



Decoding Walking Speed for Sustainable and Livable Cities: A Thematic Review

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Abstract

Walking speed, a fundamental yet often overlooked aspect of pedestrian behavior, is a critical factor in shaping the design and functionality of sustainable and livable cities. This thematic review analyzes the multifaceted determinants of walking speed, drawing upon research from transportation planning, urban design, public health, and biomechanics. We explore how individual attributes, such as age, gender, and fitness level, interact with environmental conditions, including terrain, weather, crowd density, and the quality of pedestrian infrastructure, to influence walking speeds. We also delve into the role of psychological factors, such as motivation, stress, attention, and cultural dimensions, recognizing that social norms and clothing choices can impact pedestrian movement. By decoding these complex interactions, this review aims to highlight the significance of walking speed in creating truly walkable urban environments. We argue that incorporating an understanding of walking speed into data-driven urban design interventions can lead to a multitude of benefits, including reduced car dependence, increased active transportation, and enhanced pedestrian safety, ultimately contributing to more sustainable, equitable, and livable cities.

1. INTRODUCTION

Walking, a fundamental mode of human movement, is more than just a means of transportation; it is integral to the vitality, health, and sustainability of urban environments [1]. The principle of sustainable urban design seeks to create built environments that meet present needs without compromising the ability of future generations to meet theirs [2]. This requires the careful integration of social, economic, and environmental considerations in the design and planning of cities, with a strong emphasis on reducing car dependence, promoting public health, and enhancing quality of life.

Walkability, a cornerstone of sustainable urban design, defines the ease, comfort, and safety with which people can walk within a given area [3]. Achieving high levels of walkability involves addressing a complex network of factors: a diverse mix of land uses, pedestrian-friendly infrastructure that prioritizes human scale, well-connected street networks, and a vibrant street life that fosters social interaction. However, a crucial element often overlooked in walkability discussions is walking speed.

Walking speed is not merely a measure of individual pace. It reflects a dynamic interplay between the physical attributes of the built environment, individual characteristics, social norms, and psychological influences [4]. By understanding the factors that affect walking speed, we gain a deeper understanding of how individuals experience their urban surroundings.

Optimizing walking speed contributes significantly to sustainable urban design due to its impact on:

- **Reduced Car Reliance and Lower Carbon Emissions:** Walkable environments designed to facilitate faster, and more comfortable walking speeds can encourage a shift from driving to walking, particularly for short trips. This directly reduces car dependence and greenhouse gas

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emissions. Studies [5] show a correlation between improved pedestrian infrastructure, increased walking speeds, and subsequent reductions in vehicle miles traveled and carbon emissions.

- **Active Transportation and Public Health:** Walking, as a readily accessible form of physical activity, plays a vital role in improving public health. Creating urban environments that support faster and more enjoyable walking experiences can catalyze active transportation, combating increasingly sedentary lifestyles. Research [6] links increased walking speeds to higher levels of physical activity, contributing to improved cardiovascular health and lower obesity rates.
- **Efficient and Livable Urban Spaces:** By understanding and optimizing walking speed, urban planners can create more efficient and livable urban spaces [7]. For example, crosswalk timing based on average pedestrian speeds can significantly reduce wait times, improving both pedestrian and traffic flow efficiency.

This paper explores the multifaceted determinants of walking speed and their implications for sustainable urban design through the following research question: **How can understanding walking speed contribute to urban design practices to improve pedestrian mobility and create more walkable urban environments?**

This thematic review will address this question by examining:

1. **The Multi-faceted Determinants of Walking Speed:** We will analyze the individual, environmental, psychological, and cultural factors influencing walking speed, drawing upon diverse research in transportation planning, urban design, public health, and biomechanics.
2. **Walking Speed and Sustainable Urban Design:** We will explore the relationship between walking speed and the core principles of walkability and pedestrian-oriented design strategies.
3. **Sustainable Design Solutions for Optimizing Walking Speed:** We will examine specific urban design solutions that can be employed to optimize walking speed and create more pedestrian-friendly environments, including physical infrastructure improvements and integrating smart city technologies.

By decoding the complexities of walking speed, this review aims to provide valuable insights for urban designers, planners, and engineers, ultimately contributing to the creation of more sustainable, efficient, and livable urban environments.

2. RESEARCH PROCESS AND METHODOLOGY

This research utilizes a scoping review methodology, a valuable approach for investigating the range of literature related to walking speed. This method allows for a thorough examination of existing studies, offering a broad view of key themes and patterns within the body of work [8]. Articles were selected and analyzed based on predefined inclusion criteria, with the results organized into distinct thematic categories (Table 1). The goal of this section is to systematically present the scope of research on walking speed, identifying the main themes and sub-themes found in the literature.

Table 1. Search Strings Used Across Databases.

Database	Search String
Web of Science	("walk*" AND speed*) OR ("walk*" AND pace*) OR gait AND analys*)
ScienceDirect	walking AND (speed OR analysis OR pace) OR gait analysis

In conducting this scoping review, we followed the guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) framework. PRISMA-ScR is a widely recognized methodology, commonly applied in fields such as disaster preparedness and response studies [9]. The process is structured into three main stages: Identification, Screening, and Eligibility Evaluation (Table 2).

Table 2. Inclusion and Exclusion Criteria Applied During Screening and Eligibility Assessment.

