buildings

MDPI

Article

Walking Environment Satisfaction in an Historic Block Based on POE and Machine Learning: A Case Study of Tianjin Five Avenues

Ziyao Yu [1], Yanwei Zhou [1,*] and Heng Wang [2]

[1] School of Architecture and Art Design, Hebei University of Technology, Tianjin 300401, China; ziyao_yu@126.com

[2] School of Visual Design and Handmade Arts, Tianjin Academy of Fine Arts, Tianjin 300141, China; 15122563269@163.com

* Correspondence: zhouyanwei1990@126.com

Abstract: The increasing volume of motorized traffic not only negatively impacts the structural preservation and overall planning of individual buildings within the block but also disrupts the originally harmonious and pleasant spatial environment of the area. Walking, as a primary mode of urban transportation, plays a crucial role in preserving the unique characteristics of historical blocks, enhancing the quality of the urban environment, and achieving long-term sustainable urban development. This study takes the Five Avenues historical block as a case, assessing the current walking environment from the perspective of Post-Occupancy Evaluation (POE). Machine learning techniques (including web scraping, the TF-IDF algorithm, and the LDA model) were employed to collect and analyze user feedback data, assisting in constructing walking environment satisfaction indicators. A total of 19 key factors affecting walking satisfaction were identified. Paired sample *t*-tests, ANOVA, and reliability and validity analyses were applied to examine the feasibility and practicality of the questionnaire content. Finally, using Importance–Performance Analysis (IPA), the improvement priorities for walking environment indicators were clearly defined. Although the overall satisfaction index of the Five Avenues is comparatively high, unobstructed pathways have the greatest impact on walking environment satisfaction, followed by the rationality of guiding signage facilities, and then by public security management and facility maintenance. Furthermore, visitors prioritize factors such as the cultural recognizability of the area, travel convenience, green space accessibility, and the sidewalk width proportion; they are less focused on the functional aspects of the walkways. Based on the analysis results from POE and machine learning, targeted strategies for improving the walking environment in historical blocks were proposed, aiming to provide a more comprehensive basis for improving the walking environments of similar blocks.

Keywords: walking environment; historical blocks; machine learning; post-occupancy evaluation; Five Avenues

Citation: Yu, Z.; Zhou, Y.; Wang, H. Walking Environment Satisfaction in an Historic Block Based on POE and Machine Learning: A Case Study of Tianjin Five Avenues. *Buildings* **2024**, *14*, 3047. https://doi.org/10.3390/buildings14103047

Academic Editor: Dafna Fisher-Gewirtzman

Received: 26 August 2024
Revised: 18 September 2024
Accepted: 20 September 2024
Published: 24 September 2024

1. Introduction

Historical blocks serve as vital carriers of urban culture and memory preservation, effectively reflecting the social conditions and local customs of a region during specific historical periods [1]. From the perspective of urban development history, the walking system is a primary vehicle for the evolution and development of historical blocks [2,3]. It also forms a fundamental basis for street space, architectural character, and urban vitality [4]. In recent years, urbanization in China has shifted from a period of rapid growth to a more stable phase, with the urbanization rate approaching a peak of around 80%. This transition has been accompanied by a rapid expansion of motorized transportation, leading to urban issues such as traffic congestion, air pollution, and a decline in spatial quality. These issues have directly impacted the quality of the walking environment. Historically, walking and horse-drawn carriages significantly shaped the form and transportation patterns of most historical blocks. The street layouts, walkway widths, spatial scales, and road network structures of these blocks differ considerably from those of modern cities. Historical blocks struggle to accommodate the challenges posed by the substantial volume of motorized traffic [5].

According to the 2023 Environmental Statistics Annual Report for Tianjin, the annual average concentrations of inhalable particulate matter (PM10), fine particulate matter (PM2.5), and the maximum 8 h average concentration of ozone (O3) have all exceeded national standards [6]. Tianjin's inherent resource and environmental limitations have led to a rigid increase in resource and energy consumption, a continuous decline in pollutant mitigation capacity, and growing challenges in sustaining improvements to ecological environmental quality [7]. The city's unique roadway configuration—characterized as "high on the sides, low in the middle"—factors in the orientation, width, height, and shape of adjacent buildings, and the setback distances can all impact the dispersion of urban pollutants [8]. Traditional solutions, such as widening roads or adding parking spaces, not only fail to resolve traffic congestion but also encroach upon and fragment pedestrian-friendly spaces within the blocks, adversely affecting their preservation. These are representative of two sets of solutions: the spatial logic of regionalization and gridding, respectively. Consequently, it is imperative to conduct a systematic and comprehensive study of the walking environment specific to this geographical unit.

The context of new-type urbanization necessitates a greater focus on understanding pedestrians' psychological experiences and the interactions between individuals and the walking environment from a human-centered perspective. Evaluating, analyzing, and optimizing walking environments is essential for the dynamic preservation, organic renewal, and sustainable development of historical and cultural districts in this new era. For residents and visiting tourists, the walking environment serves not only as a vital transportation link connecting clusters of historical buildings but also as a significant space where the cultural characteristics of the historical block are most directly and profoundly experienced [9]. A well-designed and rationalized walking environment, through the modulation of street interfaces and the enhancement of street and alleyway landscapes, combined with accessible and enjoyable street-side resting areas, can effectively encourage a range of activities and behaviors, thereby fostering social interactions among diverse groups [10,11]. Therefore, in the renewal and development of historical blocks, the quality of the walking environment is essential for driving the vitality and vibrancy of the block [12], and it is crucial for representing the city's history and shaping its image. Due to its low-carbon, slow-paced, and close-range nature, walking has become the most effective way to experience and understand the Five Avenues historical block.

Post-occupancy evaluation (POE) is an essential methodology for assessing the built environment. Prioritizing the user's perspective, it utilizes methods such as questionnaire surveys and field observation to identify the strengths and weaknesses of the built environment during its use. This process results in comprehensive reports and feedback on visitor behavior and needs, aiming to explore the intrinsic relationship between actual requirements and subjective evaluations [13]. Due to spatial and temporal limitations, the traditional POE method cannot comprehensively, deeply, or quickly collect evaluation data on built environments. During the distribution of questionnaires, insufficient sample sizes may result in biased experimental outcomes. However, the LDA model and TF-IDF algorithm can effectively address this issue, enabling researchers to rapidly process and analyze large-scale text datasets. These algorithms can extract valuable insights from vast amounts of user reviews and feedback, a task that may be impractical for traditional POE methods. The machine learning analysis combining LDA and TF-IDF not only provides a statistical analysis of the data but also uncovers the underlying structures and relationships within it. This deeper insight enables researchers to better understand and interpret the connections between user satisfaction and the characteristics of the built environment [14–16]. In studies using machine learning to assess satisfaction, Yang Linchuan et al. employed a random forest model to determine the importance of various walking environment indicators and conducted Importance–Performance Analysis to identify priorities for improving these indicators [17]. Wang Youcai used feature word analysis, semantic network analysis, and LDA topic modeling to establish the factors influencing tourist satisfaction [18]. Wang Xiuli and colleagues evaluated resident satisfaction with old neighborhood renovations through a combination of FAHP and machine learning analysis [19]. However, these studies often focus on online reviews, neglecting a robust analysis of the built environment's POE. Therefore, this study integrates POE with machine learning, enhancing both the efficiency and accuracy of data processing while deepening and broadening the scope of research findings. This approach provides a powerful tool for the continuous improvement and optimization of built environments.

Through a review of the relevant literature, researchers have quantitatively evaluated walking environment satisfaction from various perspectives. In terms of street planning, Cervero, R., proposed block density and street functional diversity as key indicators for measuring walking environment satisfaction [20]. Oakes, J., using the Twin Cities in Minnesota as a case study, explored the relationship between walking behavior, street patterns, pedestrian infrastructure, land use functions, and destinations [21]. Frank and colleagues conducted empirical analyses to investigate the correlation between land use mix, population density, and walking environments [22]. Jahan found that the main factors influencing walking environment satisfaction include overall service levels, safety systems, and traffic signal intervals [23]. At the street design level, Wei, D. and colleagues compared walking environments in new, old, and mixed-use neighborhoods, discovering that the diversity of living services, the number of street-front commercial buildings, and green space accessibility positively impact walking environment satisfaction [24]. Zhen, W. proposed a novel quantitative evaluation model for street walking environments, considering six indicators—greenery, walkability, safety, imageability, permeability, and complexity—from both the perspectives of urban planners and users. This model was successfully applied in a case study in Xuhui District, Shanghai [25]. In terms of measuring and evaluating the walking environment, several well-established systems have been developed internationally. These include the UK's Pedestrian Environment Review System (PERS) [26], the Microscale Audit of Pedestrian Streetscapes (MAPS) in the US, New Zealand's Community Street Review (CSR) [27], and Israel's hybrid mesoscale analysis tool [28], all of which provide empirical evaluations. Additionally, there are online evaluation tools such as the US's Walk Score [29], Walkability Score [30], and the Walkability App developed by Walkonomics in Europe for mobile-based walking index assessments [31] (Table 1).

Table 1. Walking environment assessment methods and indicator selection.

Category	Tools	Country/Region	Applicable Scope	Indicators
Empirical Evaluation	PERS	United Kingdom	Walking Environment	Travel Routes, Walking Paths, Intersections, Bus Stations, Transit Stations, Transfer Spaces, Transport Hubs, Public Spaces
	MAPS	United States	Street Environment	Crosswalk Facilities, Street Esthetics, Street Design, Sidewalk Quality, Transit Site Configuration
	CSR	New Zealand	Street Community	Route Length, Environmental Variables, Road Intersection, Traffic Variables
	Hybrid mesoscale analysis tool	Israel	Urban Environment	Street Closure Rate, Sky Visibility Factor, Vegetation Abundance, Distance between Sidewalks and Buildings
Network Evaluation	Walk score	United States	Residential Neighborhood	Distance to Amenities, Population Density, Block Length, Intersection Density
	Walkability App	Europe	Walking Environment	Road Safety, Sidewalk Quality, Orientation and Identification, Leisure and Enjoyment, Safety,
	Walkability Score	United States	Residential Neighborhood	Street Density, Intersection Complexity, Landscape Nodes, Population Density, Highways, and Water Bodies

However, these evaluation indicators and methods do not fully reflect the physical spatial and socio-cultural characteristics of the historical block's walking environment. Therefore, this study aims to identify and prioritize the main indicators affecting the satisfaction of the walking environment in the Five Avenues historical block by combining POE and machine learning methods. Based on the findings, strategies and methods are proposed to improve these factors, providing significant reference value and practical significance for the optimization of walking environments in similar historical blocks.

2. Materials and Methods

2.1. Study of the Regional Overview

The Five Avenues area, located in the southeastern corner of Heping District, Tianjin, China, was established in the early 20th century. Covering approximately 140 hectares, it is a block characterized by five parallel roads running from south to north: Machang Avenue, Munan Avenue, Dali Avenue, Changde Avenue, and Chongqing Avenue. Geographic analysis software such as ArcGIS and Global Mapper, combined with Photoshop, were used to conduct a visual analysis of the overall characteristics and spatial distribution patterns of the block. The block includes residential areas, mixed-use commercial areas, and cultural tourism areas, making it the largest and most functionally diverse historical block in Tianjin (Figure 1). Its architectural style is influenced by European eclecticism and the modernist architectural trends of the early 20th century, incorporating styles from various European countries, including England, Germany, France, Italy, and Spain, spanning from the medieval period to the early 20th century [32]. In 2010, the Five Avenues was awarded the title of "Chinese Historical and Cultural Street" by the China Cultural News and China Relics News [33].

