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Associations of Street-Level Advertising and Visual-Interface Features with Pedestrian Dwell Behavior in a Historic Commercial Street: Evidence from Guangzhou

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Abstract

In Guangzhou's Shangxiajiu Pedestrian Street, street segments with higher billboard densities exhibited greater proportions of both brief stops and extended dwell, while segments with higher densities of illuminated signage at night also showed greater proportions of extended dwell. Higher street width-to-height ratios and greater ground-floor façade transparency were associated with increased afternoon pedestrian activity and brief stopping, respectively. Using 13 street segments as the units of analysis, this study combined on-site measurements, synchronized behavioral observations, and correlation analysis to examine the associations of billboard density, illuminated signage density, street width-to-height ratio, and façade transparency with brief stopping, extended dwell, and through-movement behavior. The results showed that billboard density was strongly and positively correlated with both the mean proportion of brief stops and the mean proportion of extended dwell ($r = 0.749$, $p = 0.003$; $r = 0.832$, $p < 0.001$). Illuminated signage density was also strongly and positively correlated with the proportion of extended dwell at night ($r = 0.823$, $p = 0.001$). Street width-to-height ratio was positively correlated with both the afternoon proportion of brief stops and the afternoon proportion of total pedestrian activity, while façade transparency was positively correlated with the afternoon and mean proportions of brief stops. These findings indicate that, in the case of Shangxiajiu Pedestrian Street, pedestrian dwell was more concentrated in street segments characterized by richer commercial information, greater nighttime visibility, more open spatial configurations, or more legible storefront interfaces. The findings provide field-based quantitative evidence to inform signage layout, ground-floor interface optimization, the coordination of street enclosure, and the management of nighttime visual environments in historic commercial streets.

Keywords: commercial streets; outdoor advertising; pedestrian stopping behavior; correlation analysis

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1. Introduction and Literature Review

1.1. Research Background and Problem Statement

In *The Aesthetic Townscape*, Yoshinobu Ashihara defines the exterior wall as the boundary between the "interior" and "exterior" of a building and emphasizes the important role of building-wall orientation in shaping street form. He further argues that industrialization has led to a substantial proliferation of billboards and neon signs in urban streets, thereby markedly impairing their aesthetic quality. Ashihara therefore advocates the use of appropriate principles to guide signage design and improve this condition [1]. This conception of street space can be further situated within the pattern-language framework proposed by Alexander et al. Alexander et al. conceptualize pedestrian streets as integrated environments generated through interrelated patterns, including "pedestrian street," "street openings," "street windows," "arcades," and "path shape," thereby emphasizing the coordinated relationship among spatial form, interface organization, and public activity [2]. Building on this perspective, the "street as a room" pattern interprets continuous building façades, rows of trees, and other vertical elements as the "walls" of street space, and streets and sidewalks as its "floor." It also incorporates enclosure ratios, boundary continuity, absolute scale, and specific urban contexts into the explanatory framework for pedestrian environments [3]. Through a pattern-network analysis, Park [4] further found that "pedestrian street" and "building complex" constitute key patterns in the design of urban centers, while interface-related patterns, such as ground-floor openings, street windows, arcades, and building edges, play an important role in organizing activities in public space. Observations from related street cases likewise emphasize that absolute street width, continuous street walls, trees, and human-scale design jointly create pedestrian environments that are comfortable, legible, and vibrant [5]. Accordingly, the width-to-height relationship, façade transparency, and signage configuration of a commercial street can be understood as interrelated elements that jointly shape spatial enclosure, interface legibility, and public life. In China, rapid urbanization and increasingly intensive commercial activity have made outdoor pedestrian streets important settings for leisure and recreation. At the same time, outdoor advertising occupies visually prominent positions along urban roads and in public squares and commercial districts [6,7]. However, inadequate management and limited targeted research have allowed persistent problems relating to the quantity, scale, content, form, materials, and colors of outdoor advertising to remain unresolved [8]. As users of urban space constitute the intended audience of outdoor advertising, its visual and informational attributes directly influence pedestrians [9]. Moreover, as an important component of the external space of commercial streets, outdoor advertising directly shapes street-space form and may thereby indirectly affect patterns of pedestrian activity [10]. On this basis, the present study adopts an environment–behavior perspective to understand the relationships among outdoor advertising, street space, and pedestrian activity; these relationships are further synthesized in Section 2, "Theoretical Framework and Research Questions." More specifically, this perspective concerns the interrelationships among advertising-related informational stimuli, street-interface characteristics, and pedestrian dwell behavior. In commercial streets, signage-related attributes not only function as commercial-information stimuli but also reshape street-level interfaces and spatial perception, thereby influencing pedestrians' brief stopping and extended dwell behavior. Previous studies have shown that the effects of street environments on walking behavior are not limited to the direct influence of objective spatial conditions; pedestrians' subjective perceptions and walking experiences may also indirectly shape their behavioral choices [11]. Research on the relationship between the built environment and street vitality has similarly demonstrated measurable and systematic associations between morphological characteristics, human-scale features, and street vitality [12]. Against this background, the present study examines Shangxiajiu Pedes-

trian Street as a representative case of a commercial street in a historic urban district and focuses on a clearly defined scientific question: What associations exist between street-level visual-interface features and pedestrian dwell behavior? To address this question, the study measures billboard density, illuminated signage density, street width-to-height ratio, and façade transparency, and tests their correlations with the proportions of three categories of pedestrian activity: brief stopping, extended dwell, and through movement. Previous studies have shown that the environmental quality of commercial streets affects dwell, social interaction, and street vitality [13], while street-design qualities such as imageability, enclosure, human scale, transparency, and complexity are closely related to pedestrian experience [14]. Incorporating signage-related visual interfaces into research on pedestrian behavior in historic commercial streets can therefore help explain the connections among commercial-information stimuli, the perception of street space, and the vitality of public life, while providing context-specific evidence for the management and urban design of historic commercial streets.

1.2. Outdoor Advertising, Street-Level Visual Interfaces, and Pedestrian Behavior

Outdoor advertising functions both as a commercial-information stimulus and as an important component of the street-level visual interface. The number, area, color, luminance, contrast, placement, and content complexity of advertisements jointly shape visual salience, attention allocation, visual comfort, and evaluations of the street environment [8,15–17]. In commercial pedestrian streets, signage also interacts with storefront width, façade transparency, and street scale to form the ground-floor interface directly perceived by pedestrians. Recent studies have identified significant associations between commercial-display density, ground-floor interface transparency, street width, and other microscale street elements, on the one hand, and pedestrian movement, stopping behavior, and spatial vitality, on the other [10,18,19]. Accordingly, the present study incorporates billboard density, illuminated signage density, street width-to-height ratio, and façade transparency into an integrated behavioral-analysis framework and focuses on their statistical associations with the proportions of brief stopping, extended dwell, and through movement.

Neurodesign research provides further evidence for understanding the perceptual effects of visual complexity in façades and signage. Visual complexity is jointly shaped by repetitive regularity, luminance contrast, spatial frequency, orientation, geometric variation, graphic layering, material reflectance, and viewing distance, and it influences environmental experience through visual-processing efficiency, perceptual interest, and visual stress. Valentine et al. [20] found that façade compositions characterized by regular repetition, high contrast, and concentration within specific spatial-frequency ranges exhibited higher predicted levels of visual stress, whereas compositions with greater geometric variation exhibited lower levels. Their subsequent experiments further showed that façade type and the extent to which façades deviate from the statistical properties of natural scenes were associated with subjective complexity, visual comfort, and autonomic nervous system activity [21]. A cross-period study of building façades in Seoul similarly demonstrated that material heterogeneity, compositional regularity, and viewing distance jointly influence the visual-stress characteristics of façades [22]. Commercial-street signage can therefore be regarded as part of the visual field of the building façade, with its quantity, repetitive rhythm, contrast relationships, and spatial layering collectively shaping pedestrians' visual experience.

Research on advertising installation and governance provides an important foundation for understanding the visual environment of commercial streets. Previous studies have primarily examined changes in the visual environment caused by outdoor advertising, the coordination between advertisements and building façades, and the assessment of visual

pollution [8,23]. These findings indicate that the quantity and form of advertising should be understood in relation to specific street-interface characteristics and user perceptions. On this basis, the present study treats advertising management as a broader research context and focuses more specifically, within the literature review, on the relationships among advertising characteristics, street-level visual interfaces, and pedestrian dwell behavior.

Digitalization has increasingly endowed advertising in commercial streets with illuminated, dynamic, and interactive characteristics. Illuminated screens, LED displays, and interactive advertisements alter the nighttime visibility and visual salience of information, the speed of content updating, and the ways in which audiences interact with advertising [8,24,25]. Lighting, dynamism, and interactivity therefore constitute important contextual dimensions for understanding the relationships between advertising-related visual stimuli and pedestrian attention and behavioral responses. The present study primarily uses illuminated signage density to represent the numerical distribution of illuminated advertising at night and examines its association with pedestrian dwell behavior as one of the principal research concerns.

