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Research Article

The Multidimensional Structure of Walkability: Theoretical Foundations, Principles and the Relationship with Urban Planning

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ABSTRACT

This study examines the concept of walkability from a multidimensional perspective and presents a comprehensive theoretical evaluation in the context of the relationships between urban design, planning and transportation disciplines. Walkability is addressed with a multidisciplinary approach that enables individuals to move in safe, accessible, comfortable and aesthetic pedestrian environments. In the literature review, it is stated that walkability is addressed functionally in the transportation literature and qualitatively in the urban design and planning literature. The concept is shaped by physical, perceptual and individual factors; the effects of these factors on the pedestrian experience are detailed.

In the study, the principles of walkability are grouped under six headings: Integrity and balance, continuity and orientation, safety and comfort, sociability, accessibility, efficiency and attractiveness. The relationship between each principle and the qualitative characteristics of the urban environment is explained. The economic, environmental and social benefits of walkability are evaluated in the light of various studies, highlighting impacts such as increased physical activity, reduced transportation costs and enhanced social interaction.

As a result, walkability is considered as a fundamental tool for sustainable urban goals, public health, social equity and economic development. In this context, the study aims to present a holistic framework that links walkability not only to physical infrastructure, but also to social cohesion and spatial quality.

Yürünebilirliğin Çok Boyutlu Yapısı; Kuramsal Temeller, İlkeler ve Kent Planlama İlişkisi

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ÖZET

Bu çalışma, yürünebilirlik kavramını çok boyutlu bir bakış açısıyla inceleyerek, kentsel tasarım, planlama ve ulaşım disiplinleri arasındaki ilişkiler bağlamında kapsamlı bir kuramsal değerlendirme sunmaktadır. Yürünebilirlik, bireylerin güvenli, erişilebilir, konforlu ve estetik yaya ortamlarında hareket edebilmesini sağlayan çok disiplinli bir yaklaşımla ele alınmıştır. Literatür taramasında, yürünebilirliğin ulaşım literatüründe işlevsel, kentsel tasarım ve planlama literatüründe ise niteliksel yönleriyle ele alındığı belirtilmiştir. Kavramın fiziksel, algısal ve bireysel faktörlerle şekillendiği; bu faktörlerin yaya deneyimi üzerindeki etkileri detaylandırılmıştır.

Çalışmada yürünebilirlik ilkeleri altı başlık altında toplanmıştır: Bütünlük ve denge, süreklilik ve yönlendirme, güvenlik ve rahatlık, sosyallik, erişilebilirlik ve etkinlik ile çekicilik. Her bir ilkenin, kentsel çevrenin niteliksel özellikleriyle ilişkisi açıklanmıştır. Yürünebilirliğin ekonomik, çevresel ve sosyal faydaları çeşitli araştırmalar ışığında değerlendirilmiş; fiziksel aktivitenin artması, ulaşım maliyetlerinin düşmesi ve toplumsal etkileşimin güçlenmesi gibi etkiler öne çıkarılmıştır.

Sonuç olarak, yürünebilirlik, sürdürülebilir kent hedefleri, halk sağlığı, sosyal eşitlik ve ekonomik gelişim açısından temel bir araç olarak değerlendirilmektedir. Bu bağlamda, çalışmanın amacı, yürünebilirliği yalnızca fiziksel altyapı değil, aynı zamanda sosyal bütünlük ve mekânsal kalite ile ilişkilendiren bütüncül bir çerçeve sunmaktır.

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1. INTRODUCTION

There are many different ways of explaining walkability. In many developed countries, discussions of walkability focus on promoting a shift from motorized to non-motorized transport for short trips, or on promoting walking as a health leisure activity. In developing cities, walking is often seen as providing mobility for poor people.

The term "walkable" has been in use since at least the eighteenth century. In contrast, "walkability" is a more recent term that is relatively rarely defined in dictionaries but widely used [1]. Therefore, the physical principles and characteristics of walkability that can be observed in the built environment or that should be considered when designing walkable neighborhoods should be determined through a comprehensive review of the literature [2].

There is now a well-established literature showing that increased walking rates have positive public health outcomes [3]. It is also recognized that low-carbon cities, which are necessary to adapt to climate change, require walkable and transit-oriented neighborhoods [4].

The concept of urban 'walkability' has gained significant importance as it bridges urban design and planning with multidisciplinary fields including public health, climate change, economic efficiency, and social equity. Despite its growing relevance, walkability remains a somewhat ambiguous concept, posing challenges in its precise definition and practical application. Nonetheless, the idea of a 'walkable city' has become a prevalent theme in both popular and academic discussions concerning the future of urban environments. [1].

Walkability is the concept of how suitable and favourable a place is for pedestrian movement. This is determined by a combination of factors such as streets, pavements, pedestrian crossings, safety, accessibility, environmental quality and social interaction. Walkable areas are socially and economically vibrant places where people can meet their daily needs on foot, offering safe and comfortable walking environments.