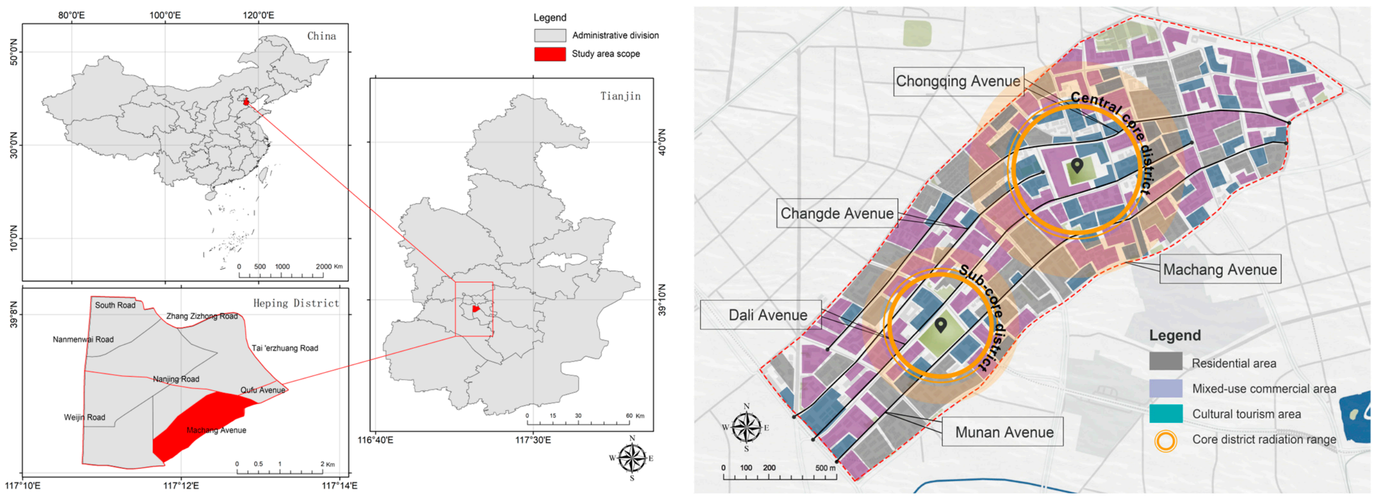

Figure 1. Geographical location and overview of the study area.

The road network of the Five Avenues exhibits distinct temporal characteristics and developmental sequences. The area north of Chongqing Road in the northeast section was developed earlier and retains the "Gordon Plan" approach [34], characterized by a grid-based road network. The remaining areas adapted to the natural conditions of the narrow, elongated shape of the Five Avenues, which is short in the north–south direction and long in the east–west direction. Five roads were established parallel to the north–south boundaries of the land, namely Chongqing Avenue, Changde Avenue, Dali Road, Munnan Avenue, and Machang Avenue. Parallel to the east–west boundaries, five additional roads were established: Kunming Road, Yunnan Road, Guilin Road, Hebei Road, and Xinhua Road. Thus, the road network of the Five Avenues was essentially finalized, forming a "six horizontal and eight vertical" layout [35]. This unique road network structure and architectural texture reflect the esthetic concepts and cultural traditions of the period.

The selection of the study area is based on several considerations. Firstly, Five Avenues is located in the central area of Tianjin, characterized by diverse land use functions, a rich pedestrian composition, and a high walking frequency. These attributes provide representative and valuable data. Secondly, the rapid increase in the number of motor vehicles and traffic in Tianjin in recent years has negatively impacted the spatial pattern of the block, severely affecting the quality of the pedestrian environment. Therefore, the study of the Five Avenues is highly representative.

2.2. Methodology

2.2.1. LDA Topic Model

Latent Dirichlet Allocation (LDA) is an unsupervised machine learning technique introduced by Blei et al. in 2003, designed to discover latent thematic structures within large collections of text data. By applying probabilistic modeling to a set of documents, LDA can reveal hidden patterns of topics across the text. In the LDA model, documents generate topics with certain probabilities, and topics in turn generate words with specific probabilities, forming a three-level hierarchy of "document–topic–word" [36]. When setting key parameters for the LDA model, based on prior research experience, the Dirichlet prior parameters α and β were set to 0.1 and 0.01, respectively, with an appropriate number of topics (K) selected for analysis.

2.2.2. TF-IDF Algorithm

Since the LDA model tends to overestimate the weight of certain commonly used words by constructing matrices based on word frequency, the TF-IDF (Term Frequency–Inverse Document Frequency) method is employed to optimize the LDA model. TF (Term Frequency) refers to the number of times a specific word appears in a given document, while IDF (Inverse Document Frequency) is the ratio of the total number of documents (N) to the number of documents containing that specific word [37,38]. In the formula, k is the word, d is the document, and N is the total number of documents. A higher TF-IDF value indicates that the word t is more important to document d. Additionally, to prevent high-frequency words from overshadowing low-frequency ones, the TF-IDF values must be normalized, where l represents the total number of different words in a specific document.

$$TF - IDF_k(d) = tf_k(d) \times log_{10}\left(\frac{N}{n_k}\right) \quad (1)$$

$$V_d = \sqrt{\sum_{k}^{l}\left(TF - IDF_k(d)^2\right)} \quad (2)$$

$$TF - IDF_k^*(d) = \frac{TF - IDF_k(d)}{\sqrt{\sum_k^l\left(TF - IDF_k(d)^2\right)}} \quad (3)$$

2.2.3. Post-Occupancy Evaluation

Post-Occupancy Evaluation (POE) is a method used to assess the performance of a building after it has been in use for a certain period. It typically involves techniques such as surveys, interviews, observations, and physical measurements to gather data on users' actual experiences and satisfaction with the space. POE focuses on whether the building meets its intended design goals and evaluates its operational performance in areas such as indoor environmental quality, user satisfaction, and energy consumption. The use of POE contributes to improving building performance, ensuring that the structure better meets the needs of its occupants [39]. Procedurally, POE generally follows five steps: "goal establishment, selection of evaluation methods, determination of evaluation factors, data collection, and final feedback" [39,40]. In the context of studying walking environment satisfaction in historical blocks, POE provides crucial insights and data support, focusing on the comprehensive social, cultural, and economic benefits. It helps in understanding the needs of residents and visitors, as well as their actual experiences of the block's walking environment. Through a systematic and rigorous evaluation process, POE enhances the overall value of historical blocks.

2.2.4. Importance–Performance Analysis

In 1977, the Importance–Performance Analysis (IPA) method was introduced by American scholars Martilla and James and has since been widely applied in fields such as tourism, retail, education, and healthcare. This approach combines objective quantification with a subjective rating system. In practice, POE and IPA are often used together to comprehensively evaluate and optimize the performance of buildings or spaces. POE provides data and user feedback, while IPA offers a framework for analyzing these data and identifying improvement strategies, facilitating direct optimization feedback [41,42]. Applied to this study, the average importance of each walking environment indicator in historical blocks is plotted on the horizontal axis, while the average satisfaction score for each indicator is plotted on the vertical axis. A linear function is formed by connecting the intersection point of the average satisfaction and importance values with the coordinate origin. The I, II, III, and IV quadrants in Figure 2 represent the areas of advantage, weakness, improvement, and concentration, respectively [43]. Areas above the linear function indicate that satisfaction has not met expectations. Therefore, indicators in the II quadrant, which show high correlation but low satisfaction, are considered key targets for improvement, while the portion of indicators in the III quadrant that lies above the linear function should also be prioritized for improvement.

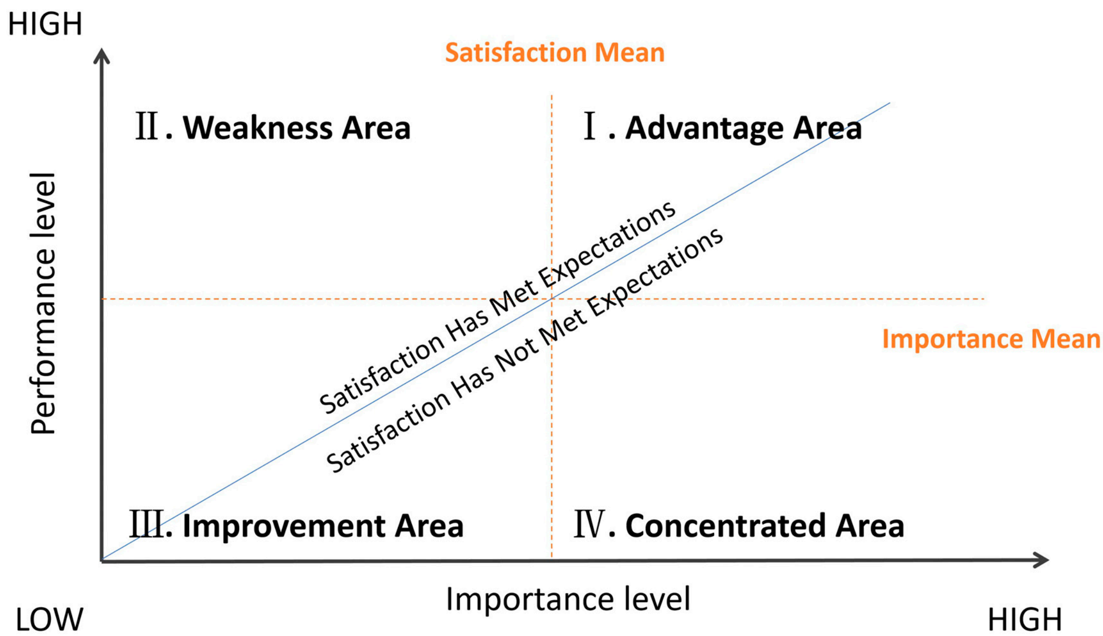

Figure 2. IPA quadrant analysis illustration.

2.3. Process of Collecting Indicators

During the process of collecting indicators, data were supplemented through machine learning algorithms based on a comprehensive literature review and field surveys, with the results presented in a visual format. Ultimately, key evaluation indicators influencing walking environment satisfaction in historical blocks were identified. Figure 3 illustrates the overall technical approach for constructing these indicators.

