, among others [52]; and (iv) transparency, showing the proportion of windows and doors at the street level having active uses [52].

To sum up, this review shows that the concept of walkability and the way people perceive walkability are influenced by a significant number of attributes. In this study, we

intended to understand which urban determinants may explain walkability according to the perceptions of a group of individuals from Bologna and Porto.

3. Method and Data

This section describes the methodology used to collect and analyse the built environment and streetscape data in Bologna and Porto.

3.1. Study Areas

This study was conducted within the research project called Smart Pedestrian Net (SPN). The main goal of SPN was to increase walkability and to encourage people to walk on a daily basis in Bologna and Porto. Bologna and Porto are two medium-sized southern European cities (Figure 1).



Figure 1. Location of Bologna and Porto.

Founded in the Middle Ages, they are recognised for their rich history and heritage. Bologna is particularly famous for its monuments and extensive porticoes that cover most of the city centre, while the historical centre of Porto has been classified as a World Heritage Site since 1996. Both cities are engaged in promoting sustainable mobility policies to limit the negative effects of motorised traffic, especially in the city centres. This includes policies that have led to an increase in electric mobility, public transport, and active modes of transport. Both cities are engaged in improving walkability through various measures such as the provision of pedestrian-only streets, the restriction of motorised traffic in some streets, and the adoption of measures to improve pedestrian facilities and traffic safety, among others.

3.2. Data Collection

Based on an extensive literature review on the influence of built environment and streetscape attributes on walkability [5], a total of 19 attributes were selected to evaluate their influence on individuals' perception of walkability (Table 1).

Table 1. Built environment and streetscape attributes included in the questionnaire.

Type of Attribute	Description
Built environment	1. Walk in areas in close proximity to public transport stops
Built environment	2. Walk in areas in close proximity to car parking
Built environment	3. Walk in areas with high street connectivity
Built environment	4. Walk in areas in close proximity to community facilities
Streetscape	5. Walk in streets with low traffic speed
Streetscape	6. Walk in streets with ≤ 2 traffic lanes
Streetscape	7. Walk in streets with wide sidewalks
Streetscape	8. Walk on sidewalks in good condition
Streetscape	9. Walk on unobstructed sidewalks
Streetscape	10. Walk on sidewalks with street furniture
Streetscape	11. Walk on sidewalks with low slopes
Streetscape	12. Walk on sidewalks with trees/greenery
Streetscape	13. Walk in streets with many pedestrians
Built environment	14. Walk in shopping streets/areas
Built environment	15. Walk in areas with high residential density
Built environment	16. Walk in areas with mixed land uses
Streetscape	17. Walk in streets providing enclosure
Streetscape	18. Walk in streets with architectural and landscape diversity
Streetscape	19. Walk in streets providing transparency

The evaluation of the 19 attributes was carried out by performing a questionnaire ($n = 1438$) in the cities of Bologna and Porto. The questionnaire was structured on Google Forms and consisted of a mix of single choice, multiple-choice, ranking, and open-ended questions divided into four main parts. The first aimed at collecting personal information, such as gender, age, education level, and type of activity. The second and the fourth parts were to collect data about the frequency and purpose of walking [55] and the use of pedestrian navigation apps [56], respectively. The third part was to evaluate the 19 attributes presented in Table 1. Participants were asked to rank the importance of each attribute when walking by using a five-point Likert scale, ranging from 1 (“not important”) to 5 (“very important”).

A description of the meaning of each attribute was included in the questionnaire as follows: “close proximity” was defined as bus stops and train stations at a walking distance up to 400 and 800 m, respectively, car parking at 500 m and community facilities at 1000 m; “street connectivity” was explained as the availability of alternative routes (street intersections) between destinations; “low traffic speed” as the streets where maximum limit is 30 km/h; streets with few lanes as those having ≤ 2 traffic lanes; “wide sidewalks” as those providing ≥ 1.50 m free of obstacles; “sidewalks in good condition” were those without major deformities (cracks, holes, raised pavements) that may cause trip hazards; “unobstructed sidewalks” as those without physical obstacles, such as parked cars; “street furniture” as objects and equipment installed along sidewalks, such as benches and litterbins; “low slopes” as sidewalks having a longitudinal gradient $\leq 2\%$; “sidewalks with trees/greenery” as those containing trees in segments of at least 10 m; “streets with many pedestrians” as those having at least some pedestrian movement/visible pedestrians walking; “shopping streets/areas” as commercial streets having different stores; “high residential density” as areas with residential buildings and more people living there; “mixed land uses” as areas containing diverse uses and functions, such as residential, retail, and recreational; “enclosure” as the extent to which streets are visually defined by buildings, walls, trees, and other vertical elements; “architectural and landscape diversity” as the visual richness of a street, namely in terms of building colours, architectural styles, and outdoor dining; and “transparency” as the proportion of windows and doors at the street level having active uses.