The organization of the study starts with **a literature review**. In this section, how walkability is addressed in transportation, planning and urban design literatures is evaluated comparatively. While transportation literature adopts a more functional, engineering-oriented approach, planning and design disciplines emphasize the qualitative, social and perceptual dimensions of walking.

Subsequently, **the concept and principles of walkability** are discussed in detail. Conceptual explanations are made under the titles of integrity and balance, continuity and orientation, safety and comfort, sociability, accessibility and effectiveness, and attractiveness, which are the basic principles of walkability. How these principles are reflected in urban spaces and how they affect the user experience are presented with the support of the literature. In addition, this chapter explains the **economic, environmental and social** benefits of walkability and evaluates the contribution of these benefits to sustainable urban life.

Then, under the heading **of factors affecting walkability**, the physical environment, perceptual qualities and individual characteristics were grouped under three main headings; the effects of these factors on walking behavior were analyzed. The contributions of variables such as the quality of physical infrastructure, how the individual perceives the environment and personal characteristics to walkability are supported with diagrams and tables.

Finally, the study discusses **the methods used to measure walkability**, examines existing indices and assessment tools, and provides criteria that will enable the transition from theoretical to practical application. In this context, the study aims to provide not only a conceptual depth on walkability but also a guiding resource for planning applications. The research concept mentioned here is given in Figure 1.

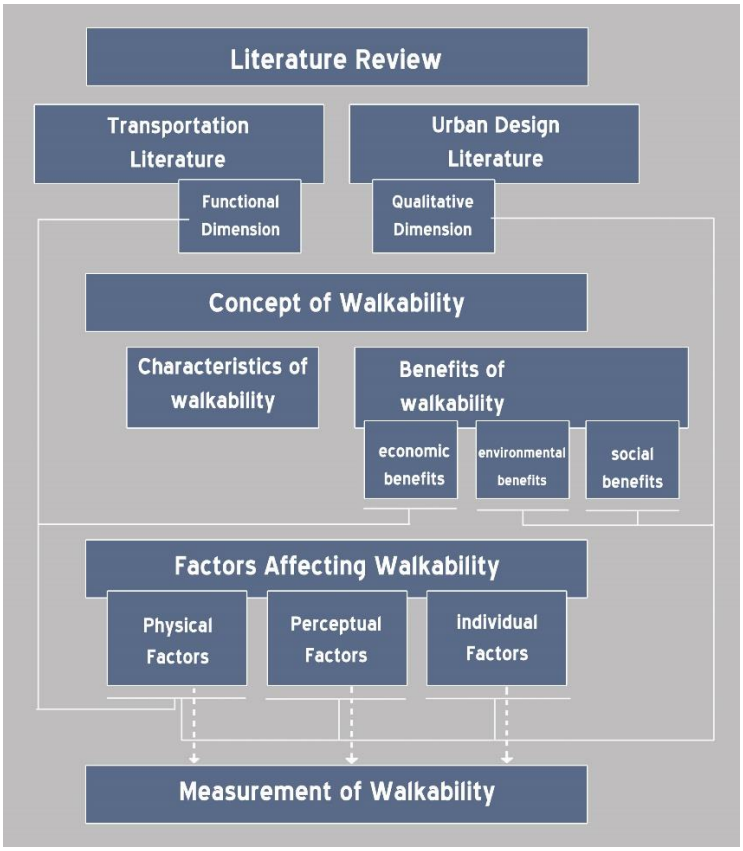

Figure 1. Conceptual Diagram of the Research

2. MATERIALS AND METHODS

This study is a qualitative research that aims to evaluate the concept of walkability in the context of its theoretical foundations, principles, benefits and influencing factors. The methodology of the study is based on a comprehensive literature review. In the literature review, national and international sources from multidisciplinary fields, particularly urban and regional planning, urban design, transportation planning and public health, were consulted.

Academic articles, master's and doctoral theses, scientific reports and theoretical books on walkability in the national and international arena were used as material. Within the scope of the research, the historical development, conceptual framework and components of walkability were analyzed; how the concept is defined in the planning literature and how it is handled in different disciplines were evaluated comparatively. For this purpose, prominent academic studies such as Dovey & Pafka (2020), Gehl (2010), Southworth (2005), Ewing & Handy (2009) and Kato (2020) were used as the main references.

3. RESULTS AND DISCUSSION

3.1. Literature Review

Recently, "walking" has become an important research topic for planning, transportation and public health. These studies aim to encourage people to "walk" because of the environmental, economic and social benefits of walking. Walkability encompasses several principles that enhance pedestrian experiences and promote sustainable urban environments. Key factors include connectivity, proximity, land use mix and retail density, which collectively form a framework for assessing walkability in various urban contexts [5].

An urban planner, an urban designer, is working to create a walkable environment that will increase the act of walking, but they have little scientific evidence and tools to support their goals and claims. This is because there is a lack of collaboration between urban design, planning and transportation researchers. Most walkability studies have been micro-level transportation-based. This does not fully test walking behavior. Likewise, urban designers and planners have not yet developed successful methods for measuring and assessing walkability.