Pedestrian behavior in commercial pedestrian streets is closely related to street scale, ground-floor interfaces, commercial displays, retail density, and activity-supporting facilities. Recent studies have found that commercial-display density, façade transparency, and interactive street elements are associated, to varying degrees, with pedestrian movement, stopping, and engagement behavior [10]. Research based on pedestrian trajectories has further shown that street width, ground-floor interface permeability, advertising area, and retail mix are jointly associated with the spatial vitality of commercial streets [18]. In addition, the vitality of commercial pedestrian streets varies significantly between weekdays and non-working days, between daytime and nighttime, and among different street segments [19]. Eye-tracking and visual-attention research further explains how pedestrians selectively perceive street-facing interfaces. Mobile eye-tracking studies have shown that pedestrians' visual engagement with street edges is concentrated primarily at ground-floor level, and that walking tasks, street type, and the side on which an interface is located jointly influence fixation distributions [26]. The number of ground-floor interface segments, storefront openings, display windows, entrances, and human-scale details can create a continuous sequence of visual anchors and prolong pedestrians' visual engagement with street-facing interfaces [27]. From the perspective of cognitive architecture, Sussman and Hollander [28] argue that biologically grounded perceptual features, including edges, openings, symmetry, curves, and face-like configurations, preferentially organize visual attention. Related biorecognition research has also shown that window arrangements and façade compositions generate distinct patterns of visual engagement [29,30]. Accordingly, street-facing interfaces can be classified into different levels of visual engagement according to their capacity to attract initial fixations, sustain gaze, and organize scanning paths, thereby providing a perceptual mechanism for explaining continuous pedestrian movement, storefront observation, and transitions from walking to dwelling.

Quantitative auditing research on public spaces provides a further integrated approach to evaluating street use. Using the Pedestrian Level of Service (PLOS) and the Sustainable Urban Mobility Indicator for Quality of Public Space (SUMI-QPS), Belaroussi et al. [31] converted walking routes, spatial comfort, safety, accessibility, and overall public-space quality into composite scores and compared evaluations obtained in real-world and immersive virtual environments. Their cross-cultural streetscape study further demonstrated that spatial scale, architectural style, walking quality, and cultural background jointly influence users' evaluations of public spaces [32]. With respect to predicting spatial use, Delhoum and Belaroussi [33] developed the Visit Potential Model, which predicts pedestrian movement, spatial occupancy, and activity hotspots in public spaces on the basis of population activity

demands, commercial and leisure attractions, and spatial networks. Taken together, these studies indicate that street use can be quantified at three complementary levels: observed behavior, perceived level of service, and potential for spatial visitation.

Overall, the existing literature has accumulated substantial evidence concerning the relationships between street-space elements and pedestrian behavior. However, evidence directly linking street-advertising characteristics with observable behaviors such as brief stopping and extended dwell remains under development. The present study therefore focuses on billboard density, illuminated signage density, street width-to-height ratio, and façade transparency, and examines the relationships between these visual-interface indicators and the proportions of pedestrian activities.

1.3. Technological Context, Regulatory Boundaries, and Research Positioning

Advertising technologies and local governance jointly define the contextual boundaries of the relationship between commercial-street advertising and pedestrian behavior. Digital screens, illuminated signage, and interactive advertising differ in their visibility, visual salience, pace of content renewal, and modes of audience engagement. Meanwhile, local regulations governing electronic displays, dynamic lighting, operating hours, luminance, and light pollution determine how these forms of visual stimulation are manifested in the street environment. Guangzhou's current regulatory documents on outdoor advertising and signage have incorporated electronic display devices, dynamic lighting, luminance control, and the prevention of light pollution into their scope of governance [34,35]. The present study treats these technological and regulatory factors as part of the research context while concentrating its empirical analysis on the associations between billboard density, illuminated signage density, street width-to-height ratio, façade transparency, and the proportions of pedestrian activities.

Taken together, the literature reviewed above comprises three interrelated strands of research: first, the visual attributes, visual pollution, and governance of outdoor advertising; second, the relationships of street scale and ground-floor interfaces with pedestrian dwelling and street vitality; and third, the relationships among nighttime lighting environments, commercial activity, and pedestrian behavior [8,10,19]. The present study further connects these strands within the context of a historic commercial street. Billboard density and illuminated signage density are treated as dimensions of informational stimulation, whereas street width-to-height ratio and façade transparency are treated as dimensions of the spatial interface. The study then examines the statistical associations between these simplified environmental indicators and the proportions of brief stopping, prolonged dwelling, and passing through. Accordingly, the aim of this study is to identify case-specific associations between street-advertising and visual-interface features and pedestrian dwell behavior and to compare how these associations differ between the afternoon and nighttime observation periods.

2. Theoretical Framework and Research Questions

This study develops an analytical framework from an environment–behavior perspective to explain the associations between street advertising and visual-interface features and pedestrian dwell behavior. The framework comprises two interrelated analytical dimensions—informational stimuli and spatial interfaces—and is operationalized through simplified environmental indicators measured at the street-segment level and observed proportions of pedestrian activity.

Within this framework, the relationships shown in Figure 1 are further interpreted from an environment–behavior perspective, with the advertising–pedestrian relationship in commercial streets conceptualized along two analytical dimensions. The first is the

informational-stimulus dimension. Billboard density and illuminated signage density reflect the quantitative distribution of exposure to commercial information, nighttime visibility, and visual salience, and can therefore be used to test their statistical associations with the proportions of brief stopping and extended dwell. Within the environment–behavior framework adopted in this study, visual attention can be understood as a perceptual pathway linking the street-level visual interface to observable behavior. Billboards and illuminated signs generate visual salience; transparent storefronts, entrances, display windows, and ground-floor subdivisions create attentional anchors; and the street width-to-height ratio influences the extent and continuity with which these interface cues enter pedestrians' visual fields. Street frontages characterized by clearly defined openings, moderate subdivision, and continuous visual information are more likely to generate organized visual-scanning paths and to support spatial orientation, storefront recognition, brief stopping, and subsequent dwelling as pedestrians move through the street [27,28,30].

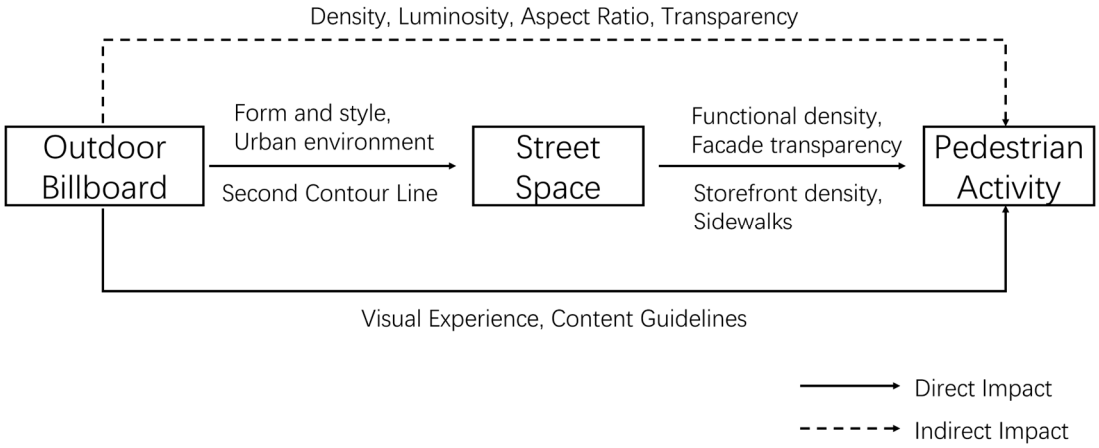


Figure 1. Schematic representation of the relationships among outdoor advertising, street space, and pedestrian activity.

The second is the spatial-interface dimension. According to the pattern-language framework and the "street as a room" concept, street space is formed by continuous spatial boundaries composed of building façades, rows of trees, signage, arcades, storefront openings, and the ground plane. Within this configuration, the street width-to-height ratio represents the cross-sectional scale of room-like street space, façade transparency represents the visual connection between the street "wall" and ground-floor activities, and the "secondary contour line" created by signage further modifies pedestrians' sense of enclosure and spatial legibility at eye level [2,3]. Park's pattern-network analysis [4] indicates that pedestrian streets and building complexes constitute key nodes in the design of urban centers, while interface patterns such as arcades, street openings, building edges, and street windows jointly support public activity. Previous eye-tracking studies have also shown that pedestrians devote substantially greater visual attention to ground-floor street interfaces than to upper façades while walking, indicating that ground-floor interface characteristics play a critical role in the street experience. Accordingly, this study treats the street width-to-height ratio and façade transparency as simplified indicators of continuous street space and active ground-floor interfaces and examines them alongside billboard density and illuminated signage density to identify their statistical associations with the observed proportions of pedestrian activity.

Accordingly, this study addresses the following research questions: What associations exist between signage-related environmental factors and different types of pedestrian dwell behavior in commercial streets? Do these associations differ between afternoon and nighttime conditions?