After consolidating the structure of the questionnaire, a pilot test was performed to gauge the various questions and their overall organisation. As a result, some changes were carried out to improve the reliability and sensitivity of the questionnaire.

The second step of the work consisted of obtaining a statistically significant sample of the population living in both cities. The widely used Cochran's formula [57] was adopted to calculate the sample size in each city. The formula is shown in Equation (1).

$$n = \frac{\frac{z^2 pq}{e^2}}{1 + \frac{1}{N} \left(\frac{z^2 pq}{e^2} - 1 \right)} \quad (1)$$

where: n is the sample size, N is the population size, z is the critical value (1.96) for the 95% confidence level, p is the sample proportion (0.5), q is equal to 0.5 ($q = 1 - p$), and e is the margin of error (0.05). Considering that the population living in Bologna and in Porto in 2019 was 301,984 inhabitants [58] and 216,606 inhabitants [59] respectively, a sample of 384 individuals in each city was required.

The third step of the work was the administration of the questionnaire. It was decided to administer the questionnaire electronically, because online surveys open up the survey to more people, they allow the respondent to complete the survey at a convenient time and at a pace that is comfortable for the respondent, and because they encourage the participation of people who have more intense attitudes regarding the asked topic [60]. Respondents were approached through the SPN website, databases from the municipalities and the universities of Bologna and Porto and through social media. In Bologna, the questionnaire was distributed in Italian from May to July 2019; in Porto, the questionnaire was distributed in Portuguese from September to November 2019. Thus, both questionnaires were administered a few months before the COVID-19 pandemic, which severely impacted urban mobility.

3.3. Data Analysis

A descriptive analysis was performed to characterise the sample and to analyse how the attributes were evaluated in terms of mean, median, and standard deviation. Statistically, the study was based on an EFA, which refers to a set of statistical techniques often used to identify the underlying factors measured by a group of observed and interrelated variables. Factor analyses of Likert questions with five or more scale points were adopted in previous transport studies [61,62]. The principal component analysis, which measures the variance in the set of variables, was the EFA method adopted. Three main steps were developed to perform the factor analysis: (i) check the suitability of data; (ii) factor extraction; and (iii) factor rotation and interpretation.

Regarding the first step, the statistical measure used to check the suitability of data was the Kaiser–Meyer–Olkin (KMO) method. The Kaiser measure is a ratio that represents the amount of the total variance explained by each factor. KMO values between 0.8 to 1.0 indicate that the sampling is adequate, while values between 0.7 to 0.8 are still acceptable [62]. In addition, the Bartlett's Test of Sphericity evaluates the overall significance of the correlation matrix, by testing the null hypothesis, e.g., if there is or if there is no correlation between the variables. If there is no correlation, the variables are unsuitable for structure detection. The significant value $p < 0.05$ shows that factor analysis may be worthwhile for the data set.

Regarding the second step, the factor extraction consists of determining the number of factors that can be used to represent the correlations among the variables. The method used was the Principal Component Analysis through the Kaiser's Criterion and the Scree Test. The Kaiser's criterion corresponds to a score called eigenvalue that represents the amount of the total variance explained by each factor (or component). Only components with high eigenvalues are likely to represent real underlying factors. As adopted in previous studies [62,63], we only selected components having eigenvalues above 1.0, because they are considered to be significant. These components will be used to identify the main determinants associated with walkability. The Scree Test was also used to help to extract the underlying factors. The Scree plot displays the components' eigenvalues versus the total number of components. Eigenvalues are plotted as dots within the graph, and a line

connects successive values. By stopping at the point where this is a levelling at the plot area, this test can be used to identify the optimum number of components that can be extracted [63]. The so-called communalities (r-square values) show the extent to which the underlying factors account for the variance of all the variables.

The factors obtained in the initial extraction could be difficult to interpret due to cross-loadings as some variables could have more than one-factor loading. The factor rotation and interpretation, performed during the third step, solve this problem by redistributing the factor loadings over the factors according to some mathematical rules. In this study, a varimax rotation, which is among the most recommended and widely used methods [64], was performed to achieve a meaningful factor matrix and to understand how the factors correlated with each component. In a varimax rotation, the correlation of each of the variables is the closest to 1.0 with only one of the factors obtained, and close to zero with all other factors identified. The Statistical Package for the Social Sciences (SPSS) was the software used to perform the described factor analysis.

Finally, the reliability coefficient Cronbach's alpha was utilised to assess the internal consistency of the obtained factors. This coefficient has been used to measure the reliability of the questionnaire with multiple Likert scale questions [65]. Cronbach's alpha values of 0.70 or higher indicate good reliability of data [63,65,66].