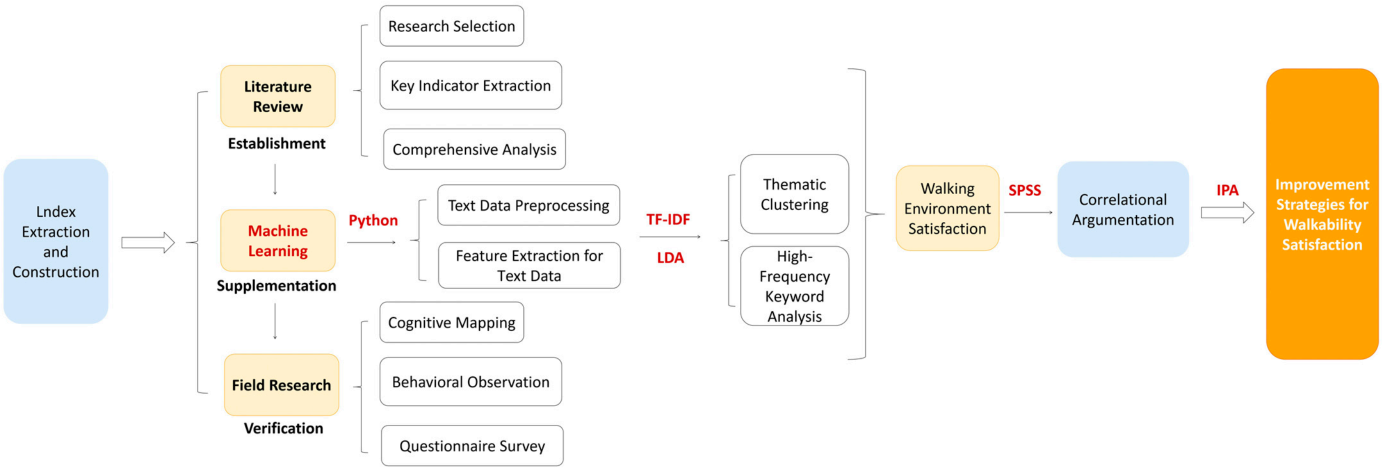

Figure 3. Technical route for indicator collection and analysis.

2.3.1. Preliminary Indicator Establishment

The literature review drew on existing evaluation standard systems, including the "Urban Road Traffic Planning and Design Specifications" (GB5022095) [44], the "China Urban Walkability Evaluation Report" [45], and pedestrian environment evaluation standard guidelines proposed by the American Planning Association (APA) and Transport for London (TFL) [46]. The study initially identified the street system and spatial environment as the primary categories and content for evaluating satisfaction with the walking environment in the block.

The overall perception of the walking environment in the Five Avenues among survey respondents primarily stems from the organization of the street system, with a well-designed street system being essential for a good walking experience. American scholar Michael Southworth proposed six standards for walkable networks [47]. He emphasized the supportive function of the street system in terms of walkability, which can be categorized into external accessibility, internal connectivity, functional diversity, and static transportation systems. These four elements represent the ease of pedestrian access to the area, the connectivity and smoothness of the internal pedestrian network, the diversity and rationality of the area's functional layout, and the completeness and scientific approach of the vehicle parking system [48,49]. This paper argues that at the meso-level of street planning, attention should be given to the impact of land use mix, street connectivity, and travel convenience within historical blocks on walking behavior, with a focus on analyzing the extent to which the built environment supports pedestrian activity [50]. At the micro-level of street design, attention must be paid to the relationship between streets and buildings, with further consideration of pedestrian facilities, green space accessibility, the safety of adjacent structures, and cultural recognizability within the block. The degree of cultural recognizability directly influences visitors' memory and recognition of the local history and culture, playing an irreplaceable role in preserving and transmitting the block's historical and cultural heritage and enhancing the quality of the pedestrian interface [51].

2.3.2. Supplementing Key Indicators Based on Machine Learning

(1) Experimental Environment

The operating system used for this experiment was Windows 10, with Python 3.9 as the programming language, and Jupyter Notebook (Anaconda3) as the development environment.

(2) Data Source

As of May 2024, using "Five Avenues" as the keyword, a search for tourist reviews from the past five years on Ctrip Travel resulted in a collection of 3500 reviews. After filtering out invalid data, a total of 3441 reviews were retained. There are three main reasons for selecting this platform. First, Ctrip has a large and diverse user base, with users coming from different regions and possessing various backgrounds and needs. Therefore, the data extracted from Ctrip can effectively represent a wide range of user opinions and experiences. Second, Ctrip's user reviews often contain rich textual information, including not only assessments of the travel experience but also detailed descriptions of specific locations, services, and facilities, providing multidimensional data for the study. Third, some websites may encrypt or restrict access to user reviews, making data collection challenging.

(3) Data Cleaning and Preprocessing

The Jieba segmentation tool in Python was used to preprocess the text, breaking down continuous text strings into meaningful word units for subsequent analysis. Following this, ROST CM6 was employed to conduct word frequency statistics and sentiment polarity analysis on the processed data. Of the 3441 reviews, approximately 70.04% were positive, while 29.96% were negative (Table 2). This suggests that overall visitor satisfaction with the Five Avenues is relatively high, though certain specific aspects may still need improvement, which may explain why some visitors provided negative feedback.

Table 2. Word frequency statistics and sentiment polarity distribution.

Sentiment Polarity	Frequency	Percentage
Positive emotion (5, +∞)	2410	70.04%
Negative emotion (−∞, 5)	1031	29.96%

To ensure the validity and reliability of the data, the study further categorized the sentiment tendencies in the reviews into six intervals based on emotional intensity (Table 3), and visualized the results using Python (Figure 4). In the negative sentiment range, 41 highly intense comments, distributed within the interval (−∞, −25), were excluded. It is important to note that some tourist attractions or related businesses may attempt to undermine competitors by maliciously posting negative reviews to damage their reputation and boost their own market competitiveness. These typically involve reviews originating from the same time or IP address, containing similarly aggressive language. As a result, 990 reviews from the [−15, 5) and [−25, −15) intervals were retained as the primary sample for assessing and improving the walking environment of the Five Avenues.

Table 3. Range of emotional intensity distribution.

Sentiment Polarity	Emotional Intensity Distribution	Frequency	Percentage
Positive emotion	Neutral Emotions: (5, 15]	1128	32.78%
	Moderate Emotions: (15, 25)	668	19.41%
	High Emotions: (25, +∞)	574	16.68%
Negative emotion	Neutral Emotions: [−15, 5)	862	25.04%
	Moderate Negative Emotions: [−25, −15)	128	3.73%
	High Negative Emotions: (−∞, −25)	41	1.19%

(4) Text Feature Representation

In this study, 990 negative reviews, accounting for 28.77% of the total number, were converted into numerical feature vectors to more accurately highlight important terms. During the feature extraction process, the threshold was set to 0.1, meaning only terms with a TF-IDF value greater than 0.1 were extracted (Table 4).

```
import matplotlib.pyplot as plt
x = ['(−∞, −25)', '[−25, −15)','[−15, 5)','(5, 15]', '(15, 25]','(25, +∞)']
y = [comment_negative_a, comment_negative_b, comment_negative_c, comment_positive_a,
     comment_positive_b, comment_positive_c]
plt.figure(dpi=100)
plt.title('negative and positive interval analysis of emotional intensity')
plt.bar(x, y, width = 0.5, align = 'center', color = 'blue')
plt.show()
```

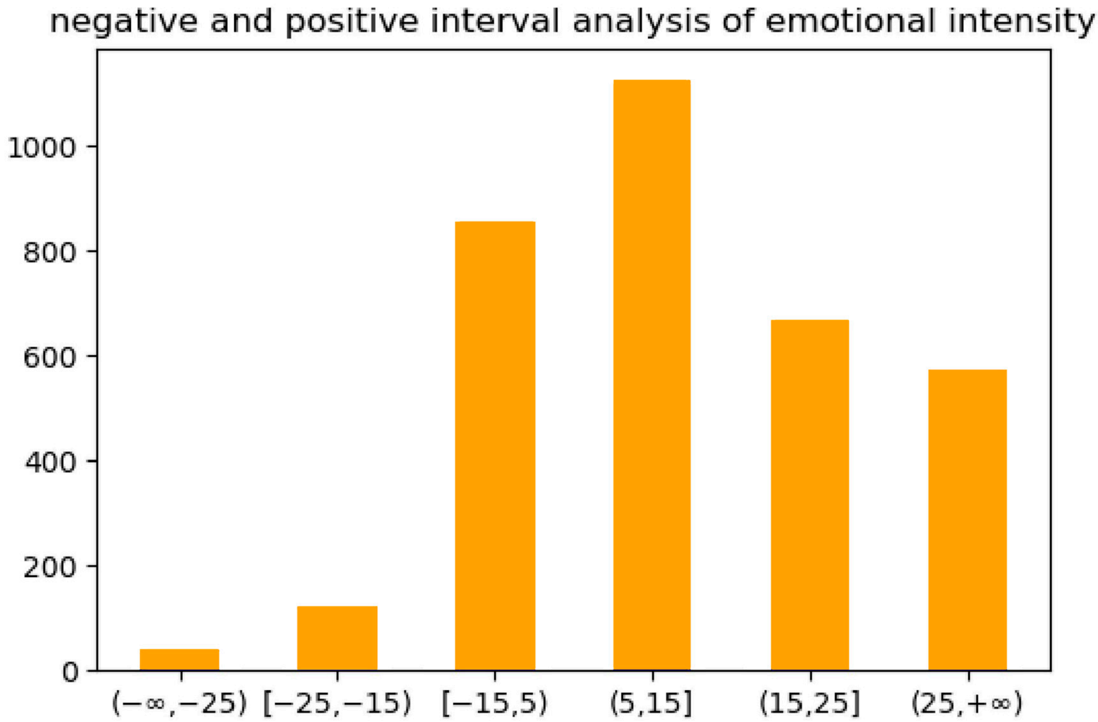

Figure 4. Visualization of sentiment intensity in intervals.

Table 4. Analysis of initial feature.

Initial Feature Terms	TF-IDF Value
traffic chaos	0.75
crowded	0.64
too congested	0.49
unclear signs	0.37
boring	0.27
poor experience	0.25
horse-drawn carriage	0.14
dilapidated facilities	0.12
service attitude	0.11
dangerous	0.11

Based on the extracted feature terms, the pyLDAvis module in Python was used to visualize the results. The output of the LDA model is shown in Figure 5, and the topic distribution results are presented in Table 5. As shown in the figure, the three topics are distributed in different quadrants without overlapping, indicating clear distinctions between the topics when selecting three as the topic number, thus demonstrating good classification performance. Topic 1 includes terms such as "traffic chaos", "crowded", "too congested", and "dangerous". Topic 2 contains terms like "boring", "poor experience", and “service attitude”, while Topic 3 consists of “dilapidated facilities”, “unclear signs”, and “horse-drawn carriage”. Accordingly, these topics can be labeled as “Spatial Environment”, “Visitor Experience”, and “Service Facilities”, respectively. From the frequency of keywords, traffic conditions are mentioned most frequently, followed by the rationality of hardware facilities and signage, and, finally, visitors’ overall impressions of the Five Avenues, including public security management and facility maintenance. These findings provide strong support for the subsequent construction of overall evaluation indicators.

