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Original Research Article

Analysis of Factors Affecting Walkability and Sustainable Urban Mobility Using the AdaBoost Approach (Case Study: Mir Emad Neighborhood, Isfahan)

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Abstract

Problem statement: Walkability is one of the key indicators of urban environmental quality and a prerequisite for achieving a sustainable city. In commercial and administrative fabrics, the dominance of motorized traffic over pedestrian spaces reduces the quality of the walking experience, decreases citizens' satisfaction, and intensifies conflicts between vehicles and pedestrians, conflicts that constitute a major barrier to urban vitality and public health.

Research objective: This study aims to assess citizens' satisfaction with walkability and to determine the priority of factors affecting it in the Mir Emad neighborhood of Isfahan, to provide a framework for improving the quality of pedestrian spaces and guiding urban planning decisions.

Research method: This research is descriptive in nature. Data were collected through 113 valid Likert-scale questionnaires administered to residents, shopkeepers, and pedestrians. The variables examined include safety and security, pavement quality, spatial legibility, land-use diversity, and climatic comfort. Quantitative analyses were conducted using the AdaBoost machine learning algorithm, and qualitative analyses were carried out through an interpretable examination of respondents' comments.

Conclusion: The results indicate that the AdaBoost algorithm has a satisfactory ability to explain variations in citizens' satisfaction (coefficient of determination ≈ 0.71). Reducing motor traffic and improving walkability play the most significant role in increasing citizens' satisfaction, followed by route safety, sidewalk quality, and nighttime lighting. Therefore, in commercial–administrative contexts, enhancing the quality of pedestrian environments cannot be achieved solely through physical improvements; it also requires sustainable transport policies, traffic management, reduced car use, and the provision of safe pedestrian routes.

Keywords: *Walkability, Citizens' satisfaction, Machine learning (AdaBoost), Traffic management, Sustainable urban mobility.*

Introduction and Problem Statement

In contemporary urban planning and design paradigms, the notion of walkability has moved beyond a purely traffic related issue and has become one of the key indicators for assessing urban environmental quality, quality of life, and the achievement of sustainable development. Recent studies indicate that walkability is not limited to facilitating physical movement; rather, it encompasses broader dimensions such as the quality of spatial experience, perceived safety, and the vibrancy of urban environments (Kavak, 2025).

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Pedestrian oriented spaces, as settings for social interaction and the presence of citizens in public spaces, play a significant role in improving public health, enhancing urban liveliness, and reducing dependence on private automobiles (Shahabi Meskoun et al., 2025). Accordingly, within the framework of the Sustainable Development Goals, particularly Goal 11, which emphasizes the creation of sustainable cities and human settlements, walkability has been recognized as an effective strategy for enhancing urban livability and mitigating the negative impacts of car oriented transportation (Moayedi et al., 2019).

Walking is one of the most natural and oldest modes of human movement in space, and its importance remains evident in the daily lives of urban residents. Walking is not only a means of observing and experiencing urban places and activities, but also a way of sensing urban life and discovering the hidden qualities of the environment. This simple yet fundamental activity plays a crucial role in shaping spatial identity, strengthening the sense of place attachment, and enhancing interactions between citizens and the urban environment (Najafpour & Haghlesan, 2025).

Despite the growing importance of walkability in urban policies and planning programs, many developing cities still face challenges such as the dominance of motorized traffic, the decline in the quality of public spaces, and the weakness of pedestrian infrastructure. These conditions reduce citizens' motivation to choose walking as a daily mode of travel (Esmaili & Karami, 2021). In such a context, assessing the quality of pedestrian environments and the level of citizens' satisfaction with their walking experience has become one of the key issues in urban planning and design. Citizens' satisfaction with walkability can be understood as the reflection of users' subjective perceptions and judgments regarding the extent to which environmental conditions match their needs and expectations during walking, an understanding that is shaped under the influence of various spatial and environmental factors (Gonzalez-Urango et al., 2020; Lee et al., 2021; Abuwaer et al., 2025).

A key challenge in studies related to walkability is the measurement and analysis of the relationships between environmental features and citizens' satisfaction. While many existing studies have identified the factors influencing the quality of walkability, most have focused primarily on physical assessments or expert judgment-based methods, paying less attention to the actual perceptions of users and the complex relationships between environmental variables. Moreover, a significant portion of these studies have employed linear analytical models, which often fail to capture the complexity of interactions among environmental variables, citizen behavior, and satisfaction.

In this context, the Miremard neighborhood of Isfahan, as one of the city's significant administrative and commercial axes, faces a notable conflict between vehicular traffic and pedestrian flows. The presence of diverse administrative and service land uses in this axis has, on one hand, increased the demand for pedestrian movement; on the other hand, the dominance of motorized traffic and physical constraints have created significant challenges for enhancing the quality of citizens' walking experience. Therefore, a precise understanding of the factors affecting citizens' satisfaction with walkability in such environments can play a vital role in improving urban environmental quality and promoting sustainable urban mobility.

Accordingly, the present study focuses on the Miremard neighborhood of Isfahan and seeks to identify the environmental and perceptual factors influencing satisfaction with walkability based on data derived from citizens' perceptions, and to analyze their relative importance. To this end, citizens' satisfaction with walkability is considered as the dependent variable, while a set of environmental factors, including safety and security, pavement quality, environmental legibility, land-use diversity, and climatic comfort, are treated as independent variables.