Screening		
	Inclusion Criteria	Go to the Next Step
1-Title Screening	The title included all these keywords: (walking speed, walking pace, gait analysis)	The title included one of these keywords: (walking speed, walking pace, gait analysis)
2-Keyword Screening	(walking speed, walking pace, gait analysis) were found in the article's keywords.	The keywords included one of these keywords: (walking speed, walking pace, gait analysis)
3-Abstract Screening	The problem statement clearly delved into walking speed.	The problem statement delved into walking speed
Eligibility Assessment		
	Inclusion Criteria	Exclusion Criteria
Introduction, methodology, and conclusion review	Studies discuss, measure, analyze walking speed, measurement techniques, technologies, and models.	Solely focus on medical aspects, surgical techniques, disease specific concerns.

3. DECODING THE DETERMINANTS OF WALKING SPEED: A MULTIDISCIPLINARY PERSPECTIVE

Walking speed is not a static value; it's a dynamic variable shaped by a complex interplay of factors, each contributing to the unique pace at which individuals navigate their urban environments. To effectively design for walkability and create truly pedestrian-friendly cities, we must unravel these multifaceted determinants. This requires drawing upon knowledge from diverse disciplines, including transportation planning, urban design, public health, and biomechanics, to understand how the human body, the urban landscape, and the human mind interact to shape the pedestrian experience.

3.1. Individual Attributes: The Human Factor

Individual attributes play a fundamental role in determining walking speed. Age, in particular, has a significant impact. As we age, physiological changes such as decreased muscle strength, reduced flexibility, and alterations in gait patterns contribute to a natural decline in walking speed [10]. Studies have shown that average walking speed decreases significantly with age, with individuals over 65 exhibiting speeds up to 20% slower than younger adults [11]. This age-related variation underscores the need to design urban environments that are sensitive to the needs of older pedestrians. Providing longer crossing times at intersections, incorporating ample resting areas along walkways, and ensuring well-maintained, even surfaces are just a few examples of how urban design can accommodate the varying speeds of older adults.

While gender is often considered a factor in walking speed, research suggests that any differences are often minimal and not necessarily deterministic. Some studies have observed slight variations, but these can often be attributed to factors like footwear choices, clothing styles, and cultural norms rather than inherent biological differences [12, 13]. Urban design should prioritize inclusivity, acknowledging that gender is not a reliable predictor of walking speed and focusing on creating environments that cater to the needs of all individuals.

An individual's level of physical fitness also influences their walking speed. Individuals who engage in regular physical activity and maintain a higher fitness level tend to exhibit faster walking speeds due to improved cardiovascular health, increased muscle endurance, and more efficient movement patterns [14]. This finding highlights the crucial link between walkability and public health. Cities that prioritize walkability and actively encourage walking as a mode of transportation are not only creating more sustainable environments but also contributing to the overall well-being of their residents.

Human perception plays a significant role in walking speed, as it is influenced by both the built environment (BE) and individual perceptions of safety, security, and attractiveness. According to Basu et al. [15], pedestrians' route choices are shaped by the characteristics of their surroundings and how these environments are perceived, particularly regarding the time of day. Pedestrians tend to favor routes that minimize walking time, feature lower posted speed limits, and offer comfortable walkway gradients. However, environmental factors such as poor lighting, the presence of vacant land, and perceptions of insecurity—especially at night—can cause pedestrians to slow down or avoid walking altogether. Female

pedestrians, in particular, tend to avoid poorly lit and uncomfortable routes at night. These findings suggest that perceptions of the environment significantly affect walking speed, as individuals adjust their pace based on their comfort, security, and the walkability of their route. This highlights the need for urban planning strategies that improve perceptions of safety and attractiveness to promote walking, particularly in suburban areas where lowering roadway speed limits and improving lighting can encourage more pedestrian activity.

Furthermore, our physical dimensions, specifically body size and composition, play a role in shaping our natural stride length and walking speed. Individuals with longer legs typically have a longer stride, allowing them to cover more ground with each step, which can lead to faster walking speeds [16]. Conversely, body weight can influence walking speed, as individuals with a higher body mass index may experience slower speeds due to the increased energy expenditure required to move their bodies [14]. Recognizing this variability in body size and composition is essential for inclusive urban design. Pedestrian infrastructure should be designed to accommodate a range of body sizes and ensure comfortable movement for all.

3.2. Environmental Conditions: Navigating the Urban Landscape

Beyond individual attributes, the physical environment presents a dynamic landscape that pedestrians must navigate, and this landscape directly impacts walking speed.

Terrain: Hills, Stairs, and Uneven Ground

Terrain, in particular, plays a significant role. Walking uphill demands more energy expenditure to overcome the force of gravity, resulting in naturally slower paces [17–19]. On the other hand, walking downhill can increase speed but requires greater control and balance to prevent falls. Stairs introduce a vertical challenge, necessitating adjustments in gait patterns and leading to varying speeds based on stair height and individual physical capabilities [20, 21]. Urban design should carefully address the influence of terrain on pedestrian movement. This might involve providing alternative routes with gentler slopes for those with mobility limitations, incorporating handrails on stairs for added support, or strategically designing pathways to minimize steep inclines.