4. Results

4.1. Sample Description

A total of 1438 individuals (60% from Bologna and 40% from Porto) evaluated the 19 attributes. As shown in Table 2, in both cities respondents included slightly more females, aged between 45–65 and 25–45 years old, who had an undergraduate degree, were living in the respective cities, and were employed full-time.

Table 2. Sample description.

Variable	Attributes	Questionnaire				Population 2019			
		Bologna		Porto		Bologna		Porto	
		Total	%	Total	%	Total	%	Total	%
Gender	Female	507	58.6	341	59.5	206,589	52.7	119,228	55.0
	Male	358	41.4	232	40.5	185,395	47.3	97,378	45.0
Age	≤24 years old	84	9.7	110	19.2	78,410	20.0	47,846	22.1
	25–44 years old	266	30.8	236	41.2	103,973	26.5	46,821	21.6
	45–64 years old	477	55.1	214	37.3	112,554	28.7	60,223	27.8
	≥65 years old	38	4.4	13	2.3	97,047	24.8	61,716	28.5
Education	Undergraduates	562	64.9	308	53.8	308,816	78.8	163,621	75.5
	Graduates	303	35.1	265	46.2	83,168	21.2	52,985	24.5
Occupation	Student	111	12.8	155	27.0	51,054	15.6	42,089	20.9
	Employed	735	85.0	402	70.2	165,768	50.5	88,452	43.8
	Unemployed/retired	19	2.2	16	2.8	111,414	33.9	71,235	35.3
Type of pedestrian	Resident	480	55.5	377	65.8	391,984	100.0	216,606	100.0
	Commuter	362	41.8	164	28.6	-	-	-	-
	Tourist/visitor	23	2.7	32	5.6	-	-	-	-

Source (Population data): ISTAT [58]; SP [59].

The sample's sociodemographic characteristics do not differ much from the population of each city in some variables (gender and people living in each city), but there are deviations in some variables. For example, elderly people (≥65 years old) are underrepresented, while adults, the employed, and graduates are overrepresented. These deviations are mostly explained by the difficulty in targeting specific groups with online questionnaires.

4.2. Sample Description

Table 3 shows some descriptive results from the evaluation made by the participants. In general, the attributes related to pedestrian facilities were those that were highly scored (mean > 4.0) and those with the lowest standard deviation values (<1.0). In turn, the less scored attributes (mean < 3.0) include some attributes such as: “walk in areas closer to car parking”, “walk in streets with ≤ 2 traffic lanes”, “walk in areas with high residential density”, and “walk in streets providing enclosure”.

Table 3. Descriptive results of the evaluation made by the participants ($n = 1438$).

Attributes	Mean	Median	SD
8. Walk on sidewalks in good condition	4.47	5.00	0.83
9. Walk on unobstructed sidewalks	4.37	5.00	0.90
7. Walk in streets with wide sidewalks	4.22	4.00	0.95
12. Walk on sidewalks with trees/greenery	4.14	4.00	0.93
10. Walk on sidewalks with street furniture	4.08	4.00	0.99
4. Walk in areas closer to community facilities	4.01	4.00	1.06
3. Walk in areas with high street connectivity	3.95	4.00	1.10
5. Walk in streets with low traffic speed	3.78	4.00	1.20
18. Walk in streets with architectural and landscape diversity	3.57	4.00	1.06
1. Walk in areas closer to public transport stops	3.51	4.00	1.33
13. Walk in streets with many pedestrians	3.39	3.00	1.10
16. Walk in areas with mixed land uses	3.21	3.00	1.06
11. Walk on sidewalks with low slopes	3.19	3.00	1.24
14. Walk in shopping streets/areas	3.04	3.00	1.19
19. Walk in streets providing transparency	2.94	3.00	1.09
6. Walk in streets with ≤ 2 traffic lanes	2.93	3.00	1.23
2. Walk in areas closer to car parking	2.88	3.00	1.44
15. Walk in areas with high residential density	2.67	3.00	1.08
17. Walk in streets providing enclosure	2.40	2.00	1.06

4.3. Factor Analysis

To ensure that the data collected was suitable and adequate for EFA, the KMO measure of sampling adequacy and Bartlett’s Test of Sphericity were firstly checked (Table 4). The KMO measures the factorability of the variables individually and as a group, which is a basic assumption for factor analysis. The obtained measure of sampling adequacy of 0.902 falls in the range between 0.8 to 1.0, which is considered adequate. In turn, the Bartlett’s Test of Sphericity was significant ($p < 0.001$), indicating that the correlations between the variables when taken collectively are significant at one per cent level, e.g., there was a substantial correlation in the data. Thus, the KMO and the Bartlett’s test indicated that the outcomes of the factor analysis were meaningful.

Table 4. Results of the KMO and Bartlett’s Test.