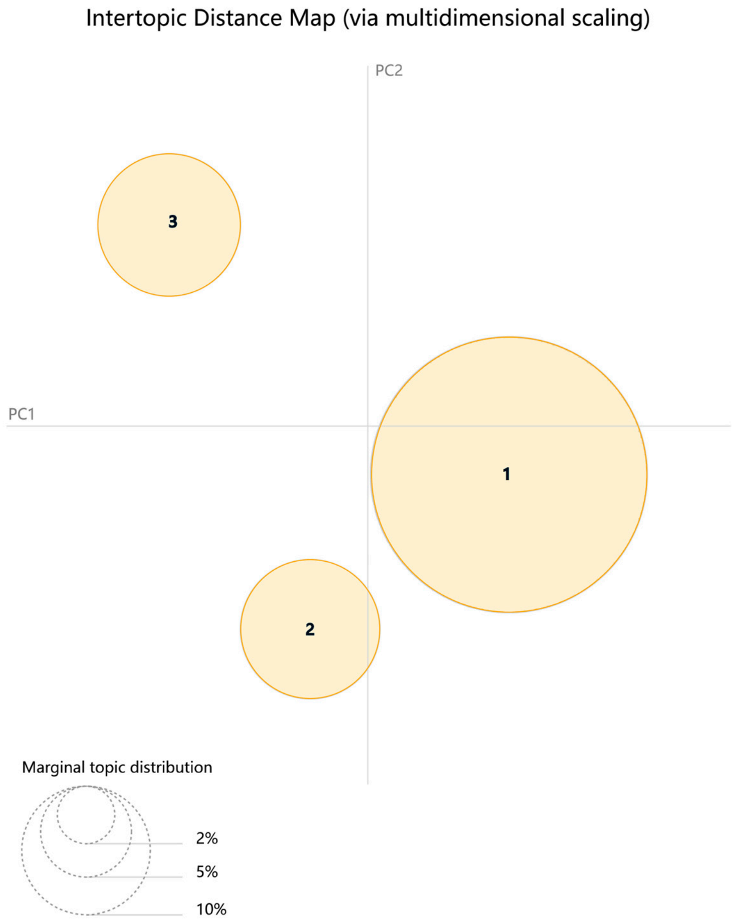

Figure 5. Topic visualization.

Table 5. Topic distribution results.

Topic	High-Frequency Keywords	Frequency
Topic 1 (Spatial Environment)	traffic chaos	228
	crowded	197
	too congested	150
	dangerous	29
Topic 2 (Visitor Experience)	boring	84
	poor experience	76
	service attitude	32
Topic 3 (Service Facilities)	dilapidated facilities	38
	unclear signs	113
	horse-drawn carriage	43

2.3.3. Construction of Comprehensive Indicators

We employed field surveys to conduct the supplementary validation of the walking environment satisfaction indicators identified through a review of the literature and machine learning, ensuring their accuracy and relevance. Our thorough examination of the Five Avenues walking environment revealed that the block's geographical location is frequently impacted by external traffic, particularly during peak periods such as holidays. In some sections, the turning radius has been severely constricted, and the influx of a large number of tourists has placed additional pressure on nearby buildings and infrastructure, heightening safety risks. Moreover, the activities of both residents and tourists are almost evenly distributed throughout the block, with predominant activities including traffic-related activities and stationary activities such as waiting, socializing, and leisure. Pedestrian traffic peaks between 7:00 p.m. and 9:00 p.m. However, our surveys indicate that lighting levels on several streets within the block fall below required standards, particularly on secondary roads, which could compromise the safety of pedestrians and vehicles during nighttime hours. These findings were integrated into the evaluation framework, necessitating adjustments and optimizations of the indicators. Consequently, we developed a scientifically rigorous and highly targeted system for evaluating walking environment satisfaction in historical blocks, consisting of 5 criterion layers and 19 indicator layers (Table 6).

Table 6. Walking environment satisfaction indicators.

Target Layer	Criterion Layer	Indicator Layer
Walking environment satisfaction	A Street System	A1 External Accessibility
		A2 Internal Connectivity
		A3 Travel Convenience
		A4 Functional Diversity
	B Spatial Environment	B1 Green Spaces Accessibility
		B2 Unobstructed Pathways
		B3 Walkway Interface Quality
		B4 Cultural Recognizability
	C Pedestrian Experience	C1 Roadway Turning Radius
		C2 Sidewalk Width Proportion
		C3 Safety of Adjacent Structures
	D Service Facilities	D1 Guidance Signage
		D2 Entertainment Facilities
		D3 Recreational Facilities
		D4 Night Lighting
	E Operational Management	E1 Sanitation
		E2 Facilities Maintenance
		E3 Security Management
		E4 Service Quality

2.4. Sample Collection

The survey was conducted in December 2023 and May 2024. To account for significant variations in foot traffic across different times and locations that could potentially skew the results, the survey was administered from 8:30 AM to 9:30 PM on weekdays and from 8:30 AM to 10:30 PM on weekends, with distributions occurring at half-hour intervals. Questionnaires were randomly distributed across three types of survey locations: residential areas, mixed-use commercial areas, and cultural tourism areas. The target respondents included tourists, residents, and local business operators across various age groups, ensuring a balanced sample throughout different times of the day. A total of 280 questionnaires were distributed, with 257 valid responses collected, resulting in an overall response rate of 91.79%. The questionnaire employed a 5-point Likert scale to assess pedestrians' evaluations of the importance and satisfaction of the walking environment, with scores ranging from high to low to indicate the weight and performance of each factor. For importance, the scale ranged from "1—Not at all important" to "5—Very important", while for satisfaction, it ranged from "1—Very dissatisfied" to "5—Very satisfied" [52]. A questionnaire was crafted based on preliminary data collection, allowing respondents to rate the importance of the evaluation indicators according to their preferences. The scoring standard in Table 7 is calculated as follows: the option average composite score = ($\sum$frequency $\times$ weight)/total respondents. Upon completion of the scoring, paired-sample t-tests and ANOVA were employed to assess the feasibility and practical application of the evaluation indicators.

Table 7. Satisfaction rating standard.

Rating Points	**S ≤ 1.5**	**1.5 < S ≤ 2.5**	**2.5 < S ≤ 3.5**	**3.5 < S ≤ 4.5**	**S > 4.5**
Rating Level	Extremely Low	Below Average	Average	Above Average	Excellent

2.5. Sample Data Analysis

2.5.1. Reliability Analysis

In this study, the primary factors were measured using scales, so verifying the data quality of these measurements is crucial to ensure that subsequent analysis is meaningful [53]. The study initially utilized SPSS 25.0 for reliability analysis, assessing the internal consistency across various dimensions by calculating Cronbach's alpha coefficient.

$$\alpha = \frac{m}{m-1}\left(1 - \frac{\sum_{i=1}^{m} S_i^2}{S_x^2}\right) \tag{4}$$

In the formula, S_i^2 is the variance of the individual items, S_x^2 is the variance of the total score, and m is the number of items. The value of Cronbach's alpha ranges from 0 to 1. The general rule is that the higher the coefficient, the more reliable the scale. Typically, a reliability coefficient below 0.6 is considered unreliable, suggesting the need to redesign the questionnaire or recollect data for reanalysis. A coefficient between 0.6 and 0.7 indicates acceptable reliability, between 0.7 and 0.8 indicates good reliability, between 0.8 and 0.9 indicates very good reliability, and between 0.9 and 1 indicates excellent reliability [54]. In this analysis, the overall reliability coefficients for the walking environment satisfaction indicators ranged from 0.75 to 0.9 (Table 8), indicating that the scale used in this study has good internal consistency.

Table 8. Reliability analysis results.

Indicator Layer	**Cronbach's α (Importance)**	**Cronbach's α (Performance)**
A Street System	0.827	0.769
B Spatial Environment	0.860	0.876
C Pedestrian Experience	0.876	0.866
D Service Facilities	0.842	0.843
E Operational Management	0.836	0.772

2.5.2. Validity Analysis

To assess the validity of the questionnaire and determine how well the results align with the study's objectives, this research conducted an exploratory factor analysis on the collected data. The research utilized the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's test of sphericity to evaluate the suitability of the selected indicators. A higher KMO value suggests stronger correlations among the indicators [55]. The results showed a KMO value of 0.831, which is greater than 0.6, and Bartlett's test rejected the null hypothesis ($p < 0.05$). These findings confirm that the selected indicators are suitable for the subsequent analysis. Detailed results are provided in Table 9.

Table 9. KMO and Bartlett's test of sphericity.

KMO Measure of Sampling Adequacy		**0.831**
Bartlett's test of sphericity	Approximate Chi-Square	2275.808
	Degrees of Freedom (df)	703
	Significance	0.000

3. Results

3.1. Sample Analysis

According to the demographic statistics (Figure 6, Table 10), the proportion of males slightly exceeds that of females, with males constituting 55.8% and females 44.2%, indicating a relatively balanced gender ratio. In terms of age distribution, the largest groups are those aged 19–30 and 31–40, collectively comprising 58.7%. The next largest group consists of individuals aged 41–60, making up 25.5%, while those over 60 represent the smallest proportion at 12.9%. As a prominent tourist destination in China and a significant showcase for Tianjin, Five Avenues attracts a substantial number of visitors. Consequently, tourists comprised the majority of respondents in the survey, accounting for 65.7% of the sample, with nearby workers and residents making up 34.3%. This distribution ensures that the sample reflects a broad range of visitor types. Furthermore, our analysis of visitors' willingness to use walking as a mode of transportation revealed that "Conducive surroundings", "Historical atmosphere", and "Abundant business types" are viewed as critical factors influencing their satisfaction with the walking environment. These attributes collectively enhance the block's distinctive appeal and attractiveness, contributing to a delightful and comfortable walking experience for visitors.

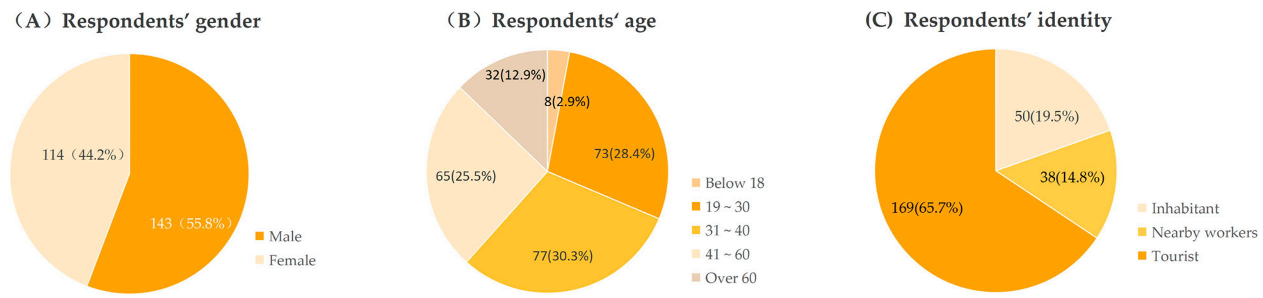

Figure 6. Respondents' basic information.

Table 10. Survey on the reasons for choosing pedestrian transportation mode.

Reason	**Frequency**	**Percentage (Multiple Choice)**
Commuting needs	60	23.35%
Transport convenience	81	31.52%
Conducive surroundings	141	54.86%
Abundant business types	123	47.86%
Comprehensive facilities	106	41.25%
Historical atmosphere	126	49.03%

3.2. IPA for Walking Environment Satisfaction

3.2.1. Indicator Layer Analysis

Using SPSS 25.0, we analyzed the importance and performance data for the 19 indicators, employing the mean, standard deviation, and paired sample *t*-tests with a significance level of 0.05. The results of the IPA are presented in Table 11. The analysis reveals that, in terms of importance, the indicators for Cultural Recognizability (B4), Travel Convenience (A3), and Green Space Accessibility (B1) received relatively high scores. This indicates that respondents place significant emphasis on these aspects, underscoring their importance as key factors for evaluating the walking environment of the block. Conversely, the score for Internal Connectivity (A2) is relatively low, suggesting that respondents are less concerned with the functionality of walkways and the internal road network planning. These elements are perceived as less significant compared to others. In terms of performance, External Accessibility (A1), Cultural Recognizability (B4), and Walkway Interface Quality (B3) received high scores, which suggests these aspects are performing well and are not the primary focus for improvement in this study. On the other hand, Guidance Signage (D1) and Unobstructed Pathways (B2) scored lower in satisfaction, indicating that improvements should be prioritized in these areas. Overall, a significant proportion of the ∣IPA∣ indices fall within the 0–20 range, suggesting that the overall quality of the walking environment is relatively favorable and supportive of walking. Additionally, most standard deviations are within 0.9, indicating that respondents' ratings are consistent and reflect high data stability.