Weather Conditions: Rain, Snow, Heat, and Cold

The whims of weather can also significantly influence walking speed. Adverse weather conditions, such as rain, snow, or extreme temperatures, introduce challenges to maintaining a consistent pace. Rain and snow reduce traction, making surfaces slippery and increasing the risk of falls, leading pedestrians to adopt a more cautious gait and slower speed [22]. Extreme heat or cold can impact physical comfort and lead to fatigue, further affecting walking speed and endurance [23]. Sustainable urban design should strive to create weather-resilient environments to mitigate the impact of these conditions on walking speed. This might involve incorporating covered walkways, designing shelters for protection from rain and snow, and considering heated pavements in colder climates to prevent ice buildup and improve pedestrian safety.

Crowd Density: Navigating the Flow of People

Moving through urban spaces often involves navigating crowds, and the density of people in a given area directly affects pedestrian flow and speed. Walking through crowded areas requires constant adjustments in path and pace to avoid collisions, resulting in slower overall movement, especially in confined spaces [24, 25]. As pedestrian density increases, personal space decreases, leading to more frequent changes in direction and speed, which ultimately slows down the entire flow of pedestrian traffic. Effective urban design strategies for managing crowd density and optimizing walking speed might include widening sidewalks in high-traffic areas, creating dedicated pedestrian plazas where foot traffic is prioritized, and implementing crowd management techniques during large events or peak hours.

3.3. Infrastructure Quality: The Foundation of a Walkable Environment

The quality of pedestrian infrastructure itself is a critical factor shaping walking speed.

Sidewalk Width: Providing Ample Space to Move

Adequate sidewalk width is essential for maintaining comfortable walking speeds. Narrow sidewalks can lead to congestion, forcing pedestrians to slow down or even step into the street to avoid collisions with other pedestrians or obstacles [26, 27].

Pavement Quality: Ensuring Smooth and Safe Surfaces

Similarly, the condition of the pavement surface has a direct impact on walking speed. Uneven or poorly maintained surfaces require pedestrians to exercise greater caution, leading to slower speeds, while smooth, well-maintained surfaces allow for faster and more comfortable walking [22]. Investing in high-quality pedestrian infrastructure with ample sidewalk widths and well-maintained surfaces is an essential step in promoting walkability and creating an environment where pedestrians can move comfortably and efficiently.

Crossing Design: Optimizing Signals and Crosswalks

Beyond the physical dimensions of infrastructure, the design of pedestrian crossings also plays a role. The timing of traffic signals, the length of crosswalks, and the presence of refuge islands can all influence walking speed and safety [28]. For instance, longer crossing times are particularly important for older adults and people with disabilities who have slower walking speeds, allowing them to cross safely without feeling rushed. A well-designed pedestrian crossing should be informed by an understanding of the average walking speeds of the local population, ensuring that signal timing and infrastructure design are tailored to accommodate their needs.

3.4. Factors: The Mind-Body Connection in Motion

While the physical environment sets the stage, psychological factors are equally important in influencing how people walk.

Motivation and Purpose: The Power of a Destination

Our mental state and the reasons behind our walk can significantly affect our pace. Individuals with a clear goal or purpose in mind, such as reaching a specific destination, completing an errand, or engaging in physical activity, tend to walk at faster speeds [29]. The presence of a defined objective, whether it's arriving at work on time or enjoying a pleasant park at the end of a walk, enhances focus and effort, resulting in a more determined and often faster pace.

Stress and Emotional State: Impact on Gait and Pace

Our emotional state also has a subtle but noticeable influence on our walking speed. When we are feeling stressed or anxious, our bodies react with muscle tension, reduced coordination, and a more hesitant gait, which translates to slower walking speeds [30]. On the other hand, when we are relaxed, content, or experiencing positive emotions, our movements tend to be more fluid and our walking speed often increases. This connection between our emotional state and our physical movement highlights the importance of creating urban environments that promote a sense of well-being. Designing urban spaces with stress-reducing elements such as green spaces, pleasant aesthetics, and minimal noise pollution can contribute to a more positive pedestrian experience and even encourage faster, more comfortable walking speeds.

Attention and Distraction: The Perils of Divided Focus

Furthermore, our ability to focus directly impacts our walking speed and safety. Distractions, such as using a mobile phone, listening to music, or being engaged in conversation while walking, can significantly reduce our awareness of our surroundings and lead to slower, more erratic walking patterns [31, 32]. These distractions divide our attention, impairing our judgment, reaction time, and spatial awareness, increasing the risk of accidents and collisions. While completely eliminating distractions in an urban environment is unrealistic, sustainable urban design can help mitigate their negative impact. Creating safe, dedicated pedestrian zones with clear signage and minimizing potential distractions like loud noises or flashing lights can encourage pedestrians to stay focused on their movements and enhance their safety.

3.5. Cultural Dimensions: Society's Influence on Pace

Finally, cultural dimensions play a unique and often overlooked role in shaping walking speed.

Social Norms: The Pace of Life

Cultural norms and societal expectations regarding what are considered an appropriate pace for walking vary widely across different societies [33]. Research has shown that people in Western countries often walk at faster speeds than those in some Asian and Middle Eastern cultures. These differences may stem from deeply rooted cultural values related to time, efficiency, and the overall pace of life. Acknowledging and respecting these variations in cultural norms is essential for designing truly inclusive urban environments. Pedestrian infrastructure should be planned and designed with sensitivity to these diverse cultural perspectives, ensuring that it accommodates a range of comfortable walking speeds and does not inadvertently privilege one cultural norm over another.