3.1.1. Walkability in transportation literature

In terms of transportation, most studies have focused on motorized transportation and little research has been done on the act of walking. In this sense, studies were conducted to create more efficient traffic flow in post-war American cities, and these early street designs paid little attention to a walkable environment. In the early 1970s, researchers began to pay more attention to pedestrians and walking behavior [6]. Walkability is the sum of the physical and social characteristics of the urban environment that enhance pedestrian mobility and suitability for pedestrian traffic. In transportation planning, walkability refers to the ability of individuals to walk short distances in their daily lives without using a vehicle. This concept is critical for designing healthy, sustainable and accessible cities. Walkability reduces the environmental impacts of urban transportation and has positive impacts on social health by encouraging physical activity [7].

Walkability studies are usually evaluated based on factors such as urban density, land use diversity, street network layout and infrastructure quality [8]. In addition, pedestrian safety, aesthetic quality and opportunities for social interaction are also important parameters for walkability [9].

However, some studies still resort to traffic engineering in relation to walking, with the main objectives focusing on pedestrian speed, distance between pedestrians, and the flow of pedestrian movement. In fact, in the transportation literature on walkability, functional values are often emphasized. Thus, they aim to design roads with traffic safety. Clearly, concepts such as encouraging pedestrian activity and spreading the benefits of walkability throughout society are not comprehensively addressed in the transportation literature.

3.1.2. Walkability in planning and urban design literature

Walkability is a multidimensional concept in planning and urban design literature that defines the level of people's ability to meet their daily needs on foot in the city. A walkable environment refers to spatial organizations that prioritize pedestrian movement, where elements such as accessibility, safety, comfort and aesthetics come together. In this respect, walkability is closely related not only to physical environmental arrangements but also to social integration, public health and environmental sustainability [10].

Since Jane Jacob's influential work in the early 1960s, many urban design and planning theorists have made creative contributions to the creation of good walking environments [11]. They have tried to answer the question "What makes for a pleasant walking experience, rather than simply presenting what makes for efficient walking flow?" [11].

Planning and urban design literature emphasizes the need for residential streets to be shared by all types of users, not just automobile drivers. In the planning literature, walkability is considered together with the principles of **mixed-use**, **density** and **connectivity**. These three components are the basic tools for creating environmental conditions that encourage pedestrian movement [12]. In contrast to the transportation literature , the non-functional aspects of walking (such as a sense of safety and visual interest) are addressed in the planning and urban design literature.

3.2. Walkability Concept

Walking is the most fundamental and longstanding mode of transportation, integral to daily travel for individuals. Despite its ubiquity, walking often receives insufficient consideration in areas such as land use planning, zoning, subdivision design, and street or highway development. People rely on pedestrian networks for a variety of purposes, including shopping, commuting, accessing public transit, exercising, and recreation.

Kato [13] defined pedestrian accessibility as "the attractiveness of daily life, associated with safety and comfort and residential environments that encourage walking or cycling". Pedestrian accessibility has been studied primarily in the field of public health as a concept that contributes to improving the health of individuals.

Kato and Kanki [14] defined walkability as "pertinent to residential settings that facilitate walking or cycling while ensuring safety, comfort, and access to daily life amenities." Walkability has been examined as a construct that enhances the well-being of inhabitants, particularly within the domain of public health. [14].

Contemporary urban planning research increasingly emphasizes the design of living environments that support and enhance walkability [13].

Discussions on walkability in many developed countries focus on supporting a shift from motorized to non-motorized vehicles for short trips or promoting walkability as a healthy leisure activity. In developing countries, walkability is seen as providing mobility for poorer communities. Some urban planners think of walkability in terms of the spatial land use organization of the city [15].

Walkability is commonly assessed based on the extent to which the built environment provides environmental, health, economic, and safety benefits for pedestrians. More generally, it reflects the degree to which an area supports and encourages walking as a mode of transportation and everyday activity.

Kato [13] This discourse posits that pedestrian-friendly urban environments not only enhance the well-being of inhabitants but also facilitate the achievement of Goal 11 (Ensure cities and human settlements are inclusive, safe, resilient, and sustainable) within the framework of the Sustainable Development Goals (SDGs). This research proposes the hypothesis that pedestrian-friendly urban environments contribute not only to the enhancement of resident health but also to the attainment of Goal 11 (Ensure cities and human settlements are inclusive, safe, resilient, and sustainable) as delineated in the Sustainable Development Goals (SDGs) of the 2030 Agenda.

3.2.1. Walkability principles;

Coherence and Equilibrium:

"Coherence and Equilibrium", one of the basic principles of walkability, refers to the continuity, consistency and spatial functionality of pedestrian routes, as well as pedestrian-vehicle balance and social inclusion [16]. This principle aims to provide a harmonious and balanced pedestrian environment on both physical and social levels. Coherence refers to the **continuity, directionality and interconnectedness** of pedestrian routes. Designing pedestrian routes that connect different parts of the city in a perceivable and comprehensible way is of great importance for pedestrian safety and wayfinding [16]. This integrity should be supported not only by physical connections but also by visual integrity and functional harmony. Equilibrium refers to the fair distribution of pedestrian paths between **vehicular traffic, commercial areas, public space use and social groups**. Pedestrian paths should be accessible to all user groups (children, the elderly, people with disabilities, etc.), and should be socially equitable (Gehl, 2010). Awnings, facade elements, lighting, signage and other features along buildings and sidewalks should be appropriate to **the human scale**. A balance between modes of transportation that supports pedestrian participation.