The contribution of this study is therefore positioned as a case-specific empirical extension. In the context of Shangxiajiu Pedestrian Street, a historic commercial street, the study examines the associations between signage-related visual-interface variables and the proportions of pedestrian dwell behavior recorded through synchronized observations, thereby extending the empirical evidence connecting outdoor advertising research with research on pedestrian behavior in commercial streets. Recent studies of commercial pedestrian streets have shown that street vitality and dwell behavior vary significantly according to time of day, spatial location, and built-environment conditions. Street-segment-level field measurements and behavioral observations can therefore provide a comparable basis for subsequent validation across multiple study sites [10,18,19]. This analytical approach is methodologically complementary to the quantitative public-space research conducted by Belaroussi and colleagues. The PLOS and SUMI-QPS primarily capture users' overall perceptions of walking conditions and public-space quality; the Visit Potential Model primarily predicts pedestrian movement, spatial occupancy, and activity hotspots; and the behavioral proportions used in the present study describe the actual composition of brief stopping, extended dwell, and through movement during specific observation periods [31–33]. Together, these three types of indicators constitute a multilevel quantitative framework extending from environmental conditions and user perceptions to actual street behavior.

3. Research Design and Methods

3.1. Research Content

Guided by the environment–behavior conceptual framework outlined above, this study conceptualizes signage configuration on commercial streets as an environmental condition that simultaneously shapes informational stimulation and the spatial interface and further examines its associations with pedestrian dwell behavior. The research comprised three main stages. First, signage-related environmental variables were measured, including billboard density, illuminated signage density, street width-to-height ratio, and façade transparency. Second, pedestrian activities were measured, with particular attention to three behavioral categories: brief stopping, prolonged dwelling, and passing through. Third, statistical analyses were conducted to examine the correlations between signage-related environmental variables and different types of pedestrian activity. This workflow operationalizes signage within the environment–behavior relationships of commercial streets, primarily to generate verifiable, case-specific correlational evidence and to provide a comparative basis for subsequent research incorporating multiple time periods, locations, and data sources. Recent studies have demonstrated that the vitality of commercial pedestrian streets can be contextually measured and interpreted using street-segment characteristics, pedestrian activities, and built-environment variables [18,19].

3.2. Research Variables

The variables examined in this study comprise signage- and street-related characteristics (X) and pedestrian activity variables (Y). Specifically, the signage- and street-related variables include billboard density, illuminated signage density, street width-to-height ratio, and façade transparency. These four variables were prioritized for two main reasons. First, they could be measured with a relatively high degree of consistency and reliability across the 13 street segments, while capturing both the quantitative effects of signage and the interface effects of street space. Second, given the current number of street-segment observations, billboard density and illuminated signage density were defined as segment-level quantitative indicators representing the respective concentrations of billboards and illuminated signs. Signage size, actual luminance, color temperature, color contrast, dy-

namic variation, content complexity, and overall visual intensity may also affect visual comfort, attention allocation, and behavioral responses. From a neurodesign perspective, billboard density and illuminated signage density in the present study primarily represent the quantity of visual exposure at the street-segment level, whereas visual complexity constitutes a complementary qualitative dimension. This dimension includes repetition, contrast intensity, spatial frequency, directional structure, graphic layering, and material reflectance within signage–façade compositions. Previous studies have shown that these visual attributes jointly influence the perceived complexity of façades, visual comfort, and physiological responses [20,21]. This conceptualization situates the quantitative indicators used in the present study within a more comprehensive framework of façade-related visual processing. Recent research has shown that outdoor advertising and visual pollution influence evaluations of the urban visual environment through attributes such as color, scale, location, density, and illumination [16,23]. Studies of interactive and roadside advertising have similarly indicated that dynamism, content presentation, and stimulus intensity affect audience engagement, comprehension, and discomfort [17,24]. Accordingly, this study uses billboard density and illuminated signage density as street-segment indicators of the quantitative dimension of signage, while their complementary relationships with luminance, size, content complexity, and visual intensity are further addressed in the Discussion and Limitations sections. Billboard density reflects the number of retail establishments and the intensity of commercial functions. Illuminated signage density refers to the concentration of self-illuminated advertisements along the street and is used to represent the nighttime effects of signage. The street width-to-height ratio represents the relationship between street width and height as perceived by pedestrians and takes into account the secondary contour line formed when signage is incorporated into the street profile. Façade transparency reflects the morphological characteristics of the ground-floor interface. Jan Gehl noted that the diversity of ground-floor interfaces exerts a substantial influence on pedestrian activity [36], while the placement of signage and display windows affects façade transparency.

The second group of variables concerns pedestrian activity. Behaviors observable in the field included walking, conversing, stopping to look, taking photographs, eating, and resting. Because the study relied on synchronized manual observations at the street-segment level and required consistent recording criteria across all 13 segments, these activities were not further classified according to specific purposes such as social interaction, window-shopping, or digital-device use. Instead, a time-based operational classification was adopted. Activities involving a cessation of movement were classified as either "brief stopping" or "prolonged dwelling" according to their duration, whereas pedestrians who continued walking without stopping were classified as "passing through." Specifically, brief stopping was defined as remaining stationary for no more than 1 min, prolonged dwelling as remaining stationary for more than 1 min, and passing through as continuing to walk without stopping. The 1 min threshold was used solely to construct comparable street-segment-level behavioral indicators and was not intended to constitute a comprehensive behavioral typology. Previous studies have shown that dwelling behavior on commercial pedestrian streets can be characterized in terms of frequency, duration, and purpose, while pedestrian behavior in public spaces often includes differentiated forms of stopping, group interaction, and social participation [10,37]. The categories of brief stopping, prolonged dwelling, and passing through used in this study are therefore more appropriately understood as an operational classification of dwelling intensity than as an exhaustive classification of behavioral purposes. Observations were conducted on one weekday and one weekend day, with two daily observation periods: 14:30–16:30 in the afternoon and 18:30–20:30 at night. This procedure generated data on the proportions of

pedestrian activities during the afternoon, at night, and on average across the observation periods. The observation schedule was designed to capture variations in pedestrian dwelling between weekdays and weekends, as well as between daytime commercial activity and the nighttime visual environment. Previous research has shown that pedestrian vitality on commercial pedestrian streets varies substantially across time, space, and built-environment conditions [19] and that street elements on commercial pedestrian streets are closely associated with pedestrian dwelling behavior [10]. The specific variables are presented in Table 1.

It should also be clarified that the Y1–Y9 indicators used in the subsequent analyses were calculated by standardizing the counts of different types of pedestrian activity as percentages of the corresponding total pedestrian sample. These indicators therefore represent pedestrian proportions rather than density in the strict spatial sense. Strictly defined, pedestrian density generally refers to the number of pedestrians per unit area [38]. Accordingly, the term "pedestrian proportion" is used consistently throughout this study.

From the perspective of quantitative approaches to street-use assessment, the pedestrian activity proportions used in this study constitute observational behavioral indicators, whereas PLOS and SUMI-QPS are perception-based composite evaluation indicators, and the Visit Potential Model represents a predictive indicator of spatial use [31,33]. Observational indicators capture the actual structure of pedestrian activities within specific street segments and observation periods; perception-based indicators reflect users' overall evaluations of walking quality, comfort, and public-space quality; and predictive indicators represent the potential distribution of visits generated jointly by spatial attractions and population activity demands. These three categories of indicators correspond to actual use, subjective evaluation, and spatial potential, respectively, and may be integrated in future research.

Table 1. Study Variables and Rationale for Selection.

Category	Variable	Rationale for Selection	Main References
Variable X1	Billboard density	Represents the overall intensity of advertising stimuli and commercial information exposure at the street-segment level, and to some extent also reflects the concentration of commercial functions. Research on commercial pedestrian streets has shown that the configuration of street elements is significantly associated with stopping behavior and street vitality.	[10,12]
Variable X2	Illuminated advertisement density	Represents the intensity of nighttime advertising stimuli and visibility, and is used to capture the nighttime salience of signboards. Relevant studies have shown that signage in the visual environment, lighting conditions, and nighttime vitality on commercial streets can all affect pedestrian experience and stopping behavior.	[19,39]
Variable X3	Street width-to-height ratio	Represents the perceived spatial scale and degree of enclosure experienced by pedestrians, while also taking into account the visual changes produced when signboards form a "second contour line." Previous research has indicated that street form and scale are important factors affecting the vitality of historic districts and commercial streets.	[12,40]
Variable X4	Facade transparency	Represents the visibility, openness, and permeability of the ground-level street interface. Relevant studies have shown that ground-level interface characteristics significantly affect pedestrians' visual engagement, street experience, and the distribution of activities.	[26,41]
Variable Y1–Y9	Pedestrian share (lingering, staying, and total pedestrian share; calculated separately for the afternoon, nighttime, and average values)	To enable synchronized observation and comparison at the street-segment level, pedestrian activity was operationalized as lingering share, staying share, and total pedestrian share, and further distinguished across three temporal dimensions—afternoon, nighttime, and average values—to reflect stopping intensity and its temporal variation.	[10,19]

3.3. Measurement of Variables

3.3.1. Billboard Density and Illuminated Sign Density

Billboard density was measured by counting the number of billboards within each 100 m of street length, including signs on both sides of the street. The formula is: Billboard density = (number of billboards ÷ street length) × 100. Illuminated sign density refers to the number of illuminated signs within each 100 m of street length, likewise including both sides. The formula is: Illuminated sign density = (number of illuminated signs ÷ street length) × 100. It should be noted that billboard density and illuminated advertisement density reflect, respectively, the overall intensity of advertising quantity and the distribution intensity of illuminated advertisements at night, but they are not equivalent to the size of individual signboards, their actual luminance, or the complexity of their informational content. In particular, illuminated advertisement density indicates only how many advertisements emit light and cannot substitute for measurements of brightness level, contrast, flicker frequency, or dynamic change. Similarly, billboard density cannot fully represent advertising area or content complexity. Brightness, contrast, size, and content characteristics may all affect visual comfort and the allocation of attention [15,17]. Therefore, the relevant findings of this study should be understood as correlational evidence derived from quantity-based indicators at the street-segment level.