Clothing and Footwear: Impact on Movement

Similarly, clothing and footwear choices can impact walking speed, particularly when traditional attire or restrictive footwear influence stride length, gait patterns, and overall comfort. For instance, studies have observed that the abaya worn by women in some Middle Eastern cultures can affect their walking speed, particularly when navigating stairs [34]. Embracing inclusivity in urban design requires recognizing that cultural attire may have implications for pedestrian movement and ensuring that infrastructure design accommodates these variations.

4. WALKING SPEED AND SUSTAINABLE URBAN DESIGN

Sustainable urban design aspires to create built environments that nurture a harmonious balance between ecological responsibility, social equity, and economic prosperity. A central tenet of this design philosophy is walkability, aiming to elevate walking as a safe, convenient, and enjoyable mode of transportation [3]. However, achieving genuine walkability requires a more comprehensive approach than simply providing sidewalks and pedestrian crossings. It necessitates the design of a holistic pedestrian experience that thoughtfully considers all aspects of walking, including the often-overlooked factor of walking speed.

4.1. The Concept of Walkability: Designing for the Pedestrian Experience

Walkability is a multifaceted concept, encompassing a rich tapestry of factors that contribute to a positive pedestrian experience. A well-connected street network, rich with frequent intersections and offering a diverse array of route options, is essential. This empowers pedestrians to navigate their surroundings with ease and reach their destinations efficiently [4]. Consider a city where a network of walking paths forms an intricate web, providing pedestrians with the flexibility to choose the most efficient and enjoyable route based on their individual needs and preferences, whether it's a direct path for a brisk commute or a meandering route through a verdant park for leisurely exploration.

A vibrant mix of land uses, seamlessly integrating residential, commercial, and recreational spaces within comfortable walking distance, is another key ingredient of a walkable city. This reduces the need for car travel while creating a dynamic urban fabric that supports a diverse range of pedestrian activities. Envision a neighborhood where residents can effortlessly walk to the grocery store, meet friends for coffee, enjoy a leisurely stroll through a park with their children, all within a pleasant 15-minute radius, experiencing the richness of urban life along the way.

High-quality pedestrian infrastructure is equally paramount. This includes wide sidewalks, meticulously maintained pavement surfaces that are smooth and obstacle-free, safe crossings designed with clear sightlines to enhance visibility for both pedestrians and drivers, and well-designed lighting that provides a sense of security and comfort during evening hours.

Furthermore, thoughtful streetscape design plays a vital role in shaping a positive pedestrian experience. Attractive streetscapes adorned with trees offering shade, inviting benches for rest and contemplation, vibrant landscaping, and active building frontages create a pleasant and engaging atmosphere that beckons people to explore on foot and linger in public spaces.

Above all, a true sense of walkability hinges on safety and security. Pedestrians must feel secure from both traffic and crime to confidently navigate the city without fear or hesitation [35, 36]. This requires streets designed with traffic calming measures, such as reduced speed limits, narrowed lanes, and raised crosswalks, to prioritize pedestrian safety and create a more relaxed environment. Crossings should be clearly marked, well-lit, and equipped with countdown timers to provide clear information and minimize pedestrian anxiety. A bustling street with a diverse mix of pedestrians, cyclists, and transit users creates a natural sense of surveillance, deterring crime and fostering a sense of collective ownership of public spaces.

Walking speed, often an implicit consideration, is intricately woven into all these elements of walkability. A well-designed environment that facilitates faster, more comfortable walking speeds naturally encourages pedestrian activity, making walking a more appealing and efficient choice for short trips. This, in turn, contributes to reduced car dependence, less traffic congestion, lower emissions, and ultimately, a more sustainable and livable city for all.

4.2. Integrating Walking Speed into Sustainable Urban Design: A Data-Driven Approach

Creating truly pedestrian-friendly and sustainable cities requires going beyond simply acknowledging the importance of walkability. It necessitates the active integration of walking speed considerations into every stage of the urban design process. This is where a data-driven approach becomes paramount. By meticulously collecting and analyzing real-world data on actual walking speeds, urban designers can gain a nuanced understanding of how people move through the city and identify areas for improvement.

Data as a Tool for Understanding Pedestrian Needs

Data collection forms the foundation of a data-driven approach to sustainable urban design. By tracking walking speeds in different neighborhoods and across diverse demographics, we can glean valuable insights into the effectiveness of existing infrastructure and identify areas where interventions are needed. Are sidewalks wide enough to accommodate peak pedestrian flows? Are traffic signals timed appropriately for all user groups, including older adults and people with disabilities? Are pedestrian crossings designed to maximize safety and minimize wait times? This data can reveal patterns related to age, physical ability, and cultural norms, ensuring that urban design solutions are tailored to the specific needs of the local community.

Transforming Traffic Planning Through Data-Driven Insights

Traditional traffic planning, often reliant on outdated or generalized assumptions about walking speed, can lead to inadequate crossing times, particularly for individuals with slower paces [28]. For example, an

older adult attempting to cross a busy intersection with a short green light phase might be forced to rush, increasing their risk of falling or being struck by a vehicle. This scenario not only compromises pedestrian safety but also discourages people from choosing walking as a mode of transportation. By embracing data-driven traffic planning, we can transition from reactive solutions to proactive strategies that anticipate and address the needs of all pedestrians, regardless of their walking speed.