The main research question is: Which environmental and perceptual factors play the most significant role in shaping citizens' satisfaction with walkability and promoting sustainable urban mobility in the Miremard neighborhood of Isfahan? Accordingly, the objective of this study is to identify and rank the factors affecting walkability based on users' perceptions and to explain

their managerial implications for urban planning. To achieve this objective, the study adopts a descriptive approach and employs survey data alongside a machine learning–based modeling technique (the AdaBoost algorithm) to analyze the relationships between environmental indicators and citizens' levels of satisfaction with walking within the study area.

Literature Review

• International studies

International studies on walkability indicate that the concept has evolved from a purely physical variable into a multidimensional phenomenon grounded in users' perceptual experiences. In this regard, Ewing & Handy (2009) conceptualize walkability as a combination of appropriate density, mixed land uses, street network connectivity, and the quality of public space design. Similarly, Speck (2012) and Gehl (2010), emphasizing the experiential dimension of urban space, argue that in contemporary urban contexts, environmental attractiveness, climatic comfort, and design quality exert a greater influence on individuals' willingness to walk than mere accessibility.

Furthermore, studies such as Park et al. (2022) and Lee et al. (2021) demonstrate that micro-scale elements such as façade transparency, shading, nighttime lighting, and perceived safety play a significant role in enhancing the pedestrian experience. More recent research, including Abuwaer et al. (2025) and Gonzalez-Urango et al. (2020), highlights the importance of variables such as safety, pavement quality, environmental legibility, land-use diversity, and climatic comfort in shaping users' satisfaction with walkability.

• Domestic studies

Domestic research has predominantly examined walkability through a physical-functional lens. Esmaili & Karami (2021) identify the poor quality of public realms and the dominance of motorized movement patterns as the core challenge facing developing cities in Iran. Similarly, Abdollahi & Holakouei (2018), in their case studies of Iranian cities, demonstrated that the success of pedestrian routes is contingent upon criteria such as safety, land-use mix, and integration with the public transportation network.

In other studies, such as Habibi et al. (2017) and Paknezhad & Latifi (2019), although efforts have been made to identify localized components and characteristics affecting the quality of pedestrian pathways, these studies have often relied on expert judgment, paying less attention to the actual perceptions and lived experiences of citizens. Furthermore, a significant portion of this body of research has employed multi-criteria decision-making (MCDM) methods or linear models, which are often unable to explain the complex, non-linear relationships governing pedestrian behavior.

• Synthesis of the literature and position of the present study

A review of both international and domestic literature indicates that global research has increasingly emphasized the experiential nature of walkability, focusing on users' perceptions and the role of micro-scale environmental elements in shaping the quality of pedestrian presence. In contrast, a considerable portion of domestic studies still adopt a predominantly physical, expert based, and largely linear perspective, with less attention given to citizens' satisfaction and the non-linear relationships among the factors influencing walkability. In many international studies, variables such as safety and security, pavement quality, environmental legibility, land-use diversity, and climatic comfort are identified as key components shaping the quality of walking experiences and user satisfaction. However, within the Iranian context, these variables have mostly been examined from a physical design perspective and through expert judgment, with limited emphasis on citizens' actual perceptions and lived experiences.

Furthermore, most previous studies have relied on linear statistical models such as multiple regression or structural equation modeling, which are not fully capable of explaining non-linear relationships, threshold effects, and complex interactions among variables. In response to these limitations, the present study develops a framework for assessing user satisfaction with walkability in the Miremard neighborhood by focusing

on five key components: safety and security, pavement quality, environmental legibility, land-use diversity, and climatic comfort.

The main contributions of this research, compared with previous studies, can be summarized in three aspects. First, it emphasizes the perceptions of actual users and utilizes data derived from citizens' lived experiences. Second, it employs the AdaBoost machine learning algorithm to model complex and non-linear relationships and to rank the relative importance of walkability components. Third, it focuses on a neighborhood characterized by predominantly administrative–commercial land uses and a significant pedestrian–vehicular conflict in an urban context that has received limited attention in domestic literature. Accordingly, this study seeks to address the methodological and contextual gaps identified in previous research and to provide an evidence based framework for prioritizing urban design and management interventions.

Theoretical Framework

• Safety and security

Safety and security represent one of the most fundamental prerequisites for pedestrian presence in urban spaces. Numerous studies have demonstrated that the perceived risk of traffic accidents, the lack of adequate separation between vehicular and pedestrian flows, poor vehicle speed control, and the fear of crime and social anomalies are the most significant mental and physical barriers to choosing walking as a mode of transportation (Guimpert & Hurtubia, 2018). Jane Jacobs and proponents of the "eyes on the street" approach argue that the continuous presence of citizens and natural surveillance play a decisive role in enhancing the sense of security, a phenomenon that requires well-designed pedestrian spaces and the effective management of pedestrian-vehicular conflicts. Consequently, it is expected that any improvement in traffic safety and social security will be directly associated with increased satisfaction with walkability (Vidal-Domper et al., 2025).