Kaiser–Meyer–Olkin Measure of Sampling Adequacy		0.902
Bartlett’s Test of Sphericity	Approx. Chi-Square	10,462.1
	df	171
	Sig.	0.000

The extraction scores of the 19 attributes are shown in Table 5. The communalities, which reflect the common variance in the database, show that after the initial extraction, most communality loadings were higher than the minimum cut-off of 0.500. From the 19 attributes, only 6 had a communality lower than 0.500: “walk in streets with ≤ 2 traffic lanes”; “walk on sidewalks with trees/greenery”; “walk on sidewalks with low slopes”; “walk on sidewalks with street furniture”; “walk in streets with low traffic speed”; and “walk in streets with many pedestrians”.

Table 5. Communalities for the 19 built environment and streetscape attributes.

Built Environment and Streetscape Attributes	Initial	Extraction
15. Walk in areas with high residential density	1.000	0.659
1. Walk in areas closer to public transport stops	1.000	0.647
4. Walk in areas closer to public facilities	1.000	0.643
3. Walk in areas with high street connectivity	1.000	0.631
8. Walk on sidewalks in good condition	1.000	0.623
14. Walk in shopping streets/areas	1.000	0.616
16. Walk in areas with mixed land uses	1.000	0.616
19. Walk in streets providing transparency	1.000	0.577
2. Walk in areas closer to car parking	1.000	0.575
9. Walk on unobstructed sidewalks	1.000	0.574
7. Walk in streets with wide sidewalks	1.000	0.570
17. Walk in streets providing enclosure	1.000	0.569
18. Walk in streets with architectural and landscape diversity	1.000	0.548
13. Walk in streets with many pedestrians	1.000	0.493
5. Walk in streets with low traffic speed	1.000	0.469
10. Walk on sidewalks with street furniture	1.000	0.466
11. Walk on sidewalks with low slopes	1.000	0.458
12. Walk on sidewalks with trees/greenery	1.000	0.386
6. Walk in streets with ≤ 2 traffic lanes	1.000	0.247

Then, a Principal Component Analysis was adopted to determine the number of factors that represent the correlations among the attributes. Table 6 shows the eigenvalues and total variance explained resulting from the application of the Kaiser's criterion. After the initial extraction, it can be observed that most eigenvalues in column 2 were less than the minimum threshold of 1.0 and only four components had an eigenvalue greater than 1.0. The dominant eigenvalues in decreasing order for Components 1–4 are 6.29, 2.34, 1.46, and 1.06, respectively. In terms of variance, Components 1–4 explain around 33%, 12%, 8%, and 6%, respectively of the total variance. Thus, 59% of the total variance is explained by these four components.

Table 6. Eigenvalues and total variance explained.

Component	Total	Initial Eigenvalues		Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
		Variance %	Cumulative %	Total	Variance %	Cumulative %	Total	Variance %	Cumulative %
C1	6.285	33.078	33.078	6.285	33.078	33.078	4.159	21.889	21.889
C2	2.339	12.312	45.390	2.339	12.312	45.390	3.193	16.807	38.696
C3	1.460	7.683	53.072	1.460	7.683	53.072	1.977	10.403	49.099
C4	1.057	5.561	58.634	1.057	5.561	58.634	1.812	9.535	58.634
C5	0.889	4.678	63.311						
C6	0.807	4.248	67.560						
C7	0.752	3.959	71.519						
C8	0.575	3.027	74.546						
C9	0.554	2.918	77.464						
C10	0.548	2.887	80.351						
C11	0.519	2.732	83.083						
C12	0.490	2.577	85.660						
C13	0.470	2.476	88.136						
C14	0.447	2.351	90.487						
C15	0.424	2.234	92.721						
C16	0.407	2.142	94.863						
C17	0.367	1.930	96.793						
C18	0.338	1.779	98.572						
C19	0.271	1.428	100.000						

The Scree Test (Figure 2) also confirms that there is a remarkable variation in slope between the 19 components. The first four components explain most of the variability, while the remaining 15 components explain a much lesser proportion of the variability and are likely to be less important. Thus, the Scree Test confirmed the Kaiser's criterion, indicating that four factors could be a realistic number to represent the determinants that influence the perceptions of walkability in both cities.