Table 11. IPA statistical analysis of walking environment satisfaction.

Criterion Layer	Indicator Layer	Importance			Performance			Sig. (Two-Tailed)	I-P Mean Difference	IPA Index	Satisfaction Level
		Mean	SD	Rank	Mean	SD	Rank				
A Street System	A1 External Accessibility	4.13	0.79	10	4.37	0.70	1	0.035	−0.24	−5.811	satisfied
	A2 Internal Connectivity	3.64	0.78	19	3.83	0.81	9	0.000	−0.19	−5.219	satisfied
	A3 Travel Convenience	4.41	0.74	2	3.89	0.68	7	0.000	0.52	11.791	average
	A4 Functional Diversity	3.73	0.73	18	3.74	0.88	11	0.015	−0.01	−0.268	very satisfied
B Spatial Environment	B1 Green Spaces Accessibility	4.39	0.62	3	3.87	0.72	8	0.000	0.52	11.845	average
	B2 Unobstructed Pathways	4.36	0.66	4	3.19	0.88	19	0.000	1.17	26.834	dissatisfied
	B3 Walkway Interface Quality	3.91	0.65	14	4.13	0.83	3	0.000	−0.22	−5.626	satisfied
	B4 Cultural Recognizability	4.45	0.75	1	4.24	0.85	2	0.007	0.21	4.719	very satisfied
C Pedestrian Experience	C1 Roadway Turning Radius	3.75	0.65	17	4.01	0.77	4	0.000	−0.26	−6.93	satisfied
	C2 Sidewalk Width Proportion	4.25	0.68	5	3.59	0.87	13	0.000	0.66	15.529	average
	C3 Safety of Adjacent Structures	3.97	0.65	13	3.58	0.74	14	0.000	0.39	9.823	satisfied
D Service Facilities	D1 Guidance Signage	4.13	0.62	10	3.24	0.81	18	0.004	0.89	21.549	dissatisfied
	D2 Entertainment Features	4.14	0.69	9	3.64	0.69	12	0.000	0.5	12.077	average
	D3 Recreational Facilities	3.81	0.65	16	3.49	0.74	17	0.000	0.32	8.398	satisfied
	D4 Night Lighting	4.17	0.64	7	3.78	0.71	10	0.005	0.39	9.352	satisfied
E Operational Management	E1 Sanitation	4.15	0.63	8	3.98	0.83	5	0.013	0.17	4.096	very satisfied
	E2 Facilities Maintenance	4.11	0.61	12	3.53	0.78	15	0.000	0.58	14.111	average
	E3 Security Management	4.23	0.67	6	3.52	0.69	16	0.000	0.71	16.784	average
	E4 Service Quality	3.88	0.59	15	3.93	0.70	6	0.000	−0.05	−1.288	very satisfied

3.2.2. IPA Quadrant Matrix Analysis

Based on the above analysis, an IPA quadrant matrix was constructed to perform a comprehensive analysis of the evaluation factors at the indicator level. After calculation, the mean importance (*y*-axis) score for the pedestrian evaluation of the walking environment elements in the Five Avenues was 4.09, and the mean satisfaction (performance) score (*x*-axis) was 3.76. Therefore, the point (x = 3.76, y = 4.09) was used as the origin to divide the scatter plot grid into four quadrants, where the 19 indicators were positioned within the IPA grid (Figure 7).

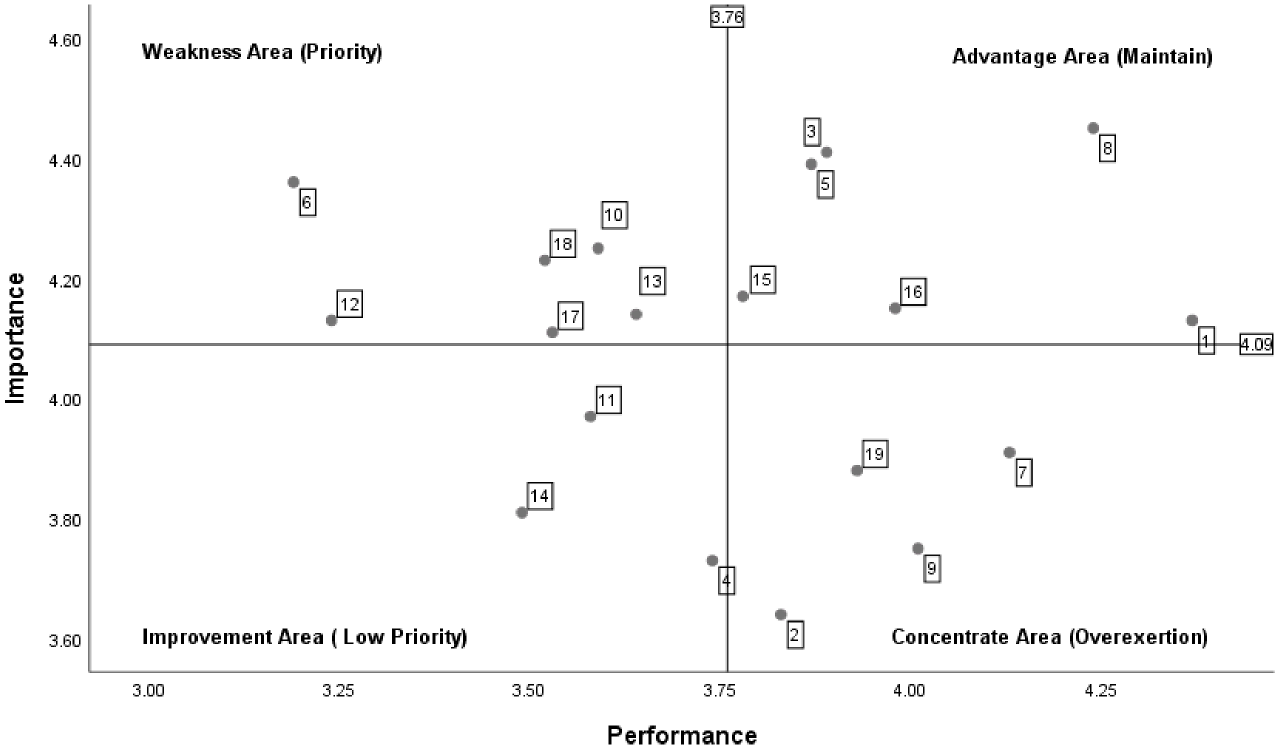

Figure 7. IPA quadrant distribution of the walking environment indicators in the Five Avenues. (1—External Accessibility, 2—Internal Connectivity, 3—Travel Convenience, 4—Functional Diversity, 5—Green Spaces Accessibility, 6—Unobstructed Pathways, 7—Walkway Interface Quality, 8—Cultural Recognizability, 9—Roadway Turning Radius, 10—Sidewalk Width Proportion, 11—Safety of Adjacent Structures, 12—Guidance Signage, 13—Entertainment Features, 14—Recreational Facilities, 15—Night Lighting, 16—Sanitation, 17—Facilities Maintenance, 18—Security Management, 19—Service Quality).

(1) Quadrant I: Advantage Area (Maintain)

Quadrant I contains six indicators that should be maintained. Within this quadrant, Cultural Recognizability (B4) has the highest importance and satisfaction levels. The Five Avenues exemplify the unique charm of East–West cultural fusion, characterized by its rich historical and cultural heritage, distinctive architectural styles, and a strong commitment to cultural preservation and transmission. Although the importance and satisfaction levels in this quadrant are above average, the performance of one indicator, Night Lighting (D4), is significantly lower than its importance rating. Field research revealed that the night lighting in Munan Park, the largest public open space in the area, does not meet the minimum standards set by the "Urban Nightscape Lighting Design Code" (JGJ/T163-2008) [56]. Not only does the road and square night lighting fail to meet national standards, but the night lighting of historical buildings in the Five Avenues also lacks unified planning. Different buildings have varying lighting facilities and colors, which are not in harmony with the architectural styles. Some historical buildings repurposed as restaurants, like

"Geda Building", have night lighting that exceeds the standard, while others that have not been repurposed have inadequate lighting. Improvements are still needed, whereas other indicators such as External Accessibility (A1), Travel Convenience (A3), Green Spaces Accessibility (B1), and Sanitation (E1) can be maintained as they are.

(2) Quadrant II: Weakness Area (Priority)

Quadrant II represents the weakness area, indicating aspects of the walking experience in the Five Avenues that need priority improvement for future optimization. This quadrant includes six indicators. These indicators are of high importance but low performance, indicating a gap between the expectations of respondents and the current performance. With the increase in motorization, Unobstructed Pathways (B2) has become the most critical indicator for respondents but has not met expectations. The core area of the Five Avenues historical block covers 120 hectares, with a total road length of 18,114.91 m and a road network density of 15.1 km/km^2, characterized by "narrow streets and dense road networks" [57]. This could lead to congestion in Sidewalk Width (C2) during holidays due to high foot traffic, ultimately reducing overall visitor satisfaction with the block's walking environment. Additionally, this "dense road network" characteristic poses challenges for Guidance Signage (D1) and Security Management (E3). On the one hand, this affects the completeness and consistency of the signage system, necessitating that the signage be more comprehensive and detailed to cover all paths and nodes within the block. On the other hand, it impacts traffic management and order maintenance, requiring traffic authorities to more precisely regulate traffic flow to ensure road efficiency and safety. Furthermore, considering the overall scale of the Five Avenues, the coverage of Entertainment Features (D2) within a 500 m service radius is approximately 72%. Although the number of facilities is relatively high, their distribution is concentrated, and Facility Maintenance (E2) is insufficient, resulting in these amenities being in a "general health" condition.

(3) Quadrant III: Improvement Area (Low Priority)

Quadrant III represents the improvement area and includes three indicators where importance and performance ratings provided by respondents are notably low, suggesting the necessity for a long-term, incremental improvement strategy. Five Avenue possesses a historical architectural legacy, with structures dating back to the 1920s and 1930s. Over time, these buildings have experienced natural erosion and human-induced wear, resulting in issues such as structural aging and material degradation. In the absence of effective maintenance, the Safety of Adjacent Structures (C3) is at risk of further decline. During the research process, it was found that the safety of adjacent structures may affect visitors' experience of using Recreational Facilities (D3). Approximately 30% of respondents expressed that if visitors are concerned about the safety of adjacent structures and are hesitant to approach or stay for long periods, the usage rate of public recreational facilities would also decrease accordingly. In addition, the satisfaction with the Functional Diversity (A4) in this quadrant is relatively high and does not require focused attention.

(4) Quadrant IV: Concentrated Area (Overexertion)

Quadrant IV represents the concentrated area, including four indicators: Internal Connectivity (A2), Walkway Interface Quality (B3), Roadway Turning Radius (C1), and Service Quality (E4). In this quadrant, the importance of these indicators is lower than their performance levels, indicating that these elements are already well met or even exceed user expectations. Therefore, improvement efforts should focus more on the indicators in Quadrant II, based on the actual situation (Table 12).