Collecting data on actual walking speeds allows traffic engineers to optimize traffic signal timing, ensuring that the green light phase at crosswalks provides ample time for even the slowest pedestrians to cross comfortably and safely. This data can also inform the design of pedestrian infrastructure, ensuring sidewalks are wide enough to prevent congestion and that crossing distances are manageable. Features like curb ramps and pedestrian refuge islands can be strategically implemented to enhance accessibility and provide safe havens for those who need additional time to cross. Areas with a higher concentration of older adults or individuals with disabilities, who often have slower walking speeds, may require wider sidewalks, longer crossing times, and more frequent resting areas along walkways.

Understanding how environmental factors influence walking speed is also crucial. The presence of hills, stairs, road width, and traffic volume can all affect pedestrian movement, and incorporating this understanding into traffic planning strategies can help create safer, more comfortable, and more efficient walking environments. In areas with high pedestrian activity, reducing speed limits, installing speed bumps, or narrowing traffic lanes can help prioritize pedestrian safety and encourage a shift towards slower, more human-centered traffic flows.

Pedestrian-Oriented Urban Design: Putting People First

Pedestrian-oriented urban design takes a human-centered approach, placing the needs and experiences of pedestrians at the forefront of planning and design decisions. This means creating urban spaces where walking is not merely an option but a truly enjoyable, efficient, and engaging experience. Understanding walking speed plays a key role in this vision, as it allows designers to create spaces that resonate with the natural rhythms of human movement.

Creating dedicated pedestrian zones and plazas, free from motorized traffic, offers a powerful strategy for enhancing walkability. These car-free spaces provide a sanctuary from the stress and danger of traffic, allowing people to walk at their own pace, engage in social interactions, and enjoy their surroundings without feeling rushed or unsafe. To illustrate, a bustling pedestrian plaza filled with outdoor cafes, street performers, public art installations, and comfortable seating, where people can gather, relax, and experience the city at a human scale, free from the noise and pollution of cars.

Designing mixed-use neighborhoods, where residential, commercial, and recreational spaces are strategically interwoven within walking distance, further reinforces walkability. When daily needs like grocery shopping, dining, healthcare services, and recreational activities can be easily met on foot, walking becomes a more convenient and appealing choice for everyone, regardless of their walking speed. This fosters a sense of community, reduces car dependence, and supports local businesses.

A well-connected street network, featuring frequent intersections and diverse route options, provides greater flexibility for pedestrians, allowing them to choose the most efficient and comfortable path to their destination. This reduces the need for long, monotonous routes, making walking a more pleasant and engaging experience. By understanding the impact of street connectivity on walking speed and pedestrian behavior, urban designers can create networks that intuitively guide people through the city, fostering a more seamless and enjoyable walking experience.

Sustainable Urban Design: Building for the Pedestrian

Integrating walking speed considerations into every facet of urban design is a cornerstone of creating truly sustainable cities. By understanding how people move and experience the built environment, we can design urban spaces that prioritize human well-being, reduce our reliance on cars, and promote a more harmonious relationship between people and their city.

5. BENEFITS OF WALKABLE CITIES: A SUSTAINABLE FUTURE ON FOOT

The pursuit of walkable cities represents a strategic and vital investment in a more sustainable, equitable, and prosperous future. Walkable cities offer a multitude of advantages that extend beyond transportation, positively impacting the environment, the social fabric of communities, and the economic vitality of urban areas. By designing cities that prioritize people rather than cars, we can unlock a cascade of positive transformations that reverberate throughout urban life.

5.1. Environmental Benefits: A Lighter Footprint on the Planet

Walkable cities are inherently more environmentally responsible. By encouraging and facilitating walking as a primary mode of transportation, we can dramatically reduce our reliance on cars, leading to a series of positive environmental outcomes. One of the most significant of these is the reduction of carbon emissions. Cars, heavily reliant on fossil fuels, are a major contributor to greenhouse gas emissions. Even a modest shift toward walking, however, can generate a substantial reduction in a city's overall carbon footprint.

Research suggests that if just 10% of car trips under one mile were replaced with walking trips, we could witness a measurable decrease in carbon emissions [5]. This reduction contributes to a cleaner atmosphere, a healthier planet, and a brighter future for generations to come. Beyond mitigating climate change, walkability also leads to tangible improvements in air quality. Decreased car traffic translates to lower concentrations of harmful air pollutants, such as nitrogen oxides, particulate matter, and ozone. These pollutants are known to trigger a range of respiratory and cardiovascular health problems, particularly for vulnerable populations like children, the elderly, and those with pre-existing conditions. In a city designed for walking, the air is noticeably cleaner, residents can enjoy outdoor activities without the fear of pollution-related health issues, and the overall burden of respiratory illnesses is reduced.

Walkable cities offer the additional benefit of reduced noise pollution. By diminishing the constant din of car engines, we can cultivate a more tranquil and serene urban environment. This sonic shift not only improves mental well-being and reduces stress but also makes walking a more pleasant and enjoyable experience.

5.2. Social Benefits: Fostering Healthy and Connected Communities

The positive impacts of walkable cities extend far beyond environmental sustainability, profoundly influencing the social fabric of our communities. Promoting walking not only fosters healthier lifestyles but also strengthens community bonds and enhances the overall quality of life. Walking, being both readily accessible and inherently enjoyable, can be seamlessly woven into daily life. By designing cities that prioritize and encourage walking, we can effectively combat the pervasive trend of sedentary lifestyles and contribute to a healthier, more active population.