Continuity and orientation:

Continuity and orientation include elements that facilitate pedestrian wayfinding by providing legibility in the city. Kevin Lynch's [17] concept of "imageability" is important in this context; urban space should be easily understandable, identifiable and orienting for users. This orientation should be supported by landmarks, wayfinding signage, clear visual hierarchy and consistent streetscapes. In walkable urban environments where there is continuity of design and use structure integrated with the pedestrian system, buildings define streets and public spaces. Thus, it directs pedestrians to public spaces and open spaces in a continuum [1]. In a pedestrian-friendly city, continuity and orientation work together to provide not only physical access but also **psychological safety and spatial comfort**.

Safety and Comfort: This includes elements such as the use of safe and passable paving materials on sidewalks and pedestrian crossings. Building safe, connected networks of sidewalks and crosswalks is an obvious starting point. Pedestrians are a diverse age group, from children to adults, and as users of space they need to feel safe and secure. Such safety includes low accident and crime rates in the area, behavior of motor vehicle users that does not threaten or endanger pedestrians, adequate pedestrian crossing facilities, and low levels of barriers or conflicts between pedestrian path users [18].

Pedestrians vary from children to adults, as space users should be able to feel safe and secure. The security in question includes the low number of accidents and crime in the area, the behaviour of motorized vehicle users that does not threaten or endanger pedestrians, adequate road crossing facilities, and low barriers or conflicts between pedestrian lane users [18].

Sociability: Being conducive to individual and community interaction. Sidewalks should provide a variety of uses and activities for different urban space features. While land use diversity significantly enhances social cohesion, high density can negatively affect it. Walkable urban designs encourage social interactions, leading to stronger community ties [19].

Accessibility and Efficiency: Accessibility and Efficiency refers to the principle that pedestrian mobility in urban areas should be both accessible to all and provide an efficient and functional transportation alternative. This principle indicates that walkability is not only a physical infrastructure, but should also be evaluated in terms of social justice and urban transportation performance [20]. Accessibility encompasses the equal access of **all individuals (children, the elderly, people with disabilities)** to pedestrian pathways and public spaces within the city. This is not limited to the removal of physical barriers, but also includes the reduction of social and economic barriers [21]. It is necessary to ensure that all pedestrian environments are accessible to the fullest extent possible. Minimal delay along the walking route and frequent and dense interconnected pedestrian routes are fundamental to walkability in terms of shortening existing and perceived distances. Efficiency refers to pedestrian transportation being **an efficient** option **in terms of time, distance and energy**. Walking routes should be direct, short and free of obstacles; unnecessary circuitous routes should be avoided [16].

Attractiveness: Pedestrian paths (sidewalks) in a clean, efficient and well-maintained environment near activities of interest. Pedestrian features should be **comfortable and attractive**. Pedestrian paths should create **a sense of comfort** for pedestrians and should be free of obstructions and **conflicts of interest**. At the same time, they should be **attractive in** a way that encourages the use of existing pedestrian routes. **Comfort and attractiveness** can be achieved through a good arrangement of supporting facilities The properties in the pedestrian path must be comfortable and attractive. Pedestrian paths must be able to create a sense of comfort, there are no obstacles, and there is no conflict of interest. Pedestrian paths must also be attractive to attract pedestrians to use the existing pedestrian paths. Comfort and attraction can be achieved by arranging good support facilities. [18].

3.2.2. Benefits of walkability

As well as making people physically active and healthy, walkability provides more opportunities for people of all ages to interact socially and encourages safe walking together. Establishing good pedestrian networks in local areas has many economic, environmental and social benefits for that area [22] (Table 1).

Economic benefits

Cities and towns that develop recreational programs that promote the use of pedestrian pathways can help revitalize downtowns, increase private investment, increase property values, promote tourism, and foster a good business climate [22]. Main streets, with good sidewalks, can provide economic benefits as pedestrians can easily and safely access shops, restaurants and local services. Walkable areas attract businesses and contribute to local economies by increasing property values [23]. Improved pedestrian infrastructure can lead to more foot traffic, benefiting local retailers [18].

Environmental benefits

Walking is the most environmentally friendly mode of transportation with a low environmental impact without air and noise pollution. Walkability contributes to a reduced reliance on motor vehicles and thus reduces carbon emissions [24]. Green pedestrian pathways support the green city concept, enhancing urban aesthetics and improving air quality [18]. Urban designs that prioritize walkability can lead to healthier lifestyles, reducing health costs associated with sedentary behavior [23] (Table 1).

Social benefits

Walking facilitates fundamental mobility and enables access to socially significant destinations, including healthcare, education, employment, and other essential services. Moreover, walkable urban design fosters social interaction, thereby contributing to the development of stronger community bonds. Land use diversity significantly enhances social cohesion, while high density can negatively affect it [19].