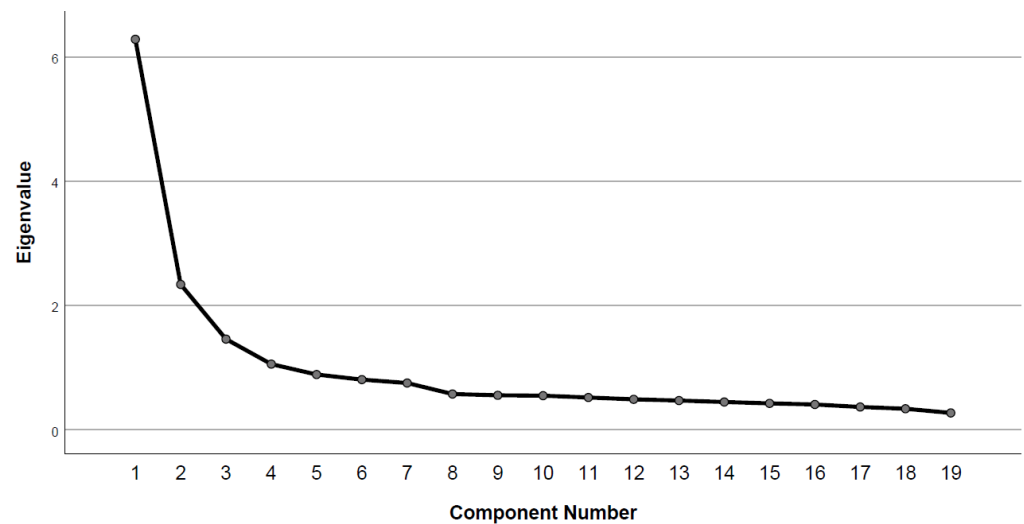


Figure 2. Scree plot model for exploratory factor analysis.

However, the components resulting from the initial extraction do not show which specific attributes are contributing more to the total variance. Thus, a varimax rotation was performed to check how these variables are correlated and how they can be reduced to a smaller number of main determinants. These results are shown in Table 7.

Table 7. Rotated Component Matrix.

Factors and Attributes	C1	C2	C3	C4
Urban Ambiance				
15. Walk in areas with high residential density	0.823			
17. Walk in streets providing enclosure	0.794			
14. Walk in shopping streets/areas	0.743			
16. Walk in areas with mixed land uses	0.729			
19. Walk in streets providing transparency	0.676			
18. Walk in streets with architectural and landscape diversity	0.557			
Pedestrian infrastructure				
8. Walk on sidewalks in good condition		0.795		
9. Walk on unobstructed sidewalks		0.770		
7. Walk on streets with wide sidewalks		0.730		
Connectivity and community facilities				
4. Walk in areas closer to community facilities			0.717	
3. Walk in areas with high street connectivity			0.705	
Access to other modes of transport				
2. Walk in areas closer to car parking				0.806
1. Walk in areas closer to public transport stops				0.758
Cronbach's alpha (α)	0.85	0.79	0.70	0.68

After rotating the components, the cumulative proportion of the described variance did not change as it was kept at 59%, but the variance credited to the components did (Table 6). After rotation, the variance of Component 1 decreased to 21.9%, while the variance of Components 2–4 rose to 16.8%, 10.4% and 9.5% respectively.

Based on the distribution of the attributes by the components, it can be concluded that, for the participants in this study, four main determinants influence their perceptions of walkability. We labelled these determinants as: (i) urban ambiance; (ii) pedestrian infrastructure; (iii) connectivity and community facilities; and (iv) access to other modes of transport. Component 1, urban ambiance, has six attributes related to land use and urban design. Component 2, pedestrian infrastructure, is defined by three streetscape attributes related to pedestrian facilities. Component 3, connectivity and community facilities, consists of two attributes associated with the structure of the street network and to the proximity to public facilities. Finally, Component 4 includes two attributes related to access to other modes of transport.

As mentioned in the Methodology, Cronbach's alpha was utilised to assess the internal consistency of the results. The Cronbach's alpha showed acceptable values for an exploratory study and a good reliability level (0.83). As shown in Table 7, the components of urban ambiance, pedestrian infrastructure and connectivity, and community facilities have Cronbach's alpha values of 0.85, 0.79, and 0.70, respectively. The component access to other modes of transport has a slightly lower value, which is still close to the threshold of 0.70. The Cronbach's alpha values confirmed the reliability of the questionnaire and attested to the confidence of the results.

5. Discussion

According to the results, four main determinants were found to be associated with perceived walkability: urban ambiance, pedestrian infrastructure, connectivity, and community facilities, and access to other modes of transport (Figure 3). These four determinants account for 59% of the total variance, fulfilling the minimum cumulative proportion of variance threshold of at least 50% [67].