Cities that prioritize walkability can see a rise in active transportation, where children walk or bike to school, adults incorporate walking into their commutes or errands, and public spaces become vibrant hubs of physical activity. This shift towards active living has the potential to lead to lower rates of obesity, diabetes, heart disease, and a multitude of other chronic illnesses, fostering a healthier, more energetic, and more resilient population.

Walkable cities also serve as catalysts for social connection. When people walk more, they naturally encounter their neighbors more frequently, creating opportunities for spontaneous conversations, friendly greetings, and a stronger sense of shared community. Sidewalks transform into social spaces, parks and plazas become hubs of activity and connection, and local businesses thrive as residents stroll through their neighborhoods, fostering a sense of belonging and shared ownership. This increased social interaction cultivates a greater sense of community, strengthens neighborhood networks, increases social capital, and encourages a collective responsibility for the well-being of the urban environment.

5.3. Economic Benefits: Investing in a Walkable Future

Walkable cities are not only healthier and more socially connected; they are also demonstrably more economically vibrant. Investing in walkability is a direct investment in a more prosperous and resilient future for urban areas. One of the most evident economic benefits is the increase in property values frequently observed in walkable neighborhoods. People are often willing to pay a premium for the convenience, livability, and lifestyle advantages associated with walkable environments, driving up demand and subsequently, property values. This, in turn, translates to increased tax revenues for cities, empowering them to reinvest in further improvements and create a positive cycle of urban development. Beyond boosting property values, promoting walkability can also lead to substantial reductions in transportation costs for residents. When individuals and families rely less on cars, they save money on fuel, car maintenance, parking fees, and insurance. These savings can be significant, especially for those who live in urban areas where car ownership can be a considerable financial burden. In a city designed for walking, some households may even be able to transition to a car-free lifestyle altogether, eliminating the financial strain of car ownership and redirecting those resources to other essential needs or desired leisure activities.

Walkable cities also create a fertile environment for local businesses to flourish. Pedestrian-friendly streetscapes, characterized by their inviting storefronts and bustling sidewalks, naturally draw in foot traffic. This makes it easier for people to discover and patronize local shops, restaurants, and services as they walk through their neighborhoods. These thriving local businesses, in turn, contribute to a stronger and more diverse local economy, creating jobs, fostering entrepreneurship, and adding to the unique character and charm that make a city truly special.

In conclusion, investing in walkable cities is an investment in a healthier, more sustainable, and more equitable future. It's not just about building better sidewalks and public spaces; it's about creating a fundamental shift in how we design and experience our urban environments. By prioritizing the needs of pedestrians, we can unlock a cascade of positive impacts that extend far beyond transportation, creating cities that are more livable, enjoyable, and prosperous for everyone.

6. THE ROLE OF SUSTAINABLE URBAN DESIGN: SHAPING THE PEDESTRIAN REALM

Sustainable urban design goes beyond mere acknowledgment of walkability; it proactively weaves pedestrian-centric principles into the fabric of the built environment. By understanding the intricate web of factors influencing walking speed and pedestrian behavior, urban designers can employ a diverse range of strategies to create cities that are not only more walkable but also more sustainable, livable, and equitable for all. This requires a fundamental shift in perspective, viewing streets not as mere conduits for motorized traffic, but as vibrant public spaces that prioritize human movement, social interaction, and a harmonious connection with nature [1].

6.1. Transforming Streets into Walkable Spaces

The transformation of streets from car-dominated thoroughfares into inviting, pedestrian-friendly spaces is at the heart of this paradigm shift. Recognizing streets as vital public realms that contribute to the social, environmental, and economic well-being of a city is key.

Rethinking Streetscapes: Inviting Exploration and Interaction

Streetscape design plays a critical role in shaping the pedestrian experience. Streets that are visually appealing, comfortable, and stimulating naturally encourage walking, inviting exploration, and fostering a sense of delight in the urban environment. A street lined with trees offering shade during hot summer months, with benches inviting people to pause and enjoy their surroundings, fosters a sense of calm and respite. Colorful storefronts with inviting window displays add visual interest to the streetscape, encouraging exploration of local businesses. Street murals and public art installations transform mundane walks into engaging journeys of discovery, adding pops of color and sparking conversations, reflection,

and a sense of wonder in the everyday urban experience. By appealing to the human senses and fostering a spirit of curiosity and interaction, sustainable urban design can transform walking from a mere necessity into a source of joy and connection [37].

Prioritizing Pedestrian Safety: A Sense of Security and Ease

Safety is paramount in walkable environments. Pedestrians must feel secure from traffic and crime to comfortably navigate the city on foot, confident in their ability to move freely without fear or anxiety. A holistic approach to street design considers both physical and social dimensions of safety.

Neighborhoods where streets prioritize pedestrians with traffic calming measures like speed bumps, narrowed lanes, raised crosswalks, and curb extensions can cultivate a sense of safety and encourage a more natural flow of pedestrian movement. Well-marked and brightly lit crosswalks with countdown timers provide clear and predictable information, reducing pedestrian uncertainty and the need to rush across the street [38]. A bustling street with a diverse mix of pedestrians, cyclists, and transit users creates a sense of collective presence and natural surveillance, deterring crime and fostering a sense of shared ownership and responsibility for public spaces [39]. Prioritizing safety in every aspect of street design transforms walking from a potential risk into a genuinely enjoyable and stress-free experience.