Case studies show that neighborhoods designed with walkability in mind promote a sense of belonging among residents [25]. The social benefits of walkability can be summarized as follows.

Table 1 . Benefits of walkability

Economic;	- Improved accessibility, especially for non-drivers - Reducing transportation costs - Can enhance regional commercial engagement and workforce opportunities. - Supports transportation and other alternative modes - Savings in health costs by improving exercise - Provides special support for some businesses, such as hiking tourism
Environmental;	- Reduces land use needs for roads and parking lots - Ensures the protection of open spaces - Reduces energy consumption and pollution emission - Improves aesthetics - Reduces water pollution - reduces the "heat island" effect
Social;	- Improves accessibility for people with disadvantaged transport - Reduces external transportation costs (e.g. collision risk, pollution) - Increases opportunities to protect cultural resources (such as historical buildings) - Increases exercise

While walkability principles offer numerous advantages, challenges such as financing, urban sprawl and limitations of existing infrastructure can hinder their implementation. Addressing these issues is crucial to realizing the full potential of walkable urban environments.

3.3. Factors Affecting Walkability

Walkability is a multidimensional concept that is shaped not only by physical infrastructure, but also by how the individual perceives his/her environment and personal characteristics (Figure 2). In this context, the factors affecting walkability can be analyzed in three main groups: **physical**, **perceptual** and **individual** [1, 20, 26]. Figure 2 shows that these factors progress from objective to subjective and that each factor directly affects gait quality [27].

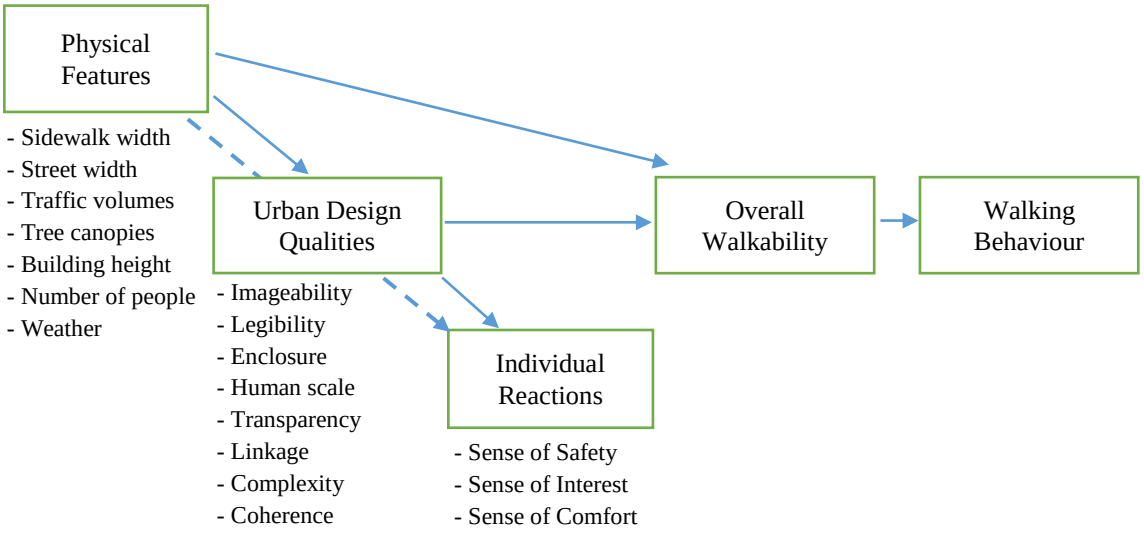

Figure 2. The relationship between environmental perception, physical characteristics of the built environment and walking [27]

3.3.1. Physical environment factors

Terri Pikora, Billie Giles-Cortia, Fiona Bulla, Konrad Jamrozika, Billie Giles-Cortia, Fiona Bulla, Konrad Jamrozika and Rob Donovan in 2003, "Developing a framework for assessing the environmental determinants of walking and cycling" [28].

-Functional dimension; direct route, slope, intersection design, intersection distance, free type, other access points, road continuity, road design, road location, road maintenance, road surface, road width, street design, street type, street width, traffic control devices, traffic speed, traffic volume, road type, parking areas.

-The safety dimension includes crossing aids, gateways, lighting, pavement width, and physical boundaries that protect from vehicular traffic.

-The aesthetic dimension includes cleanliness, landmarks, garden maintenance, parks, pollution, trees, architecture, street maintenance.

-Destination dimension includes local facilities, parks, public transportation, services, shops, car parking areas, bicycle parking areas.

These elements directly affect pedestrian safety and comfort. A quality physical environment makes walking both **safer and more attractive** [16,29].

In Ricky Pentella's 2006 study, the relationship between environmental factors and walkability is concisely presented in Table 4. [30].

Table 4 . Environmental characteristics and their relationship with walkability [30].