• Pavement quality

The quality of pavement and pedestrian infrastructure, as one of the most tangible dimensions of the walking experience, has a significant impact on users' comfort and satisfaction. Surface unevenness, cracked or slippery materials, the presence of multiple obstacles (such as improperly placed signage, irregular steps, and open drainage channels), and insufficient sidewalk width create serious barriers to the use of pedestrian routes, particularly for vulnerable groups such as older adults, children, and individuals with mobility impairments (Ewing & Handy, 2009).

Conversely, the use of appropriate materials, surface leveling, barrier free design, and compliance with standard width requirements not only enhances physical comfort but also fosters a sense of respect toward citizens and increases their willingness to walk and remain in public spaces (Kaparias et al., 2012).

• Environmental legibility

The concept of legibility, rooted in the seminal works of Kevin Lynch, refers to the ease with which the spatial structure of a city can be understood and the wayfinding capability of its users. Legible environments characterized by coherent street networks, clear landmarks, well-defined facades, and a distinct spatial hierarchy enable citizens to form a consistent and reliable mental image of the space (Damayanti, 2015). Research has shown that higher environmental legibility reduces feelings of confusion and anxiety, thereby increasing the willingness to walk and the duration of stay in urban spaces (Park et al., 2022). Consequently, environmental legibility is recognized as a key component influencing perceptual satisfaction with walkability.

• Land-use diversity

Land-use diversity, or mixed land use, is regarded within the theoretical frameworks of the "living city" and pedestrian oriented urbanism as a key factor in generating urban vitality, increasing pedestrian presence, and enhancing natural surveillance (Jacobs, 1961; Speck, 2012). The presence of complementary land uses along an urban corridor (commercial, service, administrative, recreational, etc.) creates multiple motivations for being in the space and makes local scale walking trips more justifiable and attractive. At the same time, land-use diversity contributes to a greater number of "eyes on the street,"

thereby reducing feelings of insecurity and improving the overall quality of citizens' spatial experience. In contrast, land-use homogeneity, sporadic activity throughout the day, and the dominance of single-purpose functions are often associated with reduced pedestrian appeal and lower levels of user satisfaction (Habibi & Haghi, 2016).

- **Climatic comfort**

Climatic comfort refers to the set of thermal, lighting, and wind conditions that influence an individual's sense of comfort in outdoor environments. In urban open spaces, elements such as tree shading and canopies, resting areas protected from direct solar radiation, opportunities for natural ventilation, protection from cold winds, and the appropriate design of street furniture are considered key factors in ensuring pedestrians' climatic comfort (Gehl, 2010; Park et al., 2022). Studies have shown that the absence of shade, excessive heat, or uncomfortable cold can significantly reduce both the duration of presence and the level of satisfaction associated with walking. Conversely, climate responsive design plays an important role in encouraging citizens to use pedestrian routes more frequently.

Urban open spaces provide numerous benefits for urban populations and, when supported by appropriate climatic conditions, can contribute to improving urban quality of life. Accordingly, numerous studies have sought to expand existing knowledge regarding thermal comfort in outdoor environments. Given that outdoor thermal comfort is a complex issue influenced by multiple factors, designing urban open spaces with favorable thermal conditions can play a significant role in attracting citizens, increasing their duration of stay in public spaces, and enhancing urban vitality (Shahabi et al., 2025).

However, one of the most challenging aspects of the existing literature lies in the methodology used for data analysis. Most previous studies have relied on linear statistical models such as multiple regression or structural equation modeling (SEM) to explain the relationship between environmental characteristics and walking behavior. A fundamental assumption of these models is that improvements in any environmental variable, for example, increasing sidewalk width, produce a constant and linear effect on increasing users' satisfaction (Lai et al., 2020).

However, human behavior and spatial satisfaction do not necessarily follow simple linear relationships. Variables such as the sense of security or traffic density often exhibit threshold effects; that is, they influence satisfaction up to a specific level, beyond which they may reach saturation or even exert an inverse effect. Due to their rigid structure, traditional models are unable to identify these complex and non-linear patterns (Ouali et al., 2019). In recent years, the application of machine learning (ML) algorithms has been proposed as a solution to this limitation; however, the use of such methods in Iranian urban studies remains extremely scarce.

Based on the literature review and with the aim of providing a more precise analysis within the context of the Miremard neighborhood, the following research gaps are highlighted:

1. Methodological Gap: The lack of intelligent and non-linear models for measuring the true weights of variables. To address this deficiency, the present study utilizes the AdaBoost (Adaptive Boosting) algorithm. This algorithm was selected due to its high capability in combining weak learners, reducing estimation errors, and, most importantly, its ability to provide an accurate ranking of feature importance based on empirical data.

2. Contextual Gap: Most previous studies have focused on historical or purely commercial fabrics. Axes with mixed administrative-commercial functions (such as Miremard), where the conflict between vehicular traffic and pedestrian flow reaches its peak, have been less explored in the literature.

In light of the theoretical framework and literature review, this study assumes that walkability quality results from the interaction of a set of physical, functional, and perceptual components of the urban environment, which directly influence citizens' satisfaction with the walking experience. Accordingly, five components: Safety and Security, Pavement Quality, Environmental Legibility, Land-use Diversity, and Climatic Comfort, are treated as independent variables, while citizens' satisfaction with walkability serves as the dependent variable.