Table 12. Conclusions and generalizations from the IPA.

Quadrant Position	Category	Indicators
I	Advantage Area (Maintain)	A1 External Accessibility A3 Travel Convenience B1 Green Spaces Accessibility B4 Cultural Recognizability D4 Night Lighting E1 Sanitation
II	Weakness Area (Priority)	B2 Unobstructed Pathways C2 Sidewalk Width Proportion D1 Guidance Signage D2 Entertainment Facilities E2 Facilities Maintenance E3 Security Management
III	Improvement Area (Low Priority)	A4 Functional Diversity C3 Safety of Adjacent Structures D3 Recreational Facilities
IV	Improvement Area (Low Priority)	A2 Internal Connectivity B3 Walkway Interface Quality C1 Roadway Turning Radius E4 Service Quality

4. Discussion

The walking environment of Tianjin's Five Avenues Historical Block was not adequately considered during early planning phases regarding the impact of modern motorized transportation, resulting in compressed walking spaces and diminished walking experiences. To enhance the overall quality of the block's walking environment, this study employs a machine learning-assisted decision-making approach to construct satisfaction indicators for the walking environment. This method not only quantifies and visualizes user satisfaction with the walking environment of the Five Avenues but also identifies key factors affecting satisfaction and potential areas for improvement. The integration of machine learning technology with POE methods provides a novel research pathway for optimizing the walking environment in historical blocks.

Based on the collected indicators, we conducted an in-depth investigation of the site. We discovered that the inadequacy of public transportation systems and public bicycle infrastructure has increased reliance on motor vehicles. This, in turn, has caused traffic congestion on the roads and significantly reduced visitors' satisfaction with the accessibility of pedestrian walkways. Among the roads within the Five Avenues, most have implemented traffic control measures, with only a select few, including Xikang Road, Chengdu Road, Nanjing Road, Machang Avenue, Guizhou Road, Hebei Road, Xinhua Road, and Hengyang Road, allowing for two-way traffic. Additionally, the area is served by 17 bus stops, one subway station, and 47 bus routes, all within a 300 m service radius encompassing the entire block. This extensive public transport coverage is a significant factor contributing to the high levels of satisfaction regarding external accessibility. Figure 8, made using Photoshop and InDesign, provides a more intuitive depiction of the site information.

In addition, the inherent conflict between the street network structure and modern vehicular traffic has significantly reduced pedestrian space. Currently, most sidewalks in the block are only 2.5 m wide, which, under ideal conditions, can accommodate no more than 2–3 people walking side by side. In contrast, the width of the carriageways ranges from 6 to 9 m (Figure 9). Despite the Five Avenues Historic Block's outstanding performance in terms of scale, spatial structure, architectural volume, and historical character, its land use patterns, safety measures, and street path quality do not significantly promote pedestrian activity. On the contrary, these factors may even inhibit the occurrence of walking.

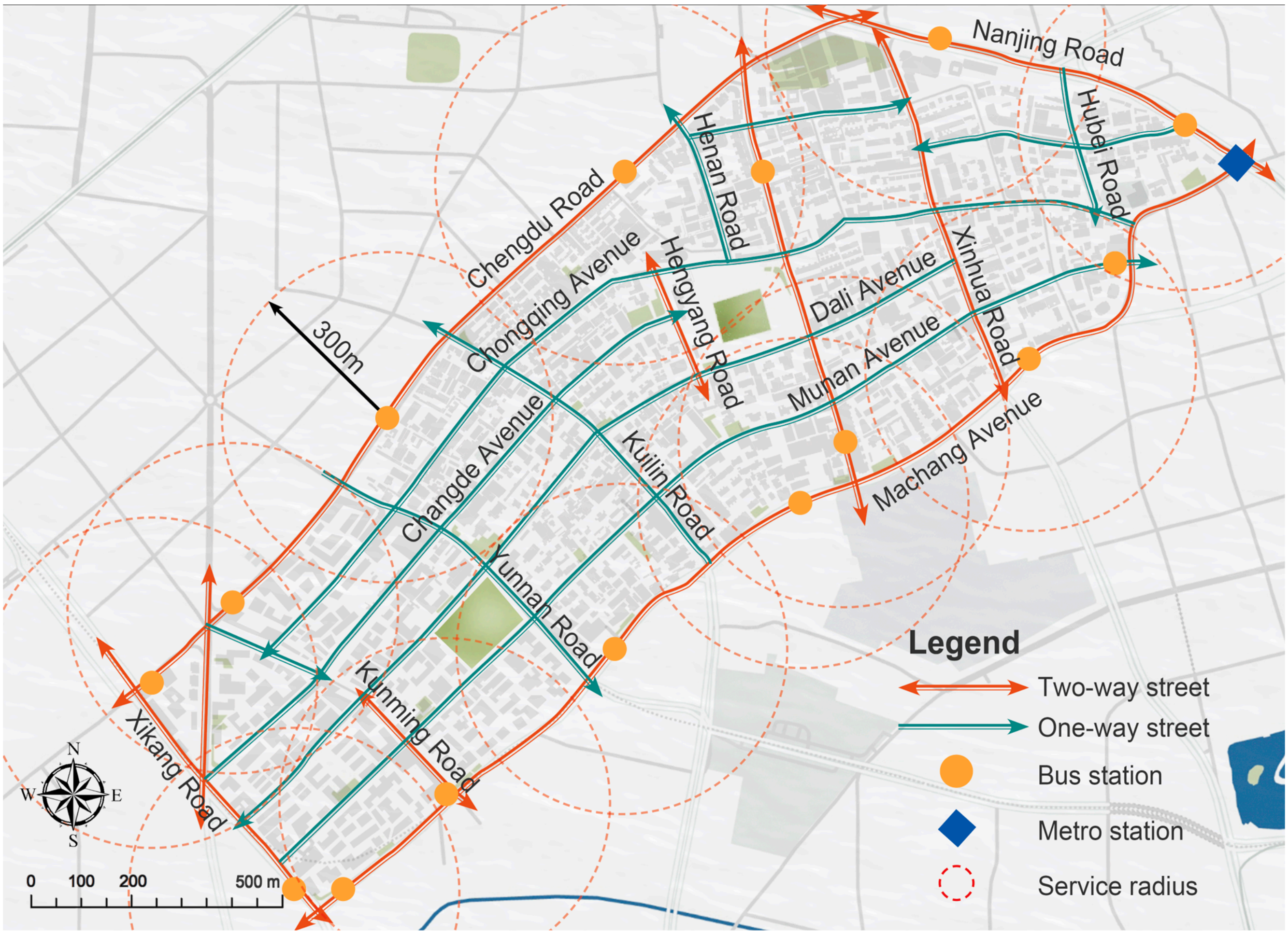

Figure 8. Five Avenues network and bus station distribution.

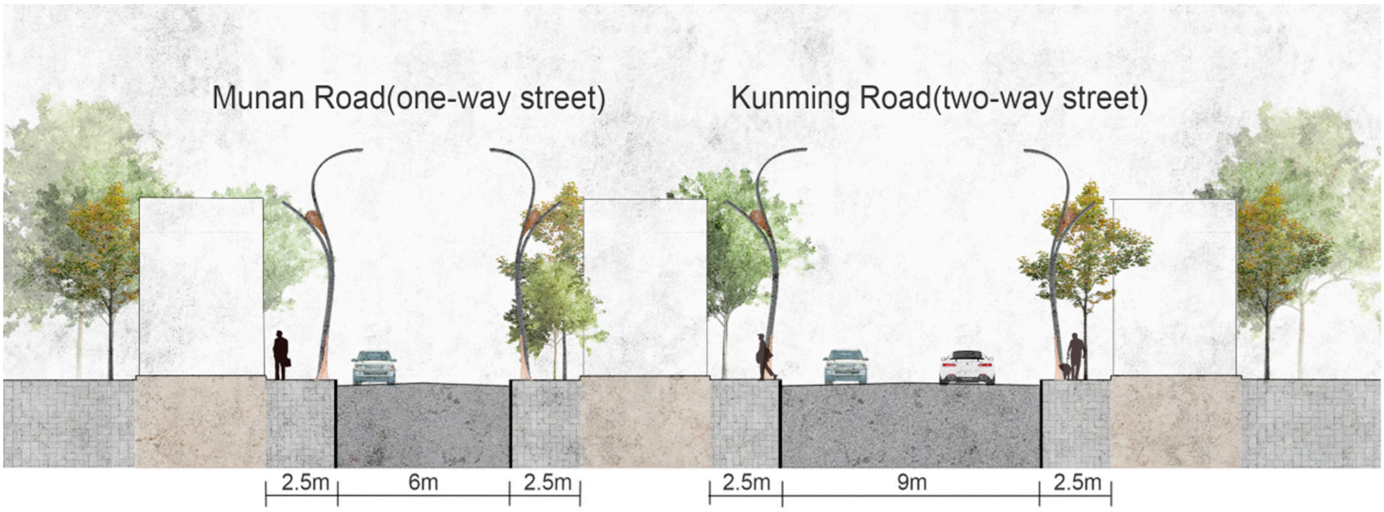

Figure 9. Typical roadway cross-section diagram of Five Avenues.

The issues can be summarized as follows: First, during the initial establishment of the Five Avenues, urban planning and design primarily focused on the architecture and courtyards, without giving sufficient consideration to road traffic. The street spaces were simple connections, lacking in-depth reflection on pedestrian behavior and psychology. Second, in the current era dominated by motor vehicle traffic, policymakers and designers often prioritize vehicular flow when addressing urban road development and related issues. Pedestrian activity is rarely a primary consideration, and existing policies and laws lack adequate support for walking. Third, the block's current division into residential, cultural-tourism, and commercial-mixed zones provides different pedestrian experiences for different user groups. If planning is inadequate, this could lead to traffic chaos within the zones. In this context, the quality of the walking environment, the adequacy of infrastructure, and the strategic layout of the public transportation system are also key factors influencing walking environment satisfaction. Therefore, the following optimization strategies are proposed:

(1) Controlling Roadway Scale and Establishing Slow-Traffic Streetscapes

The functionality of streets in Five Avenues is notably complex. Streets not only serve as conduits for urban traffic but also act as vital spaces for residents' daily lives. Therefore, in these blocks, priority should be given to pedestrian and public transport as the dominant modes of movement, reducing the need for motorized traffic. For dynamic traffic management, it is recommended that road traffic within the Five Avenues historical block be organized by improving the surrounding road infrastructure to divert traffic away from the area. Major surrounding roads, such as Nanjing Road, Machang Avenue, Xikang Road, and Chengdu Road, should be a "protective shell" to prevent traffic from entering the block. In terms of static traffic, a long-term plan to prioritize pedestrian traffic across the block should be implemented, with vehicle speeds controlled at different times of the day to create "tidal" shared spaces for both vehicles and pedestrians. This approach aims to foster a safe and shared slow-traffic block that better caters to the desire for a slower-paced, high-quality lifestyle among urban residents. Additionally, in the creation of the slow-walking scene, modern internet, and mobile big data, technologies can be utilized to focus on street facilities, pedestrian space characteristics, and the travel preferences of residents and tourists. Multi-source heterogeneous analysis methods can be applied to identify key areas for improvement around Minyuan Square and Munan Park. Scientific and intelligent solutions can then be employed to optimize the slow-traffic network system (Figure 10).