Housing density	High-density neighborhoods encourage mixed-use development (It means that the diversity of interest will cause an increase) Associated with increased diversification of retail/services. (In the short term, the result is that the distances between expectations and aspirations become more walkable)
Street connection	More street connections provide potential pathways for walking and greater accessibility. Great neighborhood connections shorten distances to destinations
Public transport congestion	High public transport density enables shorter, more walkable distances to alternative modes of transport (buses, etc.)
Crime intensity	High intensity crime restricts walking in the neighborhood. Perceived deficiencies in pedestrian safety often lead individuals to favor more secure modes of transportation, such as private vehicles or other alternatives.
Mixed uses	Multiple and diverse retail/service offerings encourage special, frequent and short shopping trips on foot.

3.3.2. Perceptual attributes

It is not only the physical environment that influences pedestrian behavior. How people **perceive, feel and experience** the environment also directly affects their walking decisions. In this context, **perceptual factors** include individuals' psychological and emotional responses to the environment and constitute the subjective aspect of walkability. The urban design literature highlights a range of perceptual attributes of the urban environment that affect walking behavior. These attributes encompass, contrast adaptability deflection, ambiguity, comfort, centrality, clarity, compatibility, , complementarity, continuity , dominance, distinctiveness, diversity and depth [27].

In Ewing, Handy, Brownson, Clemente and Winston's 2006 study, this long list was reduced to the attributes listed below by combining similar concepts and defining different concepts.

Imageability

Memorability is the qualities that make a place distinctive, recognizable and memorable. **Imageability** is the capacity of an urban environment **to be easily recognized, remembered and placed on the mental map of** individuals. According to Kevin Lynch, a city with high imageability provides people with **ease of orientation**, **spatial belonging** and **perceptual clarity**.

A place has "high imagebility" when certain physical elements and their arrangement attract attention, evoke emotions and leave a lasting impression.

Legibility

Legibility refers to the ease of understanding and navigability of the spatial structure of a place as a whole. Legibility is directly related to the perceptual dimension of walkability. Ewing and Handy [26] list legibility among urban design attributes that affect walkability. According to them, environments with high legibility levels give pedestrians a sense of direction and encourage walking. The role of legibility is important in individuals' mental mapping processes [31]. Clear visual and spatial cues facilitate pedestrian orientation and encourage walking, especially in large cities.

Enclosure-enclosure

This measure reflects the degree of enclosure in streets and public spaces, which are visually defined by elements such as buildings, walls, and trees. While empirical research on the sense of enclosure in streetscape design remains limited, urban planning and design studies indicate that visual enclosure significantly influences pedestrian movement. [32].

There is limited empirical research on the sense of enclosure within the streetscape's urban design qualities. However, studies in urban planning and design indicate that visual enclosure plays a significant role in influencing pedestrian movement.

Human Scale

Human scale means that the physical elements within the city are appropriate to human dimensions. This makes pedestrians feel safe, increases social interactions and promotes walkability. Human scale is a fundamental principle for making public spaces welcoming, accessible and usable [33]. Spaces designed at a human scale improve the spatial experience of pedestrians, as such spaces make people feel safer, increase social interactions and promote walkability.

Transparency

Transparency is a critical element in urban design that affects the pedestrian experience. Providing visual access from streets to interiors and vice versa positively affects pedestrian mobility. Transparency indicates the degree to which people can see or perceive what is happening beyond a street or other public space. Shields [34] and Gehl [33] argue that transparent façades (e.g. glass storefronts or open terraces) stimulate street life and increase social interaction. More specifically, it indicates the degree to which people can see or perceive human activity outside the boundaries of the space. Walls, windows, doors, gates, fences, mid-block gaps, landscaping and openings are physical elements that affect transparency.

Linkage

Linkage includes elements that provide a visual or physical connection from a building to a street, from a building to a building, from a street to a street, or from one space to another. Linkage, however, should be supported not only by the interconnection of physical pathways, but also by directional signage, visibility and the appropriate distribution of activity points [4]. This holistic approach strengthens walkability and promotes urban mobility. Marshall [35] has shown that urban roads offer better connectivity in grid systems, which increases pedestrian mobility. Connectivity can be seen along a longitudinal street or across a lateral street.

Complexity

Complexity is the coexistence of a variety of architectural elements, land uses, building types, landscape elements and activities in urban areas. This diversity provides visual interest and discovery in the pedestrian environment, reduces monotony and increases the desire to walk [36]. The complexity of an area is determined by the diversity within its physical environment, including variations

in buildings, architectural styles and ornamentation, landscape features, street furniture, signage, and the variety and density of human activities. Ewing and Clemente [37] highlighted that pedestrian movement and street activity tend to be higher in locations exhibiting greater environmental complexity.

Coherence

Coherence refers to the understanding of visual order. Coherence is the visual and functional harmony between streets, buildings, open spaces and infrastructure elements in urban areas. Coherence creates a sense of comfort and confidence in pedestrian movement because it facilitates understanding and orientation [17].

3.3.3. Individual factors

In addition to environmental factors, individual factors should also be considered in walkability studies [38]. Individual factors include age, gender, physical health, pedestrian experience, perception of safety, time constraints and personal preferences [39].