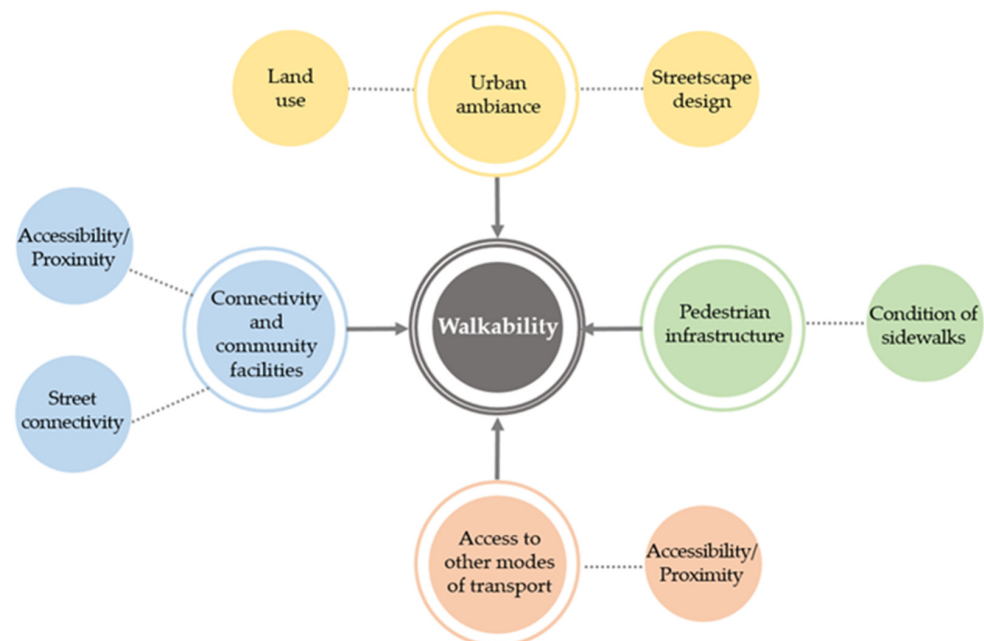


Figure 3. Urban determinants of walkability and main factors.

Urban ambiance is a concept that goes beyond the spatial attributes of spaces as it also involves a socio-aesthetic approach that enables people to grasp everyday urban atmospheres [68]. Determinant 1 was denominated urban ambiance precisely for mixing tangible and intangible attributes and bringing material and affective dimensions to the built environment. "Walk in areas with high residential density" was the attribute with the highest correlation (0.823) with urban ambiance. This finding shows that areas with high residential densities are more conducive for walking than areas with low densities,

confirming previous studies on the association of residential density with higher pedestrian movement, walking time, and people being physically active [12,33,34]. “Walk in shopping streets/areas” obtained a correlation of 0.743 with urban ambiance. This is not surprising since Bologna and Porto, mainly their central areas, contain many commercial streets. Confirming previous research [69], this study shows that shopping is a main daily trip purpose and that commercial streets are attractive for pedestrians since they fulfil various daily needs. “Walk in areas with mixed land uses” obtained a similar loading value (0.729). Providing diverse uses (residential, commercial, services, recreational) ensures that residents can benefit from essentials within their residential areas, reducing travel distances and the need of using motorised transport. Therefore, this finding also confirms previous research showing that areas with mixed uses are more pedestrian-friendly [6,12].

The analysis also indicated that some street design features are strongly correlated with urban ambiance. They are known for influencing the overall experience and satisfaction of walking, but this influence remains relatively unclear due to the difficulty in assessing these attributes, such as enclosure [70]. In our study, “walk in streets providing enclosure” has a correlation of 0.794 with urban ambiance. This attribute reflects the extent to which pedestrians are encapsulated by the built environment. Enclosure influences the perception of space confinement, creating a sense of intimacy, security, and livability [70]. The high correlation of this attribute with urban ambiance could be explained by the network of 38 km of porticoes that cover the city centre of Bologna, which provide a room-like effect and, therefore, a suitable perception of enclosure. “Walk in streets providing transparency” was also correlated with urban ambiance (0.676). This finding indicates that the degree to which people can see or perceive human activity beyond the edge of a street makes a pedestrian environment more attractive, as facade transparency, understood as the proportion of doors and windows with transparent glass, is a proxy for shopping and security (more eyes on the street). “Walk in streets with architectural and landscape diversity” was also correlated with urban ambiance (0.557). This finding suggests that the variety of buildings shapes, sizes, materials, and colours, the diversity of architectural styles, historical buildings, and ornamentation influences the visual interest of pedestrians and make the urban environments more attractive. This conclusion can also be found in some studies on the impact of urban design features on walkability [71]. The correlation of this attribute with urban ambiance could be explained by the remarkable built heritage found in both cities. Evidence from previous studies demonstrated that people do value the architectural heritage and tend to perceive these characteristics as pleasant [72].

In our study, determinant 2 is related to pedestrian infrastructure and three attributes were correlated with this determinant: (i) “walk on sidewalks in good condition” (0.795); (ii) “walk on unobstructed sidewalks” (0.770); and (iii) “walk in streets with wide sidewalks” (0.730). In general, there is evidence that a suitable pedestrian infrastructure improves the comfort and safety of walking and encourages people to walk [73]. A sidewalk in good condition requires the use of smooth, stable, and slip-resistant paving materials and suitable maintenance over time. The second correlation shows that sidewalks free from obstructions are valued by pedestrians. Obstacles on sidewalks are undesirable as they reduce the space available for walking and force pedestrians to make detours [4]. The third correlation confirms that pedestrians prefer to walk on wide sidewalks. Wide sidewalks provide enough space to walk side-by-side and are less sensitive to pedestrian congestion. This correlation could also be explained by the compact urban structure found in the centres of Bologna and Porto, where many sidewalks are not wide enough for walking comfortably namely at peak hours.