3.3.2. Street Width to Height Ratio, Interface Transparency

The street width to height ratio is the ratio of street width to height. Given that the addition of billboards creates a second contour line that alters perceived eye-level height for pedestrians, the ratio is computed both before and after signage is added. The procedure is as follows: select five cross sections along the specified street segment, compute the width to height ratio for each, then take the mean value as the ratio for that segment.

Interface transparency is defined as the proportion of visually permeable frontage length to the total length of street-facing frontage. Because signage modifies the original transparency of the interface, transparency is computed both before and after signage is added. Following the method of Chen Yong and Zhao Xinghua [42], ground-floor interfaces are classified into four types, open storefronts, transparent storefronts, display-window storefronts, and opaque storefronts, and weights are assigned according to visual permeability. The calculation formula is: Interface transparency = [(length of open storefronts × 1.25) + (length of transparent storefronts × 1.0) + (length of display-window storefronts × 0.75) + (length of opaque storefronts × 0)] ÷ total frontage length.

3.3.3. Measurement of Pedestrian Activity

Pedestrian activity was measured by counting the number of people engaged in different types of walking-related activities, and all activities were uniformly quantified using the indicator of activity-specific pedestrian share. Specifically, the pedestrian share for each activity category was calculated as follows: pedestrian share of a given activity = (number of people engaged in that activity/total number of observed activities). The total number of observed activities refers to the total number of pedestrian activities recorded on the street during the same observation period, that is, the sum of the counts for the three different activity types. By constructing activity-specific pedestrian share indicators, the influence of differences in the total number of pedestrians across street segments on the counts of individual activity types can be reduced, thereby standardizing the data and facilitating comparative analysis among different street segments.

3.3.4. Control of Other Factors

Pedestrian activity on commercial streets is shaped not only by street space and advertising configurations but also by multiple interacting factors, including climatic and seasonal variations, tourist-flow intensity, the scheduling of commercial activities, the composition of business types, and pedestrians' travel purposes. Street vitality and pedestrian volumes may fluctuate with seasonal and microclimatic conditions, while the effect of temperature on walking volume may vary across street types, day types, and periods of the day [40,43]. At the same time, historic districts and urban historic centers often accommodate highly concentrated tourist flows, and the overlapping use of space by tourists and local residents may further alter levels of public-space occupancy and the spatial distribution of pedestrian activities [44,45]. Commercial promotions, festivals, and themed marketing events may also reshape pedestrian movement routes, dwell duration, and visitation patterns within shopping districts [46,47].

Accordingly, Shangxiajiu Pedestrian Street was defined in the research design as an open-access historic commercial district, and several procedures were adopted to improve the consistency of comparisons across street segments. First, contiguous segments within the same pedestrian street were selected to ensure a basic level of consistency in traffic conditions, street characteristics, locational hierarchy, and overall commercial positioning. Second, synchronized observations were conducted within the same continuous time windows to reduce measurement bias arising from differences in crowd composition and activity rhythms across street segments. Third, all observers received standardized training and followed consistent recording criteria and synchronized counting procedures to improve the comparability of data across segments. Fourth, the counts of different activity types were converted into relative proportional indicators to reduce the influence of variations in total pedestrian volume among street segments on the comparative results.

In interpreting the findings, seasonal fluctuations, tourism intensity, commercial marketing activities, the composition of business types, and pedestrians' travel purposes collectively constitute the external contextual boundaries of this study. Recent research on commercial pedestrian streets has shown that street vitality varies substantially across time periods, spatial locations, and built-environment conditions [19]. The vitality of pedestrian streets across different cities and daytime and nighttime conditions may also be jointly shaped by the built environment and thermal-comfort factors [48]. In addition, marketing activities in commercial districts can alter cross-store visitation relationships among consumers and the distribution of behavior within the area [47]. Within these interpretive boundaries, the correlational results are regarded as context-specific evidence of the associations between signage-related environmental factors and pedestrian dwell behavior under the observed conditions. They are intended primarily to support case-based interpretation and the generation of hypotheses for subsequent research.

3.4. Selection of the Study Site

This study selected the Shangxiajiu Pedestrian Street in Liwan District, the old urban core of Guangzhou, as the study site. Spanning Shangjiu Road, Xiajiu Road, and Dishifu Road, Shangxiajiu is one of the city's three traditional commercial centers. The street block extends approximately 1237 m, is lined with more than 300 shops, and accommodates an average daily footfall of up to 600,000. The pedestrian street is composed of arcaded buildings in the Lingnan architectural style, which express a distinctive regional culture. Public transport is convenient, with multiple bus stops within the block and direct connections to the metro, providing comprehensive coverage for the entire survey area. Shop types are diverse, including well known establishments such as Guangzhou Restaurant, Tao Tao Ju, and Lian Xiang Lou. Commercial functions can be grouped into five categories, leisure and

entertainment, food and beverage, hotels, everyday services, and time-honored brands. A functional map analysis (Figure 2) shows that leisure and entertainment functions are dominant, food outlets are evenly distributed on both sides of the street, and time-honored brands are concentrated in the western Dishifu Road area where pedestrian staying activities are more frequent. Hotels are mainly located at squares and traffic junctions, sites that are prominent and convenient for access.

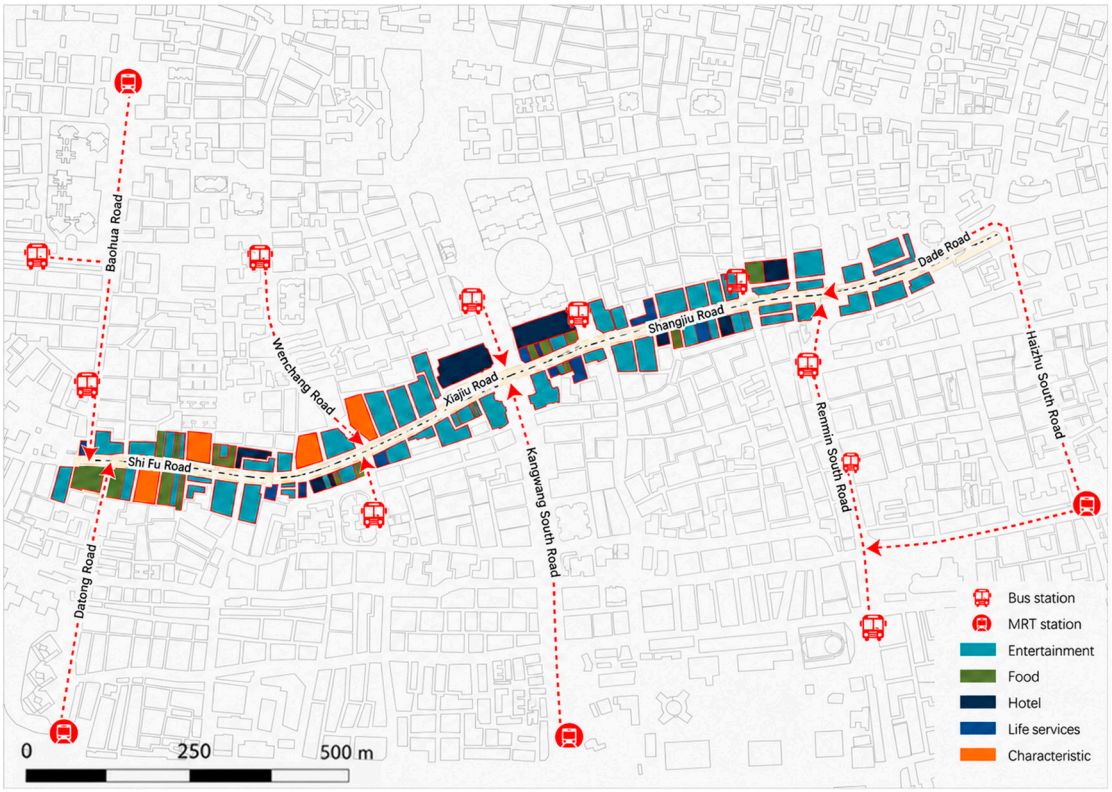


Figure 2. The distribution of surrounding functions of Shangxiajiu Pedestrian Street. Note: The red dashed arrows indicate access directions between the surrounding public transport nodes and Shangxiajiu Pedestrian Street.