Within this conceptual framework, it is hypothesized that improvements in each of the aforementioned components will lead to increased citizen satisfaction up to certain levels; however, the nature of this impact is not necessarily linear and may involve threshold and interaction effects between variables. To identify these complex patterns and estimate the relative importance of each component, AdaBoost regression is employed as a machine learning approach. By combining a series of weak learners and minimizing estimation errors, this algorithm enables the modeling of nonlinear relationships and the precise ranking of variable importance based on real-world data.

Consequently, the research's conceptual model maps the relationships between the five independent variables and the dependent variable of citizen satisfaction within a coherent analytical framework, providing a solid foundation for formulating urban design and management strategies in the Miremard neighborhood. In the following section, this conceptual framework is operationalized through the research methodology, detailing the measurement of variables and the modeling stages.

Research Methodology

The present study is applied in terms of its objective and descriptive in nature, adopting a quantitative–qualitative approach. Research data were collected through both documentary studies and field surveys, and were analyzed using statistical methods and machine learning–based modeling techniques.

The data collection process consisted of two main components: documentary and field-based. In the documentary phase, the theoretical foundations and indicators influencing walkability quality were extracted from the library and scholarly sources. In the field phase, a researcher-developed questionnaire was employed to assess the existing conditions and capture citizens' perceptions of walkability within the study area.

The statistical population of this study consists of users of the urban space in the Miremard corridor and neighborhood in Isfahan, who use this area as a pedestrian route. These users include pedestrians, residents, and shopkeepers present in the public space of the corridor who use the pedestrian paths. Considering the field-based nature of the research and the absence of a clear statistical framework regarding the exact number of pedestrian users in the study area, sampling was conducted using a non-probability convenience method among individuals present in the space. In order to increase the diversity of the sample and reduce bias, the questionnaires were distributed among users of the space at different points along the Miremard corridor and at various times of the day. In this process, only individuals who had experienced walking along this corridor at least once and were willing to participate in the study were included in the sample. In total, 113 complete and usable questionnaires were collected after excluding incomplete responses, which formed the basis for the statistical analyses and modeling in the present study.

The data collection instrument in this study was a researcher-developed questionnaire. The structure of the questionnaire was designed based on a five-point Likert scale (from strongly disagree to strongly agree). The questionnaire was organized into three sections. The first section includes general information about the respondents, such as age, gender, and the frequency of using pedestrian routes within the study area. The second section is dedicated to measuring environmental components affecting the walking experience and evaluates variables such as pavement quality, lighting, safety, sidewalk width, visual attractiveness, and other physical and environmental characteristics. The third section measures the overall level of users' satisfaction with the walking conditions along the studied corridor, which is used as the dependent variable in the analyses of the research.

The primary instrument for data collection in this study is a researcher-developed questionnaire, designed based on the components derived from the theoretical framework (safety, pavement quality, legibility, land-use diversity, and climatic comfort).

a) Validity: To assess content validity, the questionnaire was reviewed by a panel of five experts (including university professors in the fields of urban design and transportation planning). Based on their feedback,

ambiguous items were revised. The Content Validity Index (CVI) for all items was calculated to be above 0.80, indicating a high degree of alignment between the items and the research objectives.

b) Reliability: To evaluate the reliability of the instrument, a pilot study was conducted by distributing 30 questionnaires. The Cronbach's alpha coefficient for the entire questionnaire was 0.83. Furthermore, the reliability of the five dimensions of the study was also calculated, and the results (Safety: 0.79, Pavement: 0.81, Legibility: 0.84, Diversity: 0.78, and Comfort: 0.82) were all above the standard threshold of 0.70, confirming the high reliability of the measurement instrument.

The collected data used for analysis consisted of independent (predictor) variables and a dependent (target) variable (Table 1). The independent variables include the physical, functional, and perceptual components of the environment derived from the theoretical literature. These variables include:

1. Safety (lighting and security against crime),
2. Pavement and street furniture quality,
3. Legibility and permeability,
4. Land-use diversity,
5. Climatic comfort.

The dependent variable represents the overall level of satisfaction with walking in the Miremard neighborhood, which is considered the output variable in the model.

In contrast to conventional approaches in urban planning research, which predominantly rely on parametric statistical tests (such as simple or multiple linear regression in SPSS), the present study employs machine learning methods to address the complexity of human behavior and to analyze non-linear relationships among variables.

The selected model for this research is AdaBoost regression. AdaBoost is an ensemble learning technique that constructs a strong and highly accurate learner by combining multiple weak learners (typically shallow decision trees). The mechanism of this algorithm operates in such a way that, during the training process, greater weight is assigned to samples (respondents) that were not correctly predicted in previous iterations. This feature enables the model to focus on outliers or more complex data patterns and to adaptively reduce prediction error.

The main advantages of using AdaBoost in this study, compared with linear regression, are twofold:

Non-linear modeling: The relationships between environmental quality and citizens' satisfaction are not necessarily linear; for example, increasing lighting may improve safety up to a certain point, after which its effect may become less pronounced. AdaBoost is capable of learning such nonlinear patterns.