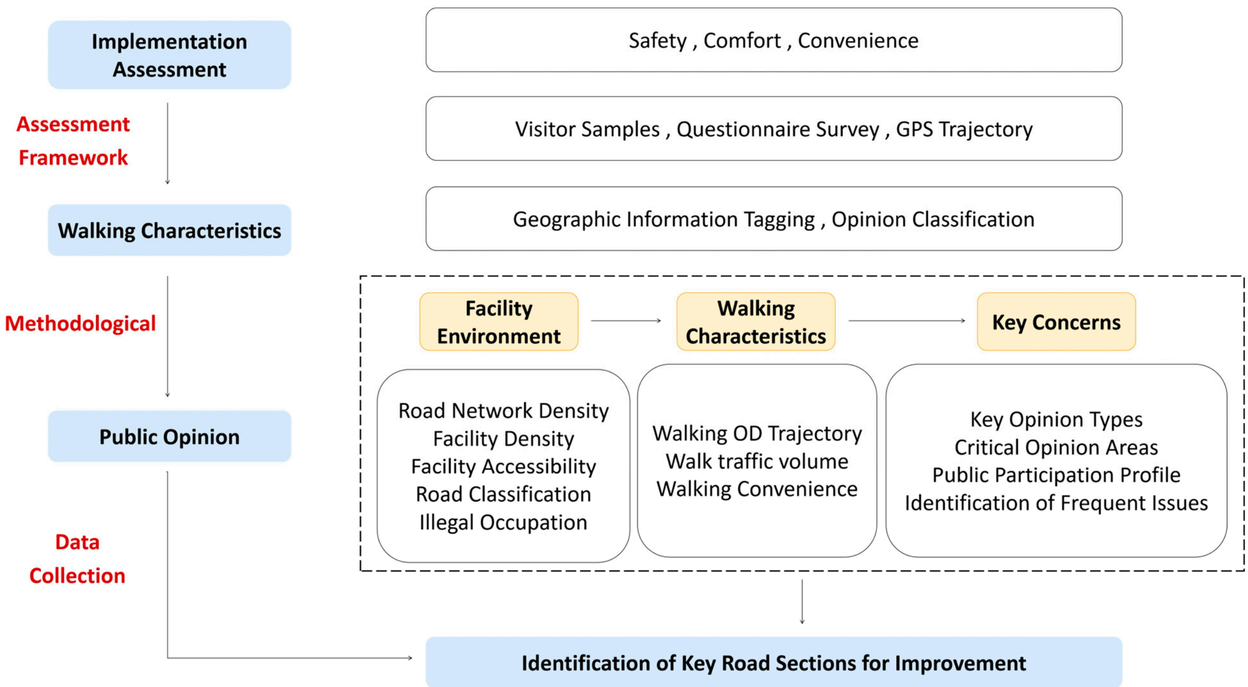

Figure 10. Framework for designing slow-traffic streetscapes.

(2) Defining Pedestrian Zone Functions and Optimizing Walkable Space

Given that the Five Avenues is a protected historical block, it is difficult to create additional open spaces. Therefore, it is necessary to carefully subdivide the functionality of the sidewalks to enhance the space's functionality and usage efficiency. Specifically, the sidewalk area can be divided into three functional subzones: the frontage zone, the pedestrian passage zone, and the facility zone. The frontage zone should be designed as a public space where residents and pedestrians can comfortably linger and enjoy leisure time. In the commercial mixed-use areas within the Five Avenues, the ground floors of street-facing buildings often serve functions such as retail and display exhibitions. During the design process, it is essential to regulate the scope of commercial activities by clearly delineating operational areas to prevent these activities from disrupting pedestrian flow and to ensure a safe and pleasant walking environment. The pedestrian passage zone is the main thoroughfare parallel to the street, this zone must maintain sufficient width to allow smooth pedestrian movement. For sidewalks adjacent to the walls of historical buildings, a recommended width of 1.5 to 2 m should be maintained. In contrast, for pedestrian zones facing active building frontages, a width of 2 to 2.5 m is suggested. To avoid interference between the passage zone and other functional areas, especially in cases where road width is limited, different paving colors and materials can be used to distinguish the functional subzones, ensuring that the design aligns with the historical and cultural characteristics of the block. The facility zone acts as a buffer between pedestrian and vehicular spaces. Currently, municipal facilities such as electrical boxes occupy areas meant for pedestrians, causing inconvenience. To address this, street service facilities should be consolidated in this zone. Additionally, in sections of the block where the pedestrian passage zone is particularly narrow, it is recommended to reduce on-street parking from both sides of the road to just one side. This would free up significant space, allowing for the redistribution of resources within the facility zone (Figure 11).

Figure 11. Cross-sectional diagram of functional zone in sidewalk design.

(3) Improving Supporting Facilities and Promoting Walkway Interface Quality

Munan Park and Minyuan Square are large public service facilities, and it is recommended to concentrate certain public services around key transportation hubs, such as within a 100 m radius of the Xiaobailou metro station. More critical services can be placed within a 30 m radius to better allocate space for traffic flow transitions. Night lighting facilities should minimize large-scale "floodlighting" on historical buildings, adhering to the principles of "authenticity, integrity, conservation, minimal intervention, recognizability, and reversibility" as outlined in the Venice Charter for the protection of traditional architecture [58]. On this foundation, the focus should gradually shift toward street lighting that enhances pedestrian spaces. Moreover, the cultural and architectural significance of the Five Avenues should be deeply explored, with signature buildings selected from each street. Architectural symbols and the language of these buildings can be incorporated into the design of signage systems, offering visitors a unique experience distinct from other tourist sites. It is also important to consider the wayfinding needs of both residents and tourists by carefully planning the number and placement of signage across the area. This will ensure that all visitors, including the elderly and people with disabilities, can easily access information from the most optimal vantage point. Additional signage for accessible facilities, along with tactile guiding systems for the visually impaired, should be installed to accommodate the needs of special pedestrian groups.

(4) Smart Integration of Multifunctionality and Reinforcement of Spatial Historic Identity

Cultural recognizability is a key indicator in visitors' evaluations of walking environment satisfaction in the Five Avenues. Scene-based and digital media can enhance the historical expression of the block's culture. These media include restored facades based on historical records, narrative-driven landscape sculptures, historical scene installations, historical images, physical exhibitions, and intangible cultural heritage activities, all of which work to create a more immersive cultural experience. In terms of scene creation, three thematic sections can be established based on the area's defining characteristics: concession culture, commercial culture, and modern history. These sections—"Concession Era", "Commercial Prosperity", and "Modern Reforms"—can draw inspiration from classic stories associated with historical buildings (Prince Qing's Mansion), commercial legends (Quanyechang), and historical events (the Anti-Japanese War), offering innovative approaches to scene creation. In terms of digital technology, AR, VR, and naked-eye 3D technologies can be leveraged to create interactive digital displays for the historical buildings and streets of the Five Avenues. These technologies expand the channels for cultural dissemination, emphasizing contextual integration, resonant reception, multimodal interaction, and immersive sensory experiences, thereby enhancing the overall walking experience for visitors.

5. Conclusions

Walking environment satisfaction in historical blocks is a complex issue influenced by multiple factors and represents a critical direction for achieving dynamic preservation, organic renewal, and sustainable development in the modern era. This study analyzes the walking environment of the Five Avenues historical block, identifying existing challenges and proposing strategies for optimization and improvement. The goal is to provide comprehensive suggestions for enhancing walking environments in similar historical blocks. The conclusions of this study are as follows:

First, this study combines POE with machine learning, overcoming the limitations of traditional POE methods in data gathering and processing. By employing Python web scraping techniques and the TF-IDF algorithm, combined with the LDA model, key information influencing walking environment satisfaction in the Five Avenues was extracted from a large volume of user reviews. Negative reviews predominantly mentioned the spatial environment, followed by the visitor experience and service facilities. Incorporating field surveys and literature reviews, a walking environment satisfaction evaluation system was developed, consisting of five dimensions and 19 indicators. This approach not only improved the efficiency of data collection but also enhanced the accuracy and objectivity of data analysis. Second, the study employed IPA to identify the key factors affecting walking environment satisfaction in the Five Avenues historical block. The results revealed that cultural recognizability, travel convenience, and green space accessibility were highly valued in the block, primarily frequented by tourists and residents. However, there was a significant gap between expectations and reality in terms of unobstructed pathways and guidance signage. These findings provide a clear direction for the improvement of the walking environment in the block. Third, based on the analysis, a series of targeted improvement strategies were proposed. These strategies include controlling roadway scale and establishing slow-traffic streetscapes, defining pedestrian zone functions and optimizing walkable space, improving supporting facilities and promoting walkway interface quality, the smart integration of multifunctionality, and reinforcing spatial historic identity.

The limitations of this study lie in the reliance on data from a single online platform during the machine learning-based indicator collection process, which may introduce bias due to the specific demographics of platform users. Moreover, as internet technology advances, user-generated content is becoming increasingly diverse, with reviews often including images, videos, and other multimedia data in addition to text. Future research will need to address these challenges to further optimize the methodology.

Author Contributions: Z.Y. contributed to the development of the idea and participated in all phases. Y.Z. and H.W. helped perform the analysis with constructive discussion. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Major Social Science Project of Tianjin Municipal Commission of Education, grant number 2023JWZD42.