Determinant 3 is related to connectivity and community facilities. These facilities include a wide range of services (educational, health, cultural, recreational, etc.) that meet people’s daily needs. The correlation of the attribute “walk in areas closer to community facilities” (0.717) confirms that distance/proximity to community facilities is critical for pedestrians as found in previous research [14,15]. From a planning perspective, this finding suggests that most urban services and amenities should be within appropriate

walkable distances. In turn, “walk in areas with high street connectivity” had a correlation of 0.705 with this factor. For the participants in this study, street connectivity, understood as the availability of alternative routes between destinations, also influences their perceptions of walkability. As found in previous studies, this finding also confirms that well-connected street networks have a significant influence on active travel [42] and on utilitarian trips [48,54].

Finally, determinant 4 comprises two attributes related to the access to other modes of transport, namely car parking (0.806) and public transport stops (0.758). This factor is associated with long multi-stage trips that cannot be done exclusively on foot. As shown in previous studies, an appropriate coverage and density of public transport stops are vital to encourage active travel to public transport [11]. The literature shows that, on average, bus stops should be within a distance of 400 m, while subways and rail stations should be within a walkable distance of 800 m [40]. The attribute “walk in areas closer to car parking” could be explained by the significant share of car trips that are still found in both cities. According to the Census of 2011, more than 50% of the commuting trips to Bologna and Porto were based on individual motorised modes [74,75]. The work of Fonseca et al. [55] on the commuting trips to the central areas of these cities also showed that 47% were multi-stage trips, while 32% were private motorised trips. For these reasons, the proximity to car parking is still seen as an important attribute with an impact on urban mobility.

From the 19 attributes evaluated, six obtained low loading values (≤ 0.500) and were less correlated with the four described determinants. From these, three are related to traffic safety and security, and the remaining to sidewalk facilities. Contrary to previous research [48,76] our findings suggest that “walk in streets with low traffic speed” and “walk in streets with ≤ 2 traffic lanes” were not associated with perceived walkability. In fact, in our previous research [55], traffic safety was not identified as a main barrier preventing utilitarian walking in both cities. Similarly, in a study conducted in Porto, Jabbari et al. [40] also concluded that traffic safety was not a critical factor for pedestrians. The relatively low importance of traffic safety in these cities could be explained by the compact urban layout of both cities, particularly of their city centres, characterised by irregular and narrow streets, which usually only have one or two lanes. The existence of low-speed limits (Zones 30), pedestrian-only streets and temporary pedestrian areas over the weekends could also explain the described perceptions about traffic safety. In turn, the low loading of the public security attribute (“walk in streets with many pedestrians”) is in line with other studies confirming that crime, incivilities, and urban violence are not perceived as a problem deterring people from walking in many European cities [5].

The remaining attributes with low loadings were “walk on sidewalks with street furniture”, “walk on sidewalks with low slopes”, and “walk on sidewalks with trees/greenery”. Slopes and the presence of trees are attributes particularly known for their influence on creating comfortable and attractive pedestrian environments [4,76]. Thus, except for some areas in the historic centre of Porto near the Douro River, both cities are relatively flat, which could explain the low correlation of slopes with walking. The low loading of the attribute “walk on sidewalks with trees/greenery” also contradicts previous research [77]. The compact urban structure of both cities and more specifically the large network of porticoes in Bologna, which replace the role performed by vegetation in terms of shade and protection from adverse weather conditions, could explain the low correlation of this attribute with perceived walkability.

The findings from this study have the potential to guide future research and support planning policies. Urban design attributes have often been assessed by street network characteristics (connectivity) at the neighbourhood scale. Our findings suggest that micro design attributes, such as enclosure, transparency, and architectural and landscape diversity, in conjunction with land use mix and residential density, are equally important to create attractive urban ambiances for pedestrians. It also shows that pedestrian infrastructure attributes, namely sidewalk width, sidewalk obstruction, and sidewalk condition, should be included in walkability indexes, since they have been seldom considered in walkability

studies and indexes [4,5]. Cities should also be planned to be connected through a network of pedestrian infrastructure and to provide increased proximity to community services. This will make walking trips more convenient and attractive. Finally, walking to public transport requires increasing the density of public transport stops/stations, to reduce walking distances and make public transport more competitive than car trips.