6.2. Designing for Human Scale: A City for People

Sustainable urban design embraces the concept of human scale, shifting away from car-centric planning towards creating spaces that are comfortable, accessible, and inviting for people walking. This involves considering the natural rhythm of human movement, the diverse needs of pedestrians, and fostering a sense of connection between people and their environment.

Buildings that interact with the street, with active ground floors featuring shops, restaurants, and public spaces, blur the lines between indoor and outdoor life and create a vibrant street-level experience. A cityscape where building heights are carefully considered to maintain a human scale allows pedestrians to feel connected to their surroundings rather than dwarfed by imposing structures that can induce anonymity and detachment [40]. Streets punctuated with frequent crosswalks, comfortable benches for rest and observation, and public art installations that spark conversation and add beauty to the everyday urban fabric make the city more intimate, engaging, and conducive to walking.

6.3. Sustainable Materials and Technologies: Building a Walkable Future

The choices we make regarding materials and technologies have a profound impact on the walkability and sustainability of our cities. Sustainable urban design embraces innovative solutions that enhance the pedestrian experience, minimize environmental impact, and contribute to a more resilient urban fabric.

Permeable Pavements: Alleviating Flooding and Cooling City Streets

Traditional impervious pavements contribute to urban flooding, exacerbate the urban heat island effect, and create harsh, uninviting walking environments. Permeable pavements offer a sustainable alternative by allowing rainwater to infiltrate the ground, reducing runoff and mitigating flood risk. They also help to reduce surface temperatures, creating a more comfortable walking environment, especially during warmer months [41].

Green Infrastructure: Weaving Nature into the Urban Fabric

Integrating green infrastructure elements, such as green roofs, bioswales, and rain gardens, into pedestrian areas enhances aesthetics and provides a multitude of environmental and social benefits. Green roofs insulate buildings, reduce energy consumption, and mitigate the urban heat island effect, creating a more comfortable microclimate for pedestrians [42]. Bioswales and rain gardens serve as natural filters for stormwater runoff, reducing pollution, improving water quality, and adding pockets of natural beauty to

the urban landscape. Walking paths shaded by lush greenery, green roofs transforming rooftops into vibrant gardens, and bioswales meandering through urban spaces contribute to a city where nature and built environment coexist harmoniously.

Smart City Technologies: Optimizing Pedestrian Flow and Safety

Smart city technologies present exciting opportunities to optimize pedestrian flow, enhance safety, and create a more responsive urban environment. Strategically placed pedestrian sensors can provide real-time data on pedestrian volumes and walking speeds, allowing for dynamic traffic signal adjustments, personalized pedestrian information through mobile apps or digital signage, and proactive identification of infrastructure maintenance needs. Adaptive traffic signals, responding to pedestrian presence, can minimize wait times at intersections, making walking a more efficient choice.

By integrating walking speed considerations into every facet of urban design and harnessing the power of sustainable materials and technologies, we can prioritize people over cars, creating more walkable, sustainable, livable, and equitable cities that enhance the quality of life for all residents.

7. DISCUSSION

This thematic review has illuminated the multifaceted nature of walking speed and its profound implications for creating sustainable, walkable, and livable urban environments. We've traversed a rich landscape of research, uncovering how walking speed is not merely a measure of individual pace but a dynamic variable shaped by a complex interplay of individual attributes, environmental conditions, psychological factors, and cultural dimensions. From the physiological changes that accompany aging to the subtle influence of weather and the nuanced impact of social norms, understanding the determinants of walking speed is essential for creating cities that truly prioritize the pedestrian experience.

Our exploration of the literature has revealed that walking speed is a tangible reflection of the intricate relationship between the human body and the built environment. Factors such as age, fitness level, and body size influence our inherent capacity for movement [10, 14]. The terrain we encounter, the weather conditions we face, and the density of crowds we navigate all contribute to shaping our pace [22, 23, 25]. Our mental and emotional state, our motivation for walking, and our level of attention can subtly yet significantly affect how we move through the city [29, 30]. Cultural norms and even clothing choices add further layers of complexity, demonstrating that walking speed is not a universal constant, but a variable intricately intertwined with the fabric of our societies [33, 34].

This knowledge empowers us to move beyond generic assumptions about pedestrian behavior and adopt a more nuanced, data-driven approach to urban design. By meticulously collecting and analyzing data on actual walking speeds across diverse demographics, terrains, and urban contexts, we can tailor infrastructure, streetscapes, and traffic management strategies to more effectively meet the needs of local communities. This data-driven approach might involve adjusting traffic signal timing to accommodate the slower walking speeds often associated with older adults, designing wider sidewalks in areas with high pedestrian density to alleviate congestion, or incorporating covered walkways to provide shelter from inclement weather, encouraging pedestrian activity regardless of rain or shine.

This review has underscored the critical role of sustainable urban design in creating genuinely walkable cities, demonstrating that walkability is not just about providing infrastructure; it's about crafting a holistic pedestrian experience. By prioritizing pedestrian-oriented design principles, we can create urban spaces that are not only functional but also inviting, comfortable, and safe for people on foot.