As a major tourist destination in Guangzhou, Shangxiajiu Pedestrian Street combines rich street spatial morphology with very high pedestrian volumes, which together create favorable conditions for examining the relationship between outdoor advertising and pedestrian activities. Advertising on the street is predominantly commercial, with relatively few public service announcements. Most signs are mounted on building facades, on column surfaces, and within the arcaded galleries. Forms include channel letters, light boxes, neon channel letters, large format printed banners, translucent glass window films, and LED displays. It should be noted that the empirical objects measured in this study were primarily common types of advertising found in actual commercial streets, including traditional physical signboards, light boxes, neon three-dimensional signage, translucent window graphics, and LED display screens. No large-scale AR projections or highly interactive digital installations were observed in sufficient quantity to constitute an independent category for reliable statistical analysis. Therefore, the empirical findings of this study are mainly applicable to conventional and illuminated advertising contexts. As for highly interactive digital advertising, such as AR-based formats, their potential additional effects on attention capture, information-refresh dynamics, and behavioral responses are discussed in this study as an extension of the conceptual framework, rather than being directly operationalized as empirical variables [8,25]. Billboard layout can be grouped into four

types, vertically projecting, mixed horizontally and vertically projecting, facade surface type, and facade linear type (Figure 3). The vertically projecting and mixed projecting types affect the perceived visual scale of the street but cause relatively limited occlusion of facades, whereas the facade surface and facade linear types have a smaller impact on perceived street scale but produce greater facade occlusion.

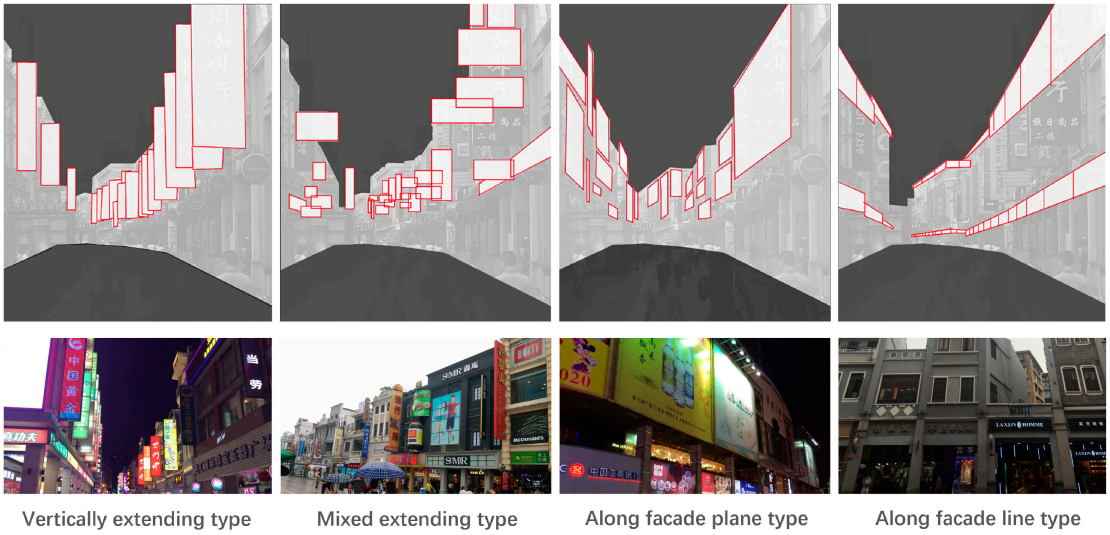


Figure 3. Advertising Layout Patterns and Site Photographs.

For statistical convenience and analysis, the street was partitioned into seven squares (S1, S2, …, S7) and six roadway segments (R1, R2, …, R6), and these were named in sequence (Figure 4). From west to east, the sequence is S1, R1, S2, R2, S3, R3, S4, R4, S5, R5, S6, R6, S7.

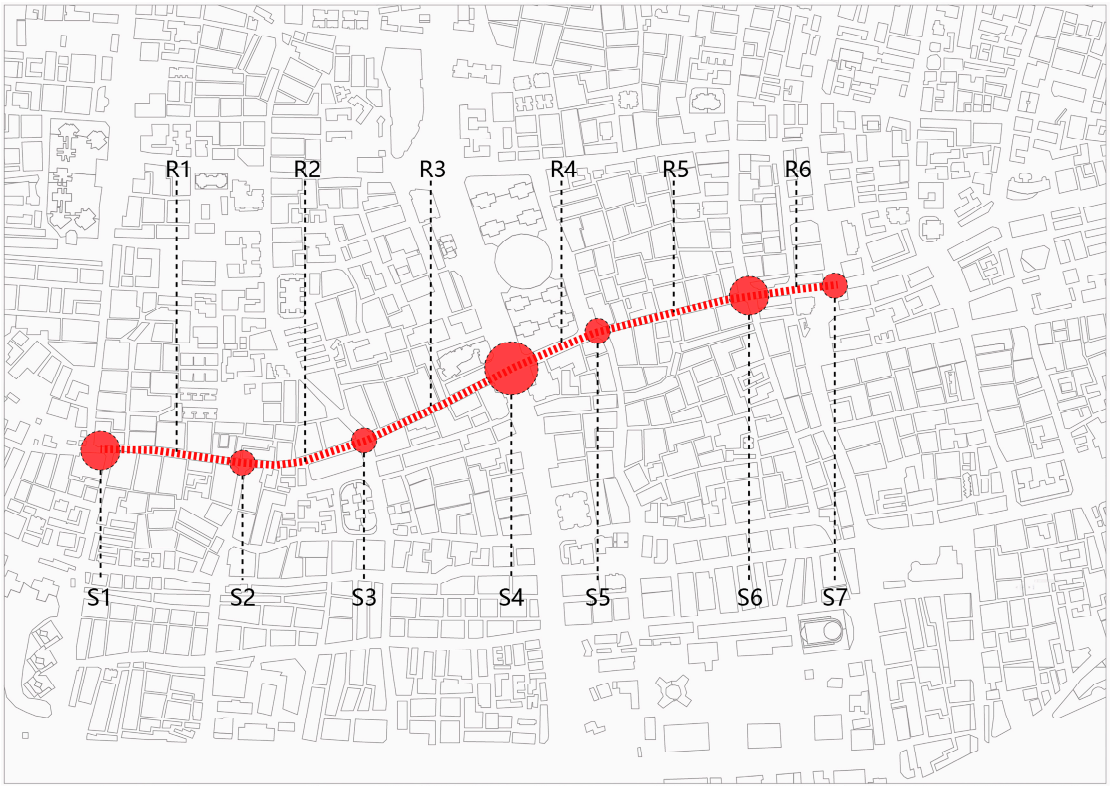


Figure 4. Division of the study area.

It should be further noted that the representativeness of Shangxiajiu Pedestrian Street lies primarily in its identity as a Lingnan arcade-style historic commercial pedestrian street, characterized by traditional architectural interfaces, concentrated tourism, and mixed consumption functions, rather than in its automatic representativeness of all types of commercial streets. Multi-city studies have shown that, although there are certain commonalities in the relationship between the built environment and street vitality, the effects of specific variables may vary according to differences in urban form, cultural context, and measurement approach [12,49]. Research on historic districts has further indicated that the thresholds and nonlinear patterns of street vitality in such areas may differ from those observed in more general urban contexts. At the same time, modern urban streets, as exemplified by those in Guangzhou's Tianhe District, differ markedly from historic commercial streets in both spatial typology and the mechanisms underlying street vitality [7,50]. Therefore, the purpose of selecting Shangxiajiu in this study was to identify the relationships among signboard placement, street space, and pedestrian stopping behavior within a typical historic commercial street, rather than to generalize the findings directly to modern commercial streets or to all types of commercial streets.