Individual factors are related to the individual's sense of safety, sense of comfort and level of individual interest. Enhancing the walkability of physical environments is closely linked to psychosocial factors such as social support, self-efficacy, and positive attitudes toward physical activity. Furthermore, individual characteristics related to walkability may interact with these psychosocial elements, thereby encouraging increased walking behavior. Personal perceptions and psychological factors are also important; for example, the perception of an area as safe or attractive influences the decision to walk [40]. Therefore, environmental and individual factors should be considered together in walkability analyses. An individual who perceives a high benefit from physical activity is influenced by environmental factors to the same extent. For example, if an individual does not think that they benefit from physical activity, street connectivity will not affect that individual (Figure 3).

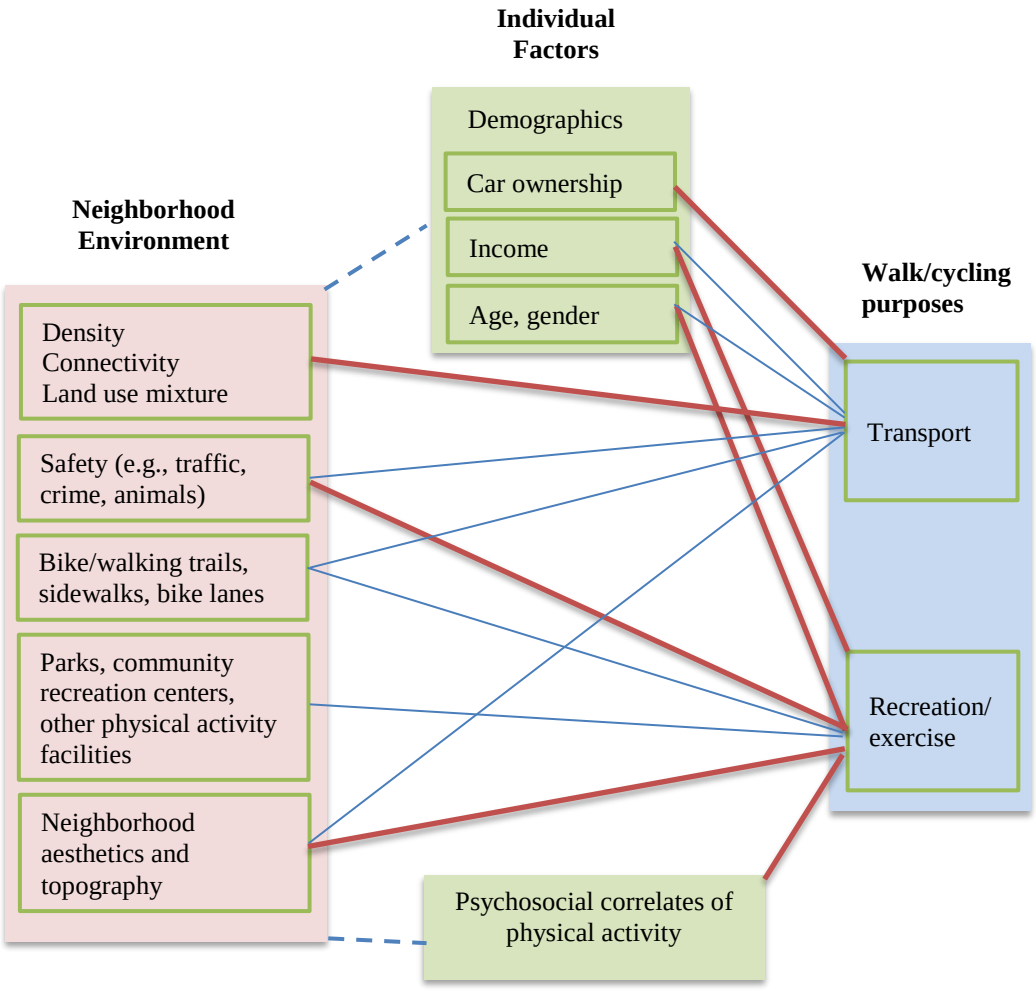

Figure 3 . Relational dimension of walkability with individual and environmental factors. [41]

The nature of the connections in the model emphasizes the strength of the relationships (strong, weak, or indirect), thereby detailing the causal structure. In this context, in Figure 3, connections shown with **bold red lines** represent strong relationships, those with **thin blue lines** indicate weak relationships, and **dashed blue lines** represent indirect relationships. The psychosocial dimension of physical activities shown in Figure 3 consists of variables such as self-efficacy, perceived benefits, perceived barriers, social support and enjoyment of physical activity.

3.4. Methods Used to Measure Walkability

One of the important studies in measuring walkability is the Pedestrian Environmental Factor Index developed by the "Making the Land Use, Transportation, Air Quality Connection" research group in 1993. In this index, four basic indicators are specified; ease of street crossings, sidewalk (pedestrian path) continuity, local street characteristics, topography. Each indicator was given a score and walkability was calculated for each of the 400 transportation analysis zones.