Feature importance assessment: This algorithm has a strong capacity to rank variables accurately and identify which indicator, for example, pavement quality or safety, has the greatest weight in predicting users' satisfaction.

Table 1. Introduction of the research variables and measurement indicators in the AdaBoost regression model. Source: Authors.

Row	Role in the Model	Measured Indicators (Questionnaire)	Main Component
1	Independent Variable (Input)	- Sense of security against crime (especially at night) - Safety of crossing the street (conflict with vehicles) - Adequate lighting in streets and pathways	Safety and Security
2	Independent Variable (Input)	- Smooth and even sidewalk surface - Absence of obstructive physical barriers - Adequate sidewalk width for two people to walk side by side	Pavement and Infrastructure Quality
3	Independent Variable (Input)	- Ease of wayfinding and spatial legibility - Continuity of the pedestrian path (without interruptions) - Convenient access to public transportation	Legibility and Accessibility
4	Independent Variable (Input)	- Presence of diverse land uses (commercial, recreational) - Vibrancy and sociability of the space - Quality and attractiveness of building frontages and shop windows	LandUse Diversity and Attractiveness
5	Independent Variable (Input)	- Availability of shade (trees or canopies) - Availability of urban furniture (benches, trash bins) - Environmental cleanliness and maintenance	Climatic Comfort and Street Furniture
6	Dependent Variable (Target)	- Overall willingness to walk along this route - Sense of satisfaction with the walking experience in the space	Overall Satisfaction

Finally, the data obtained from the 113 questionnaires were divided into a training set (80%) and a test set (20%) in order to evaluate the model's generalization accuracy.

The study area selected for this research is the Miremard neighborhood and urban corridor (Fig. 1), which is recognized as one of the vital and highly trafficked arteries within the spatial structure of Isfahan, located in District 8 of the city. This area, due to the presence of diverse commercial, administrative, and service land uses along its main frontage and dense residential fabric in the inner layers, accommodates a considerable volume of vehicular traffic on a daily basis.

The selection of Miremard as the study context is particularly significant because, despite its physical potential to evolve into a vibrant and pedestrian-oriented urban space, the corridor currently faces serious challenges arising from the unregulated interaction between vehicular and pedestrian flows. Preliminary observations and documentary analyses indicate that the dominance of private car mobility, irregular on-street parking, and physical discontinuities in the pedestrian network have negatively affected environmental quality and pedestrian safety in the area. Nevertheless, the presence of active commercial frontages and the willingness of citizens to spend time in this space provide an opportunity to identify the key factors influencing user satisfaction and to develop strategies aimed at improving the environmental quality of this valuable urban fabric.

• Results

In the first step, in order to understand the general characteristics of the data and examine the status of respondents, descriptive statistical indicators, including mean and standard deviation, were used. Table 2 presents the descriptive indicators of the study's main variables.

The descriptive statistics indicate that among the examined components, land-use diversity and environmental attractiveness had the highest mean, while climatic comfort and street furniture had the lowest mean.

Prior to conducting inferential analyses, the normality of data distribution was examined using the Kolmogorov–Smirnov test. The results showed that the significance level for all variables was below 0.05 (Sig < 0.05), indicating that the data were not normally distributed. Therefore, the use of non-linear methods and advanced analytical models was justified. To analyze the relationships between the independent variables and the dependent variable (walking satisfaction), the AdaBoost Regressor algorithm was employed. The model's performance was evaluated based on the test data (20% of the dataset).

The model evaluation results indicated that the coefficient of determination (R^2) is:

$$R^2 = 0{,}71$$

and the mean squared error (MSE) is:

$$MSE = 0{,}18$$

Location of the Study Area in Isfahan Province

Location of the Study Area within the Administrative Districting of Isfahan City

Study Area

Location of the Study Area in District 8 of Isfahan City

Fig. 1. Location of the study area. Source: Authors.

which indicates an acceptable level of accuracy of the model in predicting citizens' satisfaction based on walkability components.

Fig. 2 shows the scatter distribution of the actual walking satisfaction values and the values predicted by the AdaBoost model. The red dashed line represents the ideal line ($\hat{y} = y$), which indicates perfect agreement between the actual and estimated values. The distribution of points around this line suggests a reasonable correspondence between the model outputs and the observed data, as well as an appropriate level of accuracy of the model in predicting the dependent variable.

One of the key outputs of the AdaBoost algorithm is the determination of the relative importance of variables. The results of variable weighting are presented in Table 3.

Based on Fig. 3, which illustrates the relative weights of the variables in the AdaBoost regression model, the most influential factor in predicting walking satisfaction is the variable related to "reduced car traffic and increased willingness to walk," with the highest importance score (approximately 0.09). Following this, factors centered on safety and nighttime conditions, including pedestrian safety and walkway quality, nighttime lighting, and perceived nighttime security, occupy the next ranks. Additional variables identified as influential include route legibility and signage, pavement safety, pavement quality, sidewalk width, path continuity, and overall walking quality. These findings indicate that vehicular traffic control and perceptual aspects of safety hold the greatest weight in shaping pedestrian satisfaction in the Miremard neighborhood. Based on the model results and the obtained significance levels, the status of the research hypotheses is presented in Table 4.