This study has some limitations that should be highlighted. Firstly, the described results are based on self-reported preferences that may contain inconsistencies between reported preferences and individual behaviours. Moreover, the preferences of some demographic groups, especially elderly people, are under-represented. Online samples are regarded as biased because aged people with low levels of education and fewer tech-savvy skills are usually more difficult to target [78]. Secondly, the described evaluation is based on perceived walkability in Bologna and Porto. The replication of these findings should be done with caution. These results could be representative of medium-sized European cities, with compact urban structures, historic urban fabric, and similar socio-demographic and cultural characteristics, but could be less appropriate to describe walkability in cities with other morphologies and habits. For example, the low association of safety and security with perceived walkability could result from specificities particularly in the central areas of these cities. Thirdly, besides fulfilling the minimum cumulative proportion of variance threshold of at least 50%, the share of total variance not explained should be further analysed to identify what those are attributes. This will increase the fit of the model and enable a better understanding of the factors influencing the perceptions of walkability. Fourthly, the questionnaire should desirably be conducted at the same period of time in both cities. Due to administrative reasons, in Bologna the questionnaire was administered during the Spring and Summer, while in Porto it was conducted in the Autumn. The evaluation of the various attributes may also reflect the influence of the natural conditions associated to these seasons on perceived walkability. As shown in some studies [79], the season of the year and weather, directly affect perceptions of public spaces. Fifthly, the findings described in this study do not take into consideration the long-term changes in travel behaviour caused by the COVID-19 pandemic. In particular, attributes such as “walk in areas in close proximity to public transport stops”, “walk in areas in close proximity to car parking”, “walk in streets with wide sidewalks”, and “walk in streets with many pedestrians” could be differently evaluated due to the pandemic effects (maintain social distancing outdoors, greater preference for private and active modes of transport over public transport).

Finally, the described results explain the influence of the various attributes in a single way, without exploring the influence that individual characteristics (age, gender, education), walking purposes (utilitarian/recreational), and geographic context (Bologna/Porto) may have in such evaluation. We intend to report the influence of such variables in future studies.

6. Conclusions

During the last century, cities were planned for cars and the normal response to mobility issues was to increase road capacity [80]. Over the last decades, a policy interest for creating more sustainable, healthier, and inclusive transport systems, including more walkable environments, increased worldwide. Planning cities for people and for pedestrians is not a relatively new concept among local planners, but the relevance of walking as a mode of transport is not yet entirely recognised. This happens for various interconnected main reasons. The historically automobile-oriented development pattern resulted in prioritizing the automobile over the other modes of transport. For this reason, assigning existing lanes for the exclusive use of other modes has been a difficult task [80]. Urban sprawl leads to an increase in commuting distance, which in turn leads to increased car use, making walking less convenient. The lack of walking strategies, political commitment, and resources to ensure the sustained and consistent implementation of pedestrian policies has been another noted reason [81]. Walking is often not adequately measured in transport surveys, resulting in an underestimation of its importance as a mode of transport [82]. As

what is not measured is not seen as important, this contributes to neglecting the pedestrian mode in planning practices. And finally, due to the lack of understanding on pedestrians needs and perceptions and on the influence exerted by built environment and streetscape attributes on travel behaviour [83]. To create more pedestrian-friendly cities, planners and decision-makers need to face and overcome these challenges and gaps between theory (what is known) and practice (what has been done).

With this in mind, this study was able to provide some insights in terms of overcoming part of these challenges, namely by shedding light on how the urban space influences citizens' preferences and experiences related to walking. More specifically, this study examined the perceptions of 1438 individuals from Bologna and Porto regarding the influence of 19 built environment and streetscape attributes on walkability. The evaluation conducted with an Exploratory Factor Analysis revealed that 13 attributes were strongly correlated with four urban determinants of walkability: urban ambiance, pedestrian infrastructure, connectivity and community facilities, and access to other modes of transport.

The findings of this study showed interesting insights in terms of future research and planning policies. More specifically, these findings suggest that streetscape design attributes and the quality of pedestrian infrastructure should be taken into consideration when designing pedestrian planning policies and walkability indexes. Our findings also demonstrated that the scope of walkability is broad and relies on multiple interconnected attributes at different scales. These attributes should be analysed in conjunction. Adopting a "silo" approach that overlooks the linkages between the various urban dimensions associated to walkability could result in inefficient policies, inappropriate methods to evaluate walkability, and in potential variability across geographical units. Our findings support the development of policies and methods that combine urban ambiance, pedestrian infrastructure, street connectivity and community facilities, and access to other modes of transport attributes, namely by creating more compact urban structures. Planners and decision-makers should not view walkability in a siloed approach or as a stand-alone goal, but rather as one of the underwriting factors in creating more walkable, livable, and sustainable cities. These findings could be used to improve both the methodological and empirical foundations for evaluating walkability, as well as to contribute to the ongoing discussions on how land-use and transport planning can be guided to improve a more sustainable mobility in our cities.

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