3.5. Survey Procedure

First, the research team conducted field measurements and on-site documentation along Shangxiajiu Pedestrian Street to collect data on the outdoor advertising interface and street spatial dimensions for each street segment. These data were then quantified and statistically analyzed to calculate the relevant variable values for each segment, including billboard density, illuminated advertisement density, original street width-to-height ratio, existing street width-to-height ratio, original facade transparency, and existing facade transparency. Next, field surveys were carried out on two days with suitable temperatures and clear weather: one weekday, 11 May 2023 (Thursday), and one weekend day, 13 May 2023 (Saturday). Preliminary observation showed that pedestrian activity was relatively limited in both volume and variety during the morning, whereas both the number and types of activities increased markedly in the afternoon. However, pedestrian flow declined sharply after 21:00. Based on these activity patterns, two observation periods were selected. The first was from 14:30 to 16:30 in the afternoon, when lunch had ended and sightseeing and shopping activities on the street began to increase. The second was from 18:30 to 20:30 in the evening, corresponding mainly to post-dinner walking and shopping activities. Based on the 13 delineated segments, 13 investigators were assigned, with each investigator responsible for one street segment. A 20 min interval was adopted as the sampling interval. To reduce errors caused by time differences, all investigators began each new round of counting simultaneously. Pedestrian counts in this study were obtained through manual synchronized counting. Each street segment was monitored by one observer, who continuously scanned and recorded pedestrian activities on both sides of the segment according to a unified observation protocol. To minimize errors associated with manual counting, all observers received standardized training before the formal survey and followed the same counting rules, observation windows, and recording criteria throughout the investigation. Each round of counting was initiated simultaneously so as to reduce bias arising from fluctuations in pedestrian flow at different moments. Previous studies have shown that walking-based field audits are advantageous for identifying detailed street-level environmental characteristics, although data quality depends on observer training and standardized protocols. Similarly, in behavioral counting studies, clear task division, unified coding rules, and controls for inter-observer consistency are common practices for ensuring data reliability [51–53]. It should be noted, however, that because only one observer was assigned to each street segment and no double-observer verification was

implemented, the possibility of undercounting cannot be entirely ruled out, particularly when rapidly moving pedestrians appeared simultaneously on both sides of a segment. To mitigate this limitation, the subsequent analysis uses pedestrian share rather than absolute counts for comparison, and the results are interpreted with appropriate caution. This survey design helps improve the accuracy and consistency of the data, thereby enhancing the reliability of the study.

It should be further noted that this study selected one weekday and one weekend day for observation, and conducted the survey under relatively favorable weather conditions, with the aim of minimizing the disturbance of extreme weather and atypical time periods on the statistical results, rather than assuming that the study setting existed in a stable state free from external influences. Previous research has shown that vitality on commercial pedestrian streets exhibits clear temporal heterogeneity, with non-working-day evenings typically being more active. At the same time, climatic conditions, fluctuations in tourist flows, and the scheduling of events and activities may all affect patterns of walking and staying on streets [19,43,54]. Therefore, the survey procedure adopted in this study should be understood as a form of field observation under relative control. It provides contextual evidence within specific observation windows, and its findings are appropriate for explaining the relationship between the signboard environment and pedestrian stopping behavior on Shangxiajiu Pedestrian Street during the observed periods, rather than for fully characterizing a stable condition over a longer time scale.

3.6. Statistical Analysis

The 13 street segments served as the units of analysis. SPSS 25.0 was used to conduct bivariate correlation analyses between four signage- and street-environment indicators (X1–X4) and nine pedestrian-activity proportion indicators (Y1–Y9), yielding 36 variable pairs. All indicators were continuous numerical variables measured at the street-segment level. Before the formal analysis, descriptive statistics, boxplots, and scatterplots were examined to assess the ranges of the variables, potential outliers, and the forms of the relationships.

Given that the analysis was based on 13 street segments, bivariate Pearson correlation was adopted as an exploratory analytical strategy appropriate to the current data structure and sample size. Sample size affects the stability of correlation coefficients, significance tests, and model estimates. Multivariable regression, model-stability assessment, and external validation should therefore be undertaken using larger datasets covering multiple commercial streets and observation periods [55,56].

Pearson's correlation coefficient (r) was used to quantify the direction and strength of the linear associations between the environmental indicators and the proportions of pedestrian activities. Pearson's correlation coefficient is appropriate for assessing linear associations between continuous variables, while scatterplots facilitate the examination of relationship patterns and the distribution of data points [57,58]. All significance tests were two-tailed, with the statistical significance level set at $\alpha = 0.05$. Results with $p < 0.01$ are identified separately in the correlation results presented in Section 4.1.3. Both Pearson's correlation coefficients and exact p values are reported. Where SPSS returned a value of 0.000, the result is consistently reported as $p < 0.001$.

The correlation analysis was positioned as exploratory and focused on identifying the direction and strength of the associations between the simplified environmental indicators and the observed proportions of pedestrian activities. The findings were interpreted by jointly considering the correlation coefficients, significance levels, scatterplot patterns, and specific observational context. They also provide testable hypotheses for subsequent studies using larger samples and data collected across multiple time periods and streets.

4. Results

4.1. Data Statistics

4.1.1. Billboard and Street Characteristics

Based on field measurements and counts, values for the billboard- and street-characteristic variables were obtained for the 13 street segments of Shangxiajiu Pedestrian Street (Tables 2 and 3). With the exception of several plaza nodes, most pedestrian-street segments ranged from 80 to 430 m in length (Figure 5). As entrance nodes located at the two ends of the street, S1 and S7 exhibited slightly higher billboard densities than segments such as R1, S2, S6, and R6. This pattern may reflect an intention to attract pedestrian flows from the surrounding area into the pedestrian-street corridor. Billboard density was generally higher in the central segments, including R2–R5, indicating a greater concentration of retail establishments and a more diverse mix of business types in the middle section of the street. Illuminated signage density was relatively even overall at night. However, R2, S3, and R5 exhibited comparatively low illuminated signage densities despite their high billboard densities, indicating that many signs in these segments were not illuminated at night. This condition may influence pedestrian perception and activity (Figure 6).

Table 2. Billboard Distribution Index Table.

Road Section ID	Number of Billboards	Number of Illuminated Billboards	Road Length (m)	Billboard Density (per 100 m)	Illuminated Billboard Density (per 100 m)
S1	11	9	29	39	31
R1	116	86	428	27	20
S2	23	18	82	28	22
R2	186	97	388	48	25
S3	94	45	187	50	24
R3	289	250	782	37	32
S4	76	56	186	41	30
R4	121	106	378	32	28
S5	38	32	153	25	21
R5	46	30	86	53	35
S6	22	17	110	20	15
R6	15	12	80	19	15
S7	10	8	31	32	25
Sum	1047	765	2920	451	323

Table 3. Changes in indicators before and after the addition of billboards.

Road Section ID	Original Width-to-Height Ratio	Existing Width-to-Height Ratio	Original Transparency (%)	Current Transparency (%)
S1	1.15	1.18	62	54
R1	0.80	1.32	56	42
S2	1.30	1.48	58	44
R2	0.84	1.35	63	49
S3	1.59	1.59	69	53
R3	0.85	1.38	50	38
S4	2.11	2.13	73	58
R4	1.14	1.52	66	46
S5	1.72	1.72	62	48
R5	0.78	1.15	63	50
S6	1.52	1.52	50	38
R6	0.75	0.95	49	36
S7	1.14	1.14	65	55
Sum	15.69	18.43	786	611

The street width-to-height ratio was highest at node S4, reaching 2.11, which indicates that the street width was more than twice the building height. Within the S–R analytical-unit system adopted in this study, S4 is located between R3 and R4 and constituted the most spatially open plaza node among the 13 units analyzed (Figure 4). Across the street as a whole, the seven plaza segments from S1 to S7 had relatively high width-to-height ratios, and the inclusion of signage produced only limited changes relative to their original ratios. By contrast, the six pedestrian-street segments from R1 to R6 had lower original width-to-height ratios. After signage was incorporated, the secondary contour line reduced the perceived street-wall height, thereby increasing the existing width-to-height ratio

(Figure 7). Façade transparency was relatively consistent along the street, indicating limited variation in storefront openness. After advertising elements were taken into account, façade transparency decreased to some extent in all street segments (Figure 8).

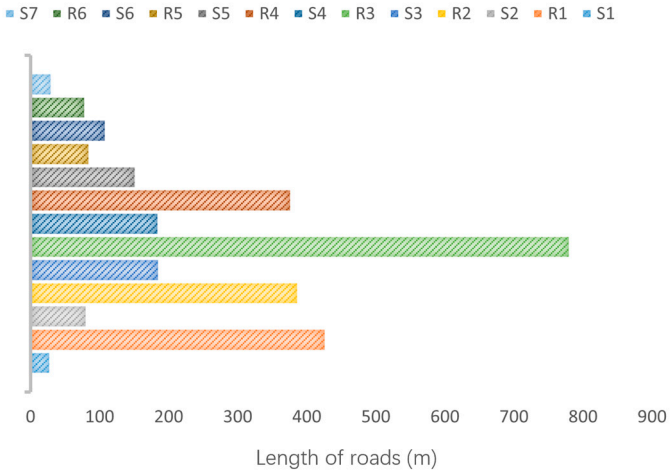


Figure 5. The length of roads in each street segment.