Based on the output of the AdaBoost model, the final conceptual framework of the study indicates that walkability components, with different weights, simultaneously and nonlinearly influence citizens' satisfaction with walking in the Miremard neighborhood. Within this framework, safety and security emerge as the dominant factor, playing a central role in enhancing the quality of the walking experience, while the other components function as reinforcing factors.

Table 2. Descriptive Statistics of the Study Variables (n = 113). Source: Authors.

Variable	Mean	Standard Deviation
Safety and Security	3.12	0.84
Pavement Quality	2.95	0.79
Legibility and Accessibility	3.28	0.72
Land-Use Diversity and Attractiveness	3.46	0.81
Climatic Comfort and Street Furniture	2.87	0.88
Overall Satisfaction with Walking	3.05	0.76

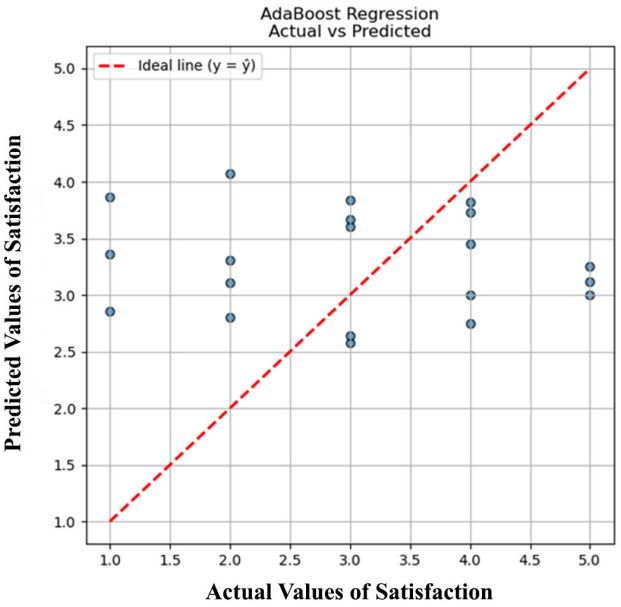

Fig. 2. Scatter Plot of Actual Walking Satisfaction Values with the AdaBoost Algorithm. Source: Authors.

Table 3. Relative Importance of Independent Variables in Predicting Walking Satisfaction. Source: Authors.

Rank	Independent Variable	Importance Weight
1	Safety and Security	0.31
2	Land-Use Diversity and Attractiveness	0.24
3	Legibility and Accessibility	0.19
4	Pavement Quality	0.15
5	Climatic Comfort and Street Furniture	0.11

Discussion

In the revised version, the results are not merely reported as numerical findings; rather, they are qualitatively interpreted in relation to the neighborhood context, the quality of the pedestrian experience, route safety, and pedestrian–vehicle conflicts. Although the reduction of car traffic and the increased possibility of walking were

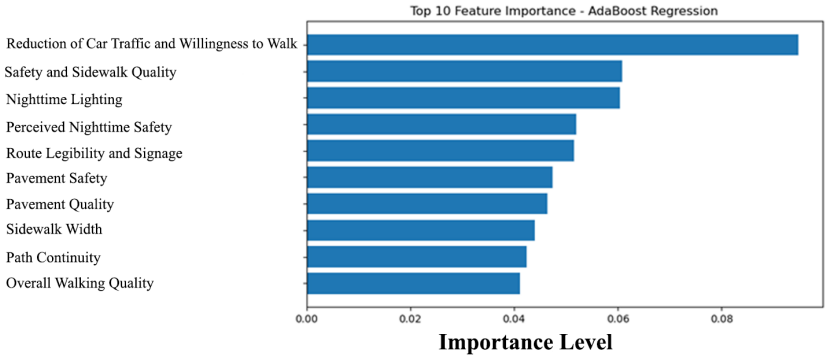

Fig. 3. Relative Importance of Variables in the AdaBoost Regression Model. Source: Authors.

Table 4. Results of the Research HypothesisT ests. Source: Authors.

Hypothesis	Hypothesis Description	Sig. Value	Result
H1	Safety and security have a significant effect on walking satisfaction.	0.001	Confirmed
H2	Pavement quality has a significant effect on walking satisfaction.	0.018	Confirmed
H3	Legibility and accessibility have a significant effect on walking satisfaction.	0.006	Confirmed
H4	Land-use diversity has a significant effect on walking satisfaction.	0.002	Confirmed
H5	Climatic comfort has a significant effect on walking satisfaction.	0.041	Confirmed

identified as the most significant factors, this finding is not considered merely self-evident. Instead, it indicates that within the studied context, the primary issue is not solely the physical quality of pedestrian routes, but the dominance of a car oriented logic over the spatial and functional organization of the neighborhood. Accordingly, factors such as route safety, sidewalk quality, and nighttime lighting gain significance through their connection to the lived experience of users and their perception of safety.

Numerous studies in the walkability literature have emphasized the role of factors such as nighttime lighting, sidewalk quality, and route safety in enhancing pedestrian satisfaction (Ewing & Handy, 2009; Gehl, 2010; Speck, 2012). However, many of these studies have analyzed the relationships among variables in a linear manner or treated them as independent from one another.