Reimagining streetscapes, as discussed earlier, plays a vital role. Incorporating elements like trees, benches, and public art can transform mundane walkways into vibrant public spaces, enhancing the aesthetic appeal and social vibrancy of walking environments [37]. Designing for human scale is equally crucial, creating a sense of intimacy and connection between people and their surroundings [40]. This

might involve limiting the height of buildings to maintain a pedestrian-friendly scale, designing streets with a rhythm of pauses and destinations, and prioritizing pedestrians' needs over cars' dominance.

Moreover, the strategic integration of green infrastructure, such as permeable pavements, green roofs, and bioswales, can enhance the aesthetics and comfort of walking environments and contribute to a more sustainable and resilient urban ecosystem [42]. These green elements provide visual appeal and practical benefits, such as reducing stormwater runoff, mitigating the urban heat island effect, and improving air quality, making walking a more pleasant and healthy experience.

Furthermore, the rapidly evolving field of smart city technologies presents exciting opportunities for optimizing pedestrian flow and safety. Pedestrian sensors, adaptive traffic signals, and personalized pedestrian information systems can all contribute to creating a more responsive and adaptable urban environment, making walking a more efficient, safe, and enjoyable experience for all [43]. To illustrate, a city where crosswalks intuitively adjust their timing based on pedestrian presence, where real-time information about walking routes and crowd density is readily available through mobile apps, and where city officials can proactively address infrastructure maintenance needs based on data from pedestrian sensors.

The benefits of creating walkable cities are far-reaching and transformative, extending far beyond the realm of transportation. By encouraging walking as a primary mode of transportation, we contribute to a healthier planet, foster stronger and more connected communities, and stimulate economic vitality. Walkable cities have the potential to significantly reduce carbon emissions, improve air quality, and create quieter, more serene urban environments [5], contributing to a more sustainable future.

They also encourage physical activity, combating sedentary lifestyles and promoting a healthier population [44]. The social fabric of walkable neighborhoods is stronger, as increased pedestrian activity enhances social interaction, fosters a sense of community, and promotes a greater sense of belonging [39]. Furthermore, walkable cities often experience economic benefits through increased property values, reduced transportation costs for residents, and a thriving local business environment [45].

Looking ahead, the quest to fully understand walking speed and its implications for sustainable urban design is an ongoing journey. Future research can delve deeper into the complex interplay of factors influencing walking speed, exploring new dimensions and refining our existing knowledge. Longitudinal studies can track how walking speeds evolve over time within individuals and populations, providing valuable insights into the long-term effects of urban design interventions and demographic shifts. Further research can also explore the impact of specific urban design features, such as the presence of greenery, street furniture, or public art, on walking speed and pedestrian behavior. The rapidly evolving field of smart city technologies presents a fertile ground for future research, as we seek to optimize their use to create more responsive and adaptable urban environments that cater to the nuanced needs of pedestrians.

Creating truly walkable cities demands a collaborative effort that transcends disciplinary boundaries. Urban designers, planners, engineers, policymakers, and community members must work together to champion a pedestrian-centric approach, placing the needs and experiences of people walking at the forefront of all urban planning and design decisions. By integrating the insights from this review and continuing to explore the dynamic relationship between walking speed and the built environment, we can create cities that are more walkable, sustainable, livable, equitable, and ultimately, more human.

Individuals with physical or mobility impairments, such as those who use wheelchairs, walkers, or other mobility aids, experience significant challenges in urban environments. Reduced walking speeds and the need for additional space are common, and urban design must account for these factors to ensure inclusivity. Research from cities worldwide demonstrates that poorly designed sidewalks and infrastructure can lead to unsafe and inaccessible conditions for these individuals [46]. Sidewalks must be wide enough to accommodate individuals using wheelchairs or other mobility devices, ideally adhering to international guidelines like the ADA or the European EN 301 standards, which recommend widths of at least 1.5 meters [47, 48]. The use of ramps instead of stairs is critical for improving accessibility.

Research has shown that appropriate ramp gradients, as recommended by global standards, should be 1:12 or gentler [47, 48].

In conclusion, walking speed is a multifaceted variable shaped by a complex interplay of individual attributes, environmental conditions, psychological states, and cultural influences. Decoding these determinants is essential for designing urban environments that are truly conducive to walking, promoting active transportation, and creating more sustainable, livable, and inclusive cities for all.

8. CONCLUSION

This scoping review provides a comprehensive examination of the existing literature on Active Shooter Incidents (ASIs), highlighting critical themes, response strategies, and gaps in current research. The use of the PRISMA-ScR framework allowed for a systematic and transparent analysis of relevant studies, ensuring the inclusion of diverse perspectives on active shooter preparedness, response, and prevention strategies across various settings, including schools, workplaces, and public spaces.

The findings reveal that while significant progress has been made in understanding ASIs, there is still a need for more detailed, evidence-based strategies that address not only the immediate response but also long-term preventative measures. Key themes that emerged include the importance of preparedness drills, architectural and design interventions, and the role of law enforcement coordination in minimizing casualties during such events.

Furthermore, this review underscores the role of environmental design and behavioral analysis in mitigating the impact of ASIs. Future research should focus on refining the integration of these strategies, considering both technological advancements and community engagement to create safer environments.

Overall, this study contributes to the growing body of knowledge on ASIs by providing a broad overview of the existing research landscape and identifying areas where further investigation is needed. The findings emphasize the need for continued research to develop more robust frameworks that can effectively reduce the occurrence and impact of active shooter incidents in various settings.

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