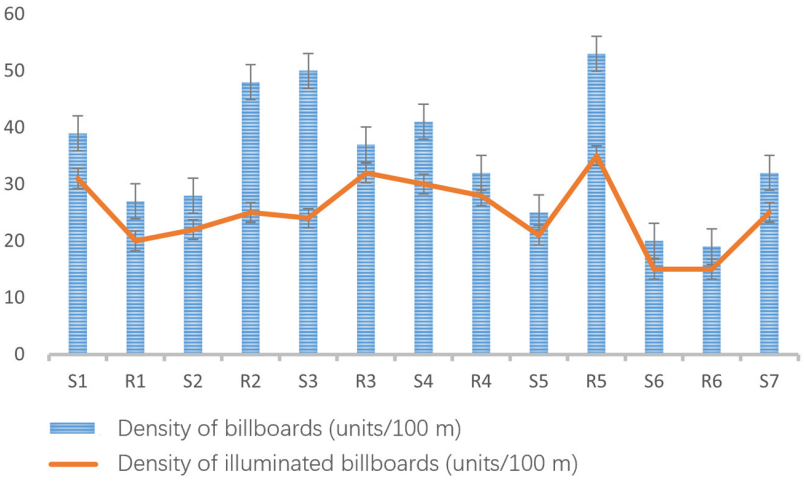


Figure 6. Distribution of billboard density in each street segment.

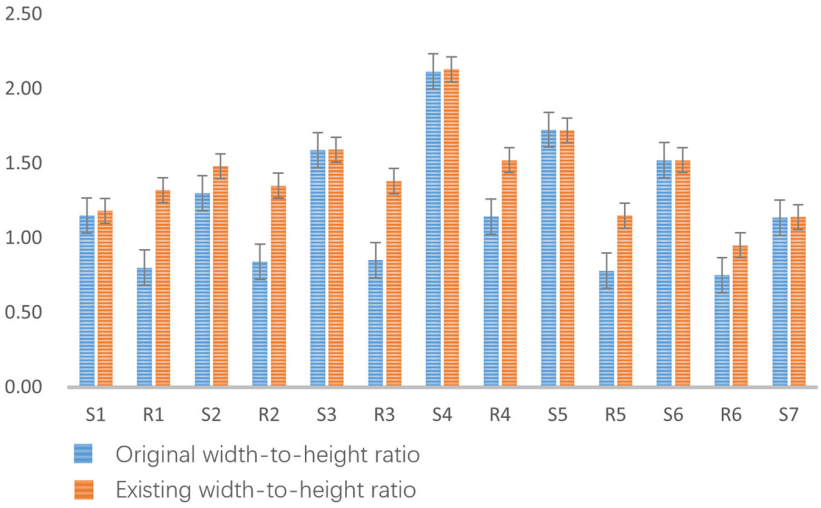


Figure 7. Distribution of Street width-to-height ratio before and after the addition of billboards.

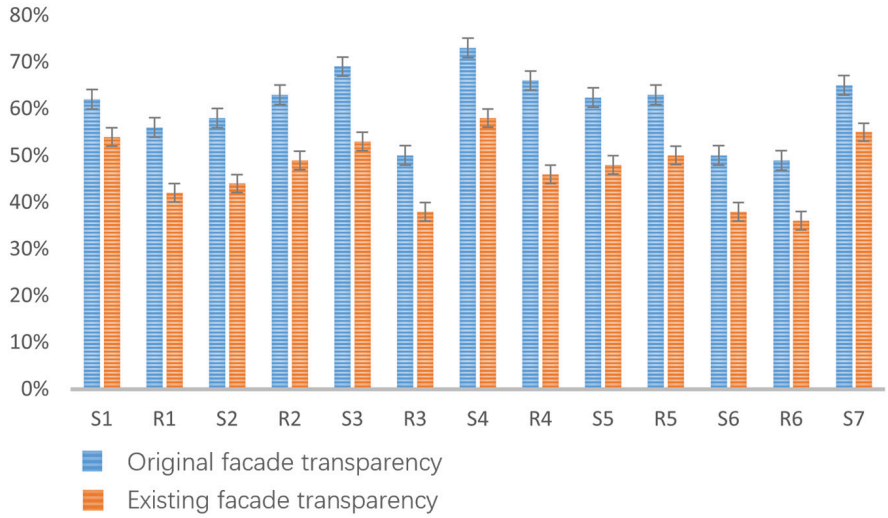


Figure 8. Distribution of aspect ratios of streets before and after the addition of billboards.

4.1.2. Pedestrian Activities

In this study, the numbers of pedestrians engaged in three types of activity—lingering, staying, and passing through—were counted separately. The counts for each activity type were then standardized as relative percentages of the corresponding total sample to obtain pedestrian share values. These values were classified by two time periods, afternoon and nighttime, and were also aggregated to yield both time-specific totals and activity-specific totals, as shown in Table 4. It should be noted that the categories of "lingering" and "staying" in this study primarily reflect differences in stopping duration, rather than direct identification of specific behavioral purposes such as social interaction, window shopping, or mobile phone use. Previous observational studies have shown that pedestrian stopping behavior may simultaneously involve heterogeneous components, including reasons for staying, group interaction, and digital distraction [10,59]. Accordingly, the following interpretation of lingering and staying is confined mainly to the level of behavioral intensity and street-segment attractiveness, rather than equating them with any single activity purpose. From a temporal perspective, the pedestrian share at night (57.91%) was higher than that in the afternoon (42.09%), and the pedestrian share on weekends (56.71%) was higher than that on weekdays (43.29%). This pattern is broadly consistent with previous findings that commercial pedestrian streets tend to be more active during evening hours on non-working days [19]. At the same time, it should be noted that such differences may also be jointly related to tourist flows, consumption-related travel arrangements, and the timing of commercial activities. They should therefore not be explained solely in terms of spatial factors, nor should they be overgeneralized. In terms of activity type, the pedestrian share of lingering (7.25%) was slightly higher than that of staying (5.15%). On weekdays, the pedestrian share of lingering (13.8%) was approximately twice that of staying (7.01%), suggesting that pedestrians on weekdays tended to have more constrained time schedules and stronger goal-oriented movement patterns. By contrast, on weekends, the pedestrian shares of lingering and staying were broadly similar, indicating that pedestrians had more time to stop for food, leisure, and rest.

As shown in the distribution of pedestrian share along the pedestrian street (Figure 9), pedestrians were more concentrated in the middle street segments, with their presence gradually decreasing toward both ends. This suggests that the central segments were denser in commercial functions and therefore more attractive. In terms of time period, pedestrian share reached its peak at Segment S4 in the afternoon (13.65%), whereas Segments R3 and R4 showed a marked decline. At night, the pattern was reversed:

pedestrian share was relatively high in Segments R2, R3, and R4, but relatively low in Segments S3 and S4. This may be related to the attractiveness of plaza spaces in the afternoon and to greater climatic comfort and improved nightscape experience in the evening. In terms of activity type (Figure 10), the variation trends of lingering and staying were generally consistent across the street segments. The pedestrian shares of both lingering and staying were relatively high in Segments S1, S3, S4, and R5, which appears to be related to the diversity of commercial functions and the attractiveness of plaza spaces in these segments. Segments S3 and S4 contain relatively large plazas, whereas the plaza spaces in S5 and S6 are smaller in scale, and some storefronts were closed, leading pedestrians to concentrate more in Segment R5.

Table 4. Statistics of Pedestrian Share.

Time Period	Lingering		Stopping		Passing		Total Volume of Activities per Time Slot	
	Number of People	Share	Number of People	Share	Number of People	Share	Number of People	Share
Weekday Afternoon 14:30–16:30	298	6.59%	155	3.43%	4068	89.98%	4521	19.31%
Weekend Afternoon 14:30–16:30	343	6.43%	327	6.13%	4666	87.44%	5336	22.79%
Weekday Evening 18:30–20:30	405	7.21%	201	3.58%	5012	89.21%	5618	23.99%
Weekend Evening 18:30–20:30	652	8.21%	523	6.59%	6769	85.20%	7944	33.92%
Total Volume of Each Type of Activity	1698	7.25%	1206	5.15%	20,514	87.60%	23,419	100.00%

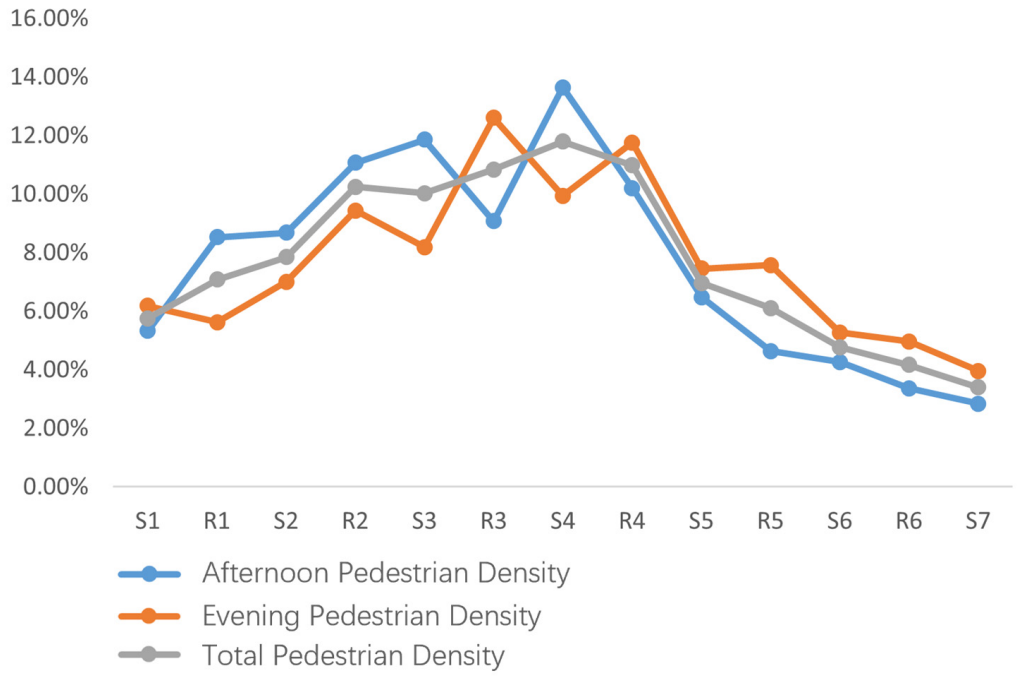


Figure 9. Line graph of the distribution of pedestrian share by time.