In contrast, the results of the AdaBoost model in this study indicate that these relationships can be nonlinear and dependent on contextual conditions. For instance, the effect of nighttime lighting declines noticeably after reaching a minimum acceptable threshold, and further increases in lighting have only a limited impact on satisfaction. The findings also show that sidewalk quality cannot compensate for the negative effects of heavy traffic under all conditions; at higher traffic levels, managerial factors such as controlling vehicular flow become more influential.

Accordingly, the main distinction of this study from previous research lies in its use of the AdaBoost machine learning algorithm to identify threshold patterns and interaction effects among variable patterns that are often less visible in conventional linear analyses.

Methodological innovation: The use of the AdaBoost Algorithm

From a methodological perspective, the use of the AdaBoost algorithm in this study demonstrates that the relationships between environmental components and user satisfaction are not necessarily linear or simple. While traditional statistical methods, such as linear regression, typically aim to estimate fixed coefficients and linear relationships, AdaBoost, by iteratively combining multiple weak models and correcting their errors, is capable of identifying more complex and nonlinear patterns and achieving noticeable improvements in predictive accuracy.

This finding carries at least two important implications for future research. First, the application of machine learning techniques in urban design and behavioral studies can lead to more flexible and realistic analytical models. Second, the use of such models enables a more precise prioritization of the factors influencing

walkability, which can support evidence-based decision-making in urban management. Accordingly, beyond its empirical contribution, the present study also represents a methodological advancement within the literature on walkability and urban planning.

The main objective of this study was to assess and predict citizens' satisfaction with walkability in the Miremard neighborhood using the AdaBoost machine learning algorithm. The findings from the data analysis indicate that this algorithm, with a coefficient of determination of R^2=0.71, demonstrates a strong capacity to explain the variance of the dependent variable and can serve as a reliable tool for modeling the complex relationships between environmental components and users' perceptions. In this section, key findings are interpreted and discussed within the broader framework of the theoretical literature on walkability and sustainable urban development.

• Prioritizing traffic control over aesthetics in commercial–administrative contexts

The most prominent finding of this study is that the variable "reduced car traffic and increased willingness to walk" ranks first in importance. This indicates that in dense, commercial–administrative contexts such as Miremard, the pedestrian–vehicle conflict is the principal perceptual barrier to pedestrian satisfaction. This result aligns with the views of scholars such as Speck and Gehl, who emphasize safety from traffic as a precondition for walkability; they similarly contend that unless the threat posed by vehicular flow is contained, other environmental attributes (including visual quality) cannot play a decisive role in encouraging walking.

Conversely, this finding differs to some extent from strands of research that have placed their primary emphasis on components such as pavement surfacing quality or visual aesthetics. Along corridors with commercial–administrative functions and high motor traffic, users' priorities are oriented less toward the fine-grained details of environmental design and more toward bodily safety, noise exposure, and collision risk. Therefore, in such spaces, controlling and calming vehicular flows is a fundamental prerequisite: until traffic-related risks are reduced, investments in beautification and street furniture cannot realize their full potential in enhancing satisfaction and the use of public spaces. This is also consistent with the hierarchy of human needs: meeting basic needs, such as safety, is a precondition for attending to higher-order needs, including visual beauty and identity.

• The role of safety, sidewalk quality, and lighting in the use of public spaces

The placement of the variables "safety and sidewalk quality" and "nighttime lighting" in the second and third ranks of importance highlights the key role of social security and the temporal dimension of space use. This finding is consistent with the theories of defensible space and the CPTED approach (Crime Prevention Through Environmental Design), which emphasize the importance of route legibility, clearly defined boundaries, natural surveillance, and adequate lighting in reducing opportunities for crime and enhancing citizens' sense of safety.

In an area such as the Miremard neighborhood, where a considerable portion of land use is administrative, and the intensity of activity declines during nighttime, levels of natural social surveillance decrease. Under such conditions, the quality of sidewalks (appropriate paving, adequate width, and the absence of obstacles or blockages) and targeted lighting in blind spots become among the most important tools for maintaining a sense of security and encouraging citizens' presence in public spaces. In other words, safety and path quality influence not only perceived satisfaction but also the frequency and duration of pedestrian presence in the space. By increasing liveliness and the continuous presence of citizens, they, in turn, contribute to the reproduction of social security. This positive cycle has been widely emphasized in the walkability and urban vitality literature as a key principle in the design of safe and vibrant public spaces.

• Limited effectiveness of purely physical interventions without traffic management

The findings of this study indicate that focusing solely on physical improvements, without substantial interventions in traffic management, cannot produce the full and expected impact on citizens' satisfaction

with walkability. Although physical elements such as street furniture, vegetation, and pavement quality are considered important by users, in commercial–administrative contexts with heavy vehicular traffic, these elements tend to be overshadowed by more fundamental issues such as traffic volume, vehicle speed, and irregular on-street parking.