Since mid-1990s, researchers have developed various indices to evaluate the walking environment, including the pedestrian level of service, transportation convenience factor, environmental rating scale, and walking suitability assessment. These studies aim to establish reliable tools for examining the relationship between the built environment and physical activity influencing walking behavior. One notable study compiled an extensive list of 162 built environment attributes categorized under accessibility, satisfaction, perceived traffic safety, and perceived crime safety, with a strong focus on precise measurement of each item by the researchers.

There are efforts to develop environmental audit methods and GIS-based environmental models to quantify the interrelationship between the built environment and physical activity. The aim of this research is to develop an operational definition of walkability that will provide an objective way of measuring and quantifying walkability in a systematic way.

In 2006, Ewing and Handy conducted a qualitative urban design study in terms of explaining walkability and evaluating its characteristics. They made evaluations on how to make more attractive urban designs to increase the walkability of streets. They analyzed the measurement of walkability and tried to reveal statistical relationships. Based on the results of multidimensional models, they developed an operational definition and measurement protocols for urban design features that affect walkability. Litman's "Economic value of walkability" evaluates walkability under the categories of accessibility and savings, health, external costs, efficient use of space, livability, economic development and equity and specifies measurement techniques (Table 5).

Table 5. Measurement techniques for some walkability criteria

Description	Criteria	Measurement Method
Accessibility and Savings	Easy access to goods and services, especially for disadvantaged groups	Travel modeling, option analysis
Health	Amount of active transportation and health impacts	Travel and health surveys
External Costs	Reduced traffic and environmental costs	The impact of walking on reducing car use
Efficient Land Use	Pedestrian-oriented use of space	Economic, environmental and social assessment
Livability	Quality of local environment and social interaction	Property value, business volume, consumer surveys
Economic Development	Change in trade and local spending	Market research, property evaluation
Equality	Distribution of resources and opportunities	Equality indicators

Cities that promote walkability and foster frequent face-to-face interactions tend to be more productive within an innovative knowledge economy, where the generation of ideas, creativity, and knowledge exchange are paramount [42]. Moreover, cosmopolitan cities characterized by accessible and walkable public spaces are increasingly acknowledged as vital for promoting social equity across diverse dimensions such as class, ethnicity, gender, age, and ability [43].

Sadeghi and Di Marzo Serugendo have elucidated that although conventional methodologies yield significant insights, they frequently overlook socio-economic and demographic variables that exert influence on pedestrian behavior. In this vein, considerable attention is directed towards instruments such as Geographic Information Systems (GIS), Walk Score, and Agent-Based Modelling (ABM) for the evaluation of walkability. ABM facilitates dynamic simulations that integrate individual preferences, environmental conditions, and urban design attributes, thus promoting a more profound comprehension of pedestrian mobility [44]. Other methods used to measure walkability are indices that focus on dimensions such as density, diversity, design, destination accessibility, and distance to transit. However, these criteria often focus solely on opportunities within walking distance and do not adequately capture the morphological structure of the physical environment [45].

4. CONCLUSIONS

This study comprehensively evaluates the concept of walkability using a multidimensional approach, assessing its place in urban planning, urban design, and transportation. The findings reveal that walkability is an experience that is shaped not only by the physical environment but also by the way the individual perceives the environment and individual characteristics, emphasizing the necessity of a holistic approach in the measurement and implementation of the concept. The results of the research show that increasing walkability not only encourages physical activity, but also positively affects many urban processes such as economic vitality, environmental sustainability, social integration and public space use. In particular, spatial planning principles such as density, land use diversity and connectivity, and urban design criteria such as safety, accessibility, aesthetics and orientation stand out as key determinants in the construction of walkable environments.

In this context, a number of recommendations have been developed for urban design and planning disciplines. Mixed-use areas where daily needs can be met on foot should be encouraged, pedestrian-first street designs and uninterrupted pedestrian connections should be provided. The connectivity of the street network should be strengthened and pedestrian routes should be organized in a directive and comprehensible manner. Comfort should be increased with building facades, shades, seating areas and lighting elements appropriate to human scale; at the same time, public spaces should be designed to encourage social interaction. The perceptual quality of urban space should be supported by visual clues that facilitate wayfinding by addressing concepts such as legibility and mental mappability. Physical and social arrangements to ensure access for disadvantaged groups such as the elderly, children and the disabled should be expanded, thus strengthening the principle of social justice. Indices such as Walk Score and Pedestrian Environment Factor should be adapted to the local context to measure the level of walkability, and these tools should be used in the impact analysis of planning decisions.

As a result, walkability is not only a mode of transportation, but also a fundamental approach in the creation of healthy, livable, equitable and sustainable cities. In this context, a multidimensional approach to walkability by planners, designers and decision makers has the potential to improve the quality of social life beyond supporting individual mobility. As a strategy that promotes social interaction, economic efficiency and environmental sensitivity, the creation of walkable environments plays an important role in shaping the cities of the future.

AUTHOR CONTRIBUTIONS

The article is written by a single author.

CONFLICT OF INTEREST

There is no conflict of interest.

ETHICS

There is no ethical problem in the publication of this article.

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