Institutional Review Board Statement: Ethical review and approval were waived for this study by the Academic Committee of Hebei University of Technology, due to involving no more than minimal risk.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Zhang, R. *Research on the Protection of Historical and Cultural Blocks*; Francis Academic Press: London, UK, 2017.
2. Zeng, F.; Shen, Z. Study on the impact of historic district built environment and its influence on residents' walking trips: A case study of Zhangzhou ancient city's historic district. *Int. J. Environ. Res. Public Health* **2020**, *17*, 4367. [CrossRef] [PubMed]
3. Wijaya, D.N.; Pratama, A.Y.; Yafie, E.; Nagari, P.M.; Wulandari, P.K. Historical Walking Tour in Lasem: A Local Perspective. In Proceedings of the International Conference on Social Knowledge Sciences and Education (ICSKSE 2023), Malang, Indonesia, 25–26 July 2023.
4. Kanellopoulou, D. Walking, feeling, talking: The experience of public space in the historical center of Athens. *Senses Soc.* **2017**, *12*, 177–192. [CrossRef]
5. Sundling, C.; Jakobsson, M. How Do Urban Walking Environments Impact Pedestrians' Experience and Psychological Health? A Systematic Review. *Sustainability* **2023**, *15*, 10817. [CrossRef]
6. Tianjin Municipal Ecology and Environment Bureau. *Tianjin Municipal Environmental Status Bulletin*; Tianjin Municipal People's Government: Tianjin, China, 2024. Available online: https://sthj.tj.gov.cn/YWGZ7406/HJZL9827/HJZKGB866/TJSLNHJZKGB6653/202406/W020240607552214186412.pdf (accessed on 1 August 2024).
7. Zhao, S.M.; Ma, Y.F.; Wang, J.L.; You, X.Y. Landscape pattern analysis and ecological network planning of Tianjin City. *Urban For. Urban Green.* **2019**, *46*, 126479. [CrossRef]
8. Yu, Z.; Xu, E.; Zhang, H.; Shang, E. Spatio-temporal coordination and conflict of production-living-ecology land functions in the Beijing-Tianjin-Hebei region, China. *Land* **2020**, *9*, 170. [CrossRef]
9. Purwantiasning, A.W.; Bahri, S. Creating Better Environment by Implementing The Concept Of Walking And Cycling Within Historical Area Of Kota Tua Jakarta. *Int. J. Built Environ. Sci. Res.* **2021**, *5*, 131–142. [CrossRef]
10. Lotfata, A. *Walkable Access and Walking Quality of Built Environment: A Case Study of Englewood, Chicago City Metropolitan. The Palgrave Encyclopedia of Urban and Regional Futures*; Springer International Publishing: Berlin/Heidelberg, Germany, 2023; pp. 2149–2164.
11. Borthwick, D.; Stenning, A.; Marland, P. (Eds.) *Walking, Landscape and Environment*; Routledge: London, UK, 2020.
12. Readman, P. Walking, and knowing the past: Antiquaries, pedestrianism and historical practice in modern Britain. *History* **2022**, *107*, 51–73. [CrossRef]
13. Zimring, C.M.; Reizenstein, J.E. Post-occupancy evaluation: An overview. *Environ. Behav.* **1980**, *12*, 429–450. [CrossRef]
14. Tian, C.; Zhang, J.; Liu, D.; Wang, Q.; Lin, S. Technological topic analysis of standard-essential patents based on the improved Latent Dirichlet Allocation (LDA) model. *Technol. Anal. Strateg. Manag.* **2024**, *36*, 2084–2099. [CrossRef]
15. Gao, L.; Cui, F.; Zhang, C. Library Similar Literature Screening System Research Based on LDA Topic Model. *J. Inf. Knowl. Manag.* **2024**, *23*, 2450077. [CrossRef]
16. Dai, S.; Li, K.; Luo, Z.; Zhao, P.; Hong, B.; Zhu, A.; Liu, J. AI-based NLP section discusses the application and effect of bag-of-words models and TF-IDF in NLP tasks. *J. Artif. Intell. Gen. Sci. (JAIGS)* **2024**, *5*, 13–21. [CrossRef]
17. Yang, L.; Tang, X.; Yang, H.; Shi, Y. Research on the Satisfaction of Elderly People's Walking Environment and Strategies for Elderly-friendly Environmental Improvement Supported by Machine Learning. *J. Hum. Settl. Environ.* **2024**, *39*, 35–40.

18. Wang, Y.C. *Research on Tourist Satisfaction of Red Tourism Classic Scenic Spots in Jiangxi Province Based on Machine Learning*; Nanchang University: Nanchang, China, 2023.
19. Wang, X.L.; Chen, L.; Yuan, B.F. Research on the Evaluation of Resident Satisfaction in the Renovation of Old Residential Areas: An Analysis Based on FAHP and Machine Learning. *Price Theory Pract.* **2023**, *2*, 71–74.
20. Cervero, R.; Wu, K.L. Polycentrism, commuting, and residential location in the San Francisco Bay area. *Environ. Plan. A* **1997**, *29*, 865–886. [CrossRef] [PubMed]
21. Oakes, J.M.; Forsyth, A.; Schmitz, K.H. The effects of neighborhood density and street connectivity on walking behavior: The Twin Cities walking study. *Epidemiol. Perspect. Innov.* **2007**, *4*, 16. [CrossRef]
22. Frank, L.D.; Pivo, G. Impacts of mixed use and density on utilization of three modes of travel: Single-occupant vehicle, transit, and walking. *Transp. Res. Rec.* **1994**, *1466*, 44–52.
23. Jahan, M.I.; Mazumdar AA, B.; Hadiuzzaman, M.; Mashrur, S.M.; Murshed, M.N. Analyzing service quality of pedestrian sidewalks under mixed traffic condition considering latent variables. *J. Urban Plan. Dev.* **2020**, *146*, 04020011. [CrossRef]
24. Wei, D.; Yan, L.; Yu, D.; Wen, W.; Ying, C. How the Perceived Built Environment Affects Pedestrian Well-Being: Evidence from Three Types of Neighborhoods in Harbin, China. *China City Plan. Rev.* **2024**, *33*, 65.
25. Wei, Z.; Cao, K.; Kwan, M.P.; Jiang, Y.; Feng, Q. Measuring the age-friendliness of streets' walking environment using multi-source big data: A case study in Shanghai, China. *Cities* **2024**, *148*, 104829. [CrossRef]
26. Kelly, C.E.; Tight, M.R.; Hodgson, F.C.; Page, M.W. A comparison of three methods for assessing the walkability of the pedestrian environment. *J. Transp. Geogr.* **2011**, *19*, 1500–1508. [CrossRef]
27. Newell, P. Citizenship, accountability and community: The limits of the CSR agenda. *Int. Aff.* **2005**, *81*, 541–557. [CrossRef]
28. Yosifof, R.; Fisher-Gewirtzman, D. Hybrid quantitative mesoscale analyses for simulating pedestrians' visual perceptions: Comparison of three New York City streets. *Environ. Plan. B Urban Anal. City Sci.* **2024**, *51*, 140–156. [CrossRef]
29. King, K.E.; Clarke, P.J. A disadvantaged advantage in walkability: Findings from socioeconomic and geographical analysis of national built environment data in the United States. *Am. J. Epidemiol.* **2015**, *181*, 17–25. [CrossRef] [PubMed]
30. Carr, L.J.; Dunsiger, S.I.; Marcus, B.H. Walk score™ as a global estimate of neighborhood walkability. *Am. J. Prev. Med.* **2010**, *39*, 460–463. [CrossRef] [PubMed]
31. Monreal, C.O.; Pichler, M.; Krizek, G.; Naumann, S. Shadow as route quality parameter in a pedestrian-tailored mobile application. *IEEE Intell. Transp. Syst. Mag.* **2016**, *8*, 15–27. [CrossRef]
32. Brown, H.C. *Fifth Avenue Old and New, 1824–1924*; Fifth Avenue Association: New York, NY, USA, 1924.
33. Zhang, T.; Sunsheng HA, N. Preservation and Regeneration Strategies for the Wudadao (Five Avenues) Area, Tianjin, China. *China City Plan. Rev.* **2014**, *23*, 62.
34. Geng, M.; Hong, L.; Ma, K.; Wang, K. Evolution of urban public space landscape in Tianjin port city. *J. Coast. Res.* **2020**, *104*, 142–146. [CrossRef]
35. Gravari-Barbas, M.; Guinand, S.; Lu, Y. Hybridisation and circulation of models in Tianjin's former concessions. *J. Herit. Tour.* **2021**, *16*, 513–532. [CrossRef]
36. Mo, Y.; Kontonatsios, G.; Ananiadou, S. Supporting systematic reviews using LDA-based document representations. *Syst. Rev.* **2015**, *4*, 172. [CrossRef]
37. Jelodar, H.; Wang, Y.; Yuan, C.; Feng, X.; Jiang, X.; Li, Y.; Zhao, L. Latent Dirichlet allocation (LDA) and topic modeling: Models, applications, a survey. *Multimed. Tools Appl.* **2019**, *78*, 15169–15211. [CrossRef]
38. Khadija, M.A.; Nurharjadmo, W. Enhancing Indonesian customer complaint analysis: LDA topic modelling with BERT embeddings. *SINERGI* **2024**, *28*, 153–162. [CrossRef]
39. Meir, I.A.; Garb, Y.; Jiao, D.; Cicelsky, A. Post-occupancy evaluation: An inevitable step toward sustainability. *Adv. Build. Energy Res.* **2009**, *3*, 189–219. [CrossRef]
40. Stevenson, F. Post-occupancy evaluation and sustainability: A review. *Proc. Inst. Civ. Eng. Urban Des. Plan.* **2009**, *162*, 123–130. [CrossRef]
41. Azzopardi, E.; Nash, R. A critical evaluation of importance–performance analysis. *Tour. Manag.* **2013**, *35*, 222–233. [CrossRef]
42. Abalo, J.; Varela, J.; Manzano, V. Importance values for Importance–Performance Analysis: A formula for spreading out values derived from preference rankings. *J. Bus. Res.* **2007**, *60*, 115–121. [CrossRef]
43. Nizza, I.E.; Farr, J.; Smith, J.A. Achieving excellence in interpretative phenomenological analysis (IPA): Four markers of high quality. *Qual. Res. Psychol.* **2021**, *18*, 369–386. [CrossRef]
44. *GB 5022095*; Standard for Urban Residential Area Planning and Design. MOHURD: Beijing, China, 2016.
45. NRDC. *Evaluation Report on Walkability of Chinese Cities*; NRDC: Beijing, China, 2014.
46. Lee, S.; Lee, S.; Son, H.; Joo, Y. A new approach for the evaluation of the walking environment. *Int. J. Sustain. Transp.* **2013**, *7*, 238–260. [CrossRef]
47. Southworth, M. Designing the walkable city. *J. Urban Plan. Dev.* **2005**, *131*, 246–257. [CrossRef]
48. Liu, B.; Yan, L.; Wang, Z. Reclassification of urban road system: Integrating three dimensions of mobility, activity and mode priority. *Transp. Res. Procedia* **2017**, *25*, 627–638. [CrossRef]
49. Liang, C.; Zeng, J. Optimization of Walking Environment in Historical and Cultural Districts Based on Importance-Performance Analysis: A Case Study of Tianjin Five Avenues Area. *Mod. Urban Res.* **2019**, *2*, 54–59.

50. Lytvynenko, T.; Tkachenko, I.; Ilchenko, V. Principles of street and urban road space formation in modern cities. *Int. J. Eng. Technol.* **2018**, *7*, 642–648. [CrossRef]
51. Ewing, R.; Handy, S. Measuring the unmeasurable: Urban design qualities related to walkability. *J. Urban Des.* **2009**, *14*, 65–84. [CrossRef]
52. Joshi, A.; Kale, S.; Chandel, S.; Pal, D.K. Likert scale: Explored and explained. *Br. J. Appl. Sci. Technol.* **2015**, *7*, 396–403. [CrossRef]
53. George, D.; Mallery, P. *Reliability Analysis/IBM SPSS Statistics 25 Step by Step*; Routledge: London, UK, 2018; pp. 249–260.
54. Tavakol, M.; Dennick, R. Making sense of Cronbach's alpha. *Int. J. Med. Educ.* **2011**, *2*, 53. [CrossRef] [PubMed]
55. Papadimitriou, E.; Lassarre, S.; Yannis, G. Introducing human factors in pedestrian crossing behaviour models. *Transp. Res. Part F Traffic Psychol. Behav.* **2016**, *36*, 69–82. [CrossRef]
56. *JGJ/T 163-2008*; Urban Night Lighting Design Standards. China Architecture & Building Press: Beijing, China, 2009.
57. Liu, T.; Butler, R.J.; Zhang, C. Evaluation of public perceptions of authenticity of urban heritage under the conservation paradigm of Historic Urban Landscape—A case study of the Five Avenues Historic District in Tianjin, China. *J. Archit. Conserv.* **2019**, *25*, 228–251. [CrossRef]
58. Hardy, M. (Ed.) *The Venice Charter Revisited: Modernism, Conservation and Tradition in the 21st Century*; Cambridge Scholars: Newcastle upon Tyne, UK, 2008.