For instance, while replacing pavement materials or installing new street furniture may enhance the visual quality of the environment, as long as pedestrians are still forced to navigate between parked vehicles or confront excessive vehicle speeds, their overall level of satisfaction will not increase significantly. This finding underscores the need for an integrated approach in which traffic management, geometric street design, and physical improvements are addressed as a coordinated package of policies and design interventions rather than as isolated measures. Such an interpretation is consistent with contemporary approaches in sustainable transport planning, which emphasize the simultaneous integration of behavioral, managerial, and physical interventions.

• Contribution of the study to urban management and sustainable development

From a managerial and planning perspective, the principal contribution of this research is the presentation of a framework for prioritizing interventions based on the relative weights of variables in the AdaBoost model. This framework enables urban managers to allocate limited budgets and resources toward interventions that have the greatest impact on improving citizens' satisfaction with walkability, rather than relying on subjective decisions or purely aesthetic considerations. Accordingly, priorities should first focus on traffic management and safety, followed by sidewalk quality and lighting, and finally on beautification and visual quality enhancements.

From a sustainability perspective, the findings indicate that reducing car traffic and supporting walking influence not only user satisfaction but also broader dimensions of sustainable urban development, including reduced fuel consumption, lower pollutant emissions, improved physical and mental health of citizens, and increased vitality of public spaces. In this sense, traffic management in commercial–administrative contexts should not be viewed merely as a localized street-level intervention; rather, it functions as an instrument for advancing broader objectives such as sustainable transportation and the development of human-centered cities.

Conclusion

By moving beyond classical statistical analysis toward intelligent modeling, this study outlined a new pattern of factors influencing walkability in the Miremard neighborhood. The application of the AdaBoost algorithm and the achievement of a relatively high coefficient of determination demonstrate that this method can serve as an effective tool for analyzing complex and nonlinear relationships between environmental variables and citizens' satisfaction, while also providing a foundation for evidence based decision making in urban management.

The results of this study are directly applicable to the Miremard neighborhood of Isfahan, and their generalization to other neighborhoods should be undertaken with consideration of the specific physical, functional, and social characteristics of each context. Nevertheless, since the observed patterns, such as pedestrian–vehicle conflicts, safety deficiencies, and inadequate quality of pedestrian routes, are present in many similar urban environments, the findings of this research may also offer practical implications for comparable contexts, particularly commercial–administrative corridors with high traffic volumes.

The model results clearly indicate that urban interventions in this neighborhood should not be limited solely to physical improvements such as replacing pavement or installing street furniture. Rather, traffic management and the calming of vehicular flows constitute the key mechanisms for enhancing citizens' satisfaction and moving toward more sustainable transportation patterns. Based on these findings, the following recommendations are proposed for urban managers and designers:

Prioritizing traffic calming: Given the high importance of the traffic-related variable, measures such as widening sidewalks, creating pedestrian refuge islands, reducing vehicle speeds, limiting on-street parking, and improving

the geometric design of intersections along the Miremard corridor can have the greatest impact on increasing citizens' satisfaction and encouraging walking.

Enhancing nighttime vitality and perceived security: Considering the importance of nighttime lighting and sidewalk quality, it is recommended that targeted lighting be installed in blind spots, the continuity of pedestrian routes be maintained, physical obstacles be removed, and active nighttime uses (such as cafés and small-scale services) be encouraged. These measures can increase natural surveillance while strengthening pedestrians' sense of security.

Adopting a systemic approach to walkability interventions: The findings show that improving walkability requires a systemic approach in urban management in which transport policies, public space design, land-use planning, lighting strategies, and perceived security are planned simultaneously and in coordination. Although the model reveals differences in the relative importance of variables, focusing solely on beautification elements and street furniture without addressing pedestrian–vehicle conflicts and without improving safety and lighting cannot lead to sustainable user satisfaction. Within such a systemic framework, interventions should be designed as components of an interconnected network in order to prevent resource waste and the implementation of low-impact projects.

This study was subject to several limitations that should be considered when interpreting the results. First, the sample size consisted of 113 questionnaires. Although this number was sufficient for the initial modeling process, increasing the sample size in future studies could improve the model's generalizability and predictive accuracy. Second, data collection was conducted within a specific time period without accounting for seasonal variations. Consequently, the effects of factors such as temperature, precipitation, and weather conditions on the perception of walkability were not directly examined in this study.

Based on the findings, several directions for future research are proposed in three main areas:

Comparative evaluation of machine learning models: Future studies could compare the performance of the AdaBoost model with other machine learning and deep learning algorithms in order to assess their relative accuracy and efficiency in predicting pedestrian behavior.

Day–night comparative analysis of satisfaction models: Examining pedestrian satisfaction separately during daytime and nighttime could provide a more precise understanding of how variables such as lighting, safety, and activity vitality influence users' perceptions.

Application in different urban contexts: Conducting similar research in residential neighborhoods and comparing the relative weights of variables with those identified in commercial–administrative contexts (such as Miremard) could help clarify how land-use type and spatial structure shape pedestrians' expectations and perceptions.

Overall, this study not only provides empirical evidence regarding the factors influencing walkability satisfaction in a commercial–administrative urban context but also demonstrates that the use of machine learning approaches can contribute to improving decision-making in urban planning, sustainable transportation, and the design of human-centered public spaces.

Declaration of No Conflict of Interest

The authors declare that they have no conflict of interest in conducting this research.

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