As shown by the variation in pedestrian activity share in the afternoon (Figure 11) and at night (Figure 12), the shares of both lingering and staying were relatively high at Segment S4 in the afternoon, which may be associated with the concentration of food-related functions in the western street segments. At night, by contrast, the shares of lingering and staying increased substantially in Segments S1 and R5, possibly owing to the nightscape effects in these segments.

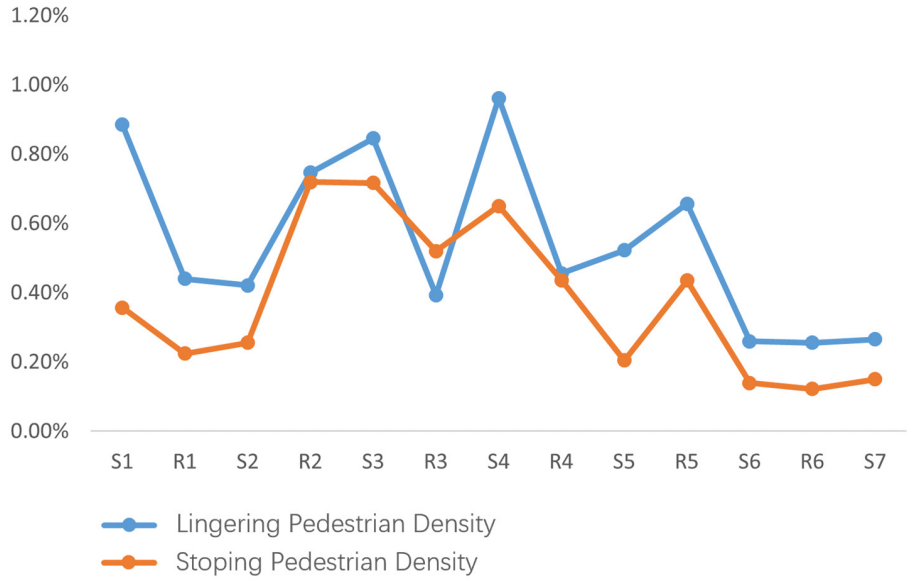


Figure 10. Line graph of the distribution of pedestrian share by activities.

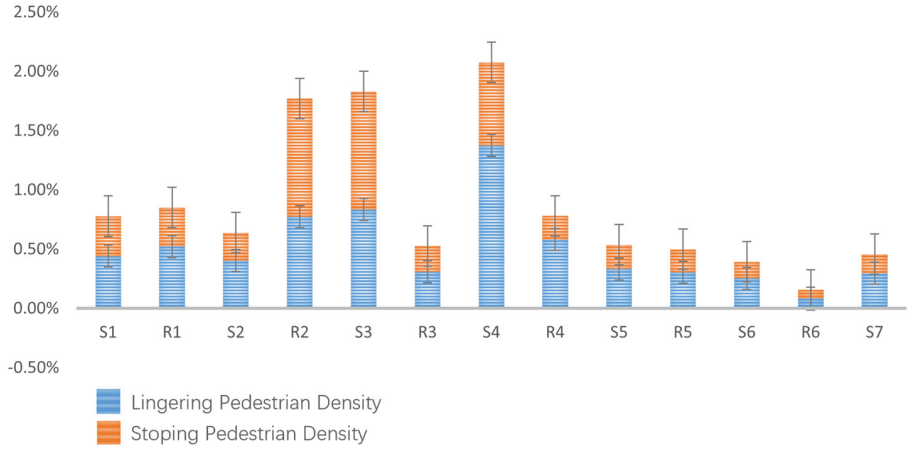


Figure 11. Distribution of afternoon pedestrian share.

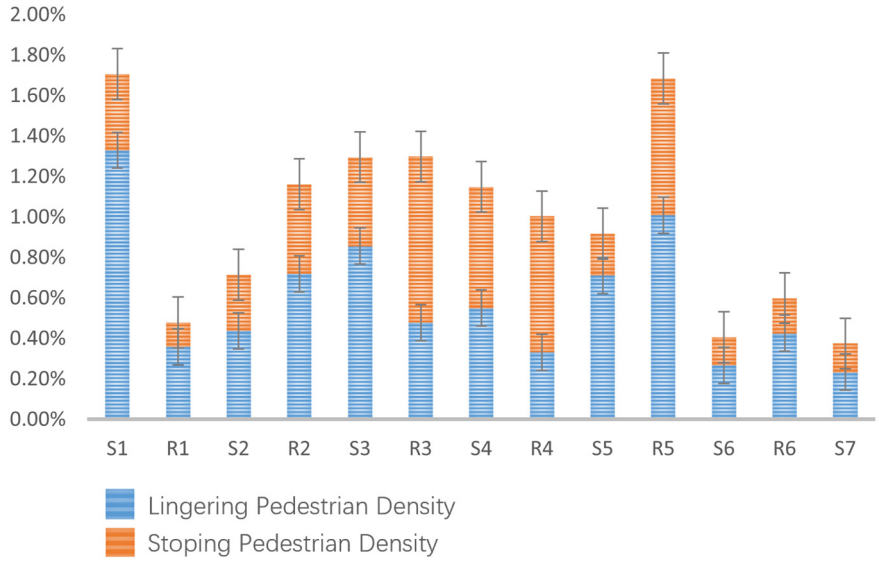


Figure 12. Distribution of evening pedestrian share.

4.1.3. Correlation Analysis

Table 5 reports Pearson's correlation coefficients and the results of two-tailed significance tests for the relationships between the four signage- and street-environment indicators (X1–X4) and the nine pedestrian-activity proportion indicators (Y1–Y9). The specific results are presented below.

Table 5. Correlation Data Between Signboard and Street Characteristic Variables (X) and Pedestrian Activity Variables (Y).

		Y1 Afternoon Lingering Pedestrian Share	Y2 Afternoon Stopping Pedestrian Share	Y3 Total Afternoon Pedestrian Share	Y4 Evening Lingering Pedestrian Share	Y5 Evening Stopping Pedestrian Share	Y6 Total Evening Pedestrian Share	Y7 Average Lingering Pedestrian Share	Y8 Average Stopping Pedestrian Share	Y9 Average Total Pedestrian Share
X1 Billboard Density	Pearson Correlation	0.502	0.664 *	0.446	0.622 *	0.645 *	0.420	0.749 **	0.832 **	0.469
	Sig.	0.080	0.013	0.127	0.023	0.017	0.153	0.003	0.000	0.106
X2 Illuminated Billboard Density	Pearson Correlation	0.321	0.170	0.281	0.519	0.823 **	0.565 *	0.557 *	0.571 *	0.435
	Sig.	0.284	0.578	0.352	0.069	0.001	0.044	0.048	0.042	0.137
X3 Street Width-to-Height Ratio	Pearson Correlation	0.748 **	0.402	0.712 **	−0.094	0.235	0.455	0.439	0.420	0.648 *
	Sig.	0.003	0.173	0.006	0.759	0.439	0.118	0.133	0.153	0.017
X4 Facade Transparency	Pearson Correlation	0.631 *	0.500	0.298	0.461	0.174	0.026	0.733 **	0.457	0.195
	Sig.	0.021	0.082	0.323	0.113	0.571	0.932	0.004	0.117	0.523

* Significant at the 0.05 level (2-tailed). ** Significant at the 0.01 level (2-tailed).

(1) During the afternoon observation period, Y3 (afternoon total pedestrian proportion) was significantly and positively correlated with X3 (street width-to-height ratio), indicating that a larger street width-to-height ratio was associated with a higher afternoon total pedestrian proportion. In addition, Y1 (afternoon brief-stopping proportion) was significantly and positively correlated with both X3 (street width-to-height ratio) and X4 (façade transparency). Y2 (afternoon prolonged-dwelling proportion) was significantly and positively correlated with X1 (billboard density).

(2) During the nighttime observation period, Y6 (nighttime total pedestrian proportion) was significantly and positively correlated with X2 (illuminated signage density), indicating that a higher illuminated signage density was associated with a higher nighttime total pedestrian proportion. Y4 (nighttime brief-stopping proportion) was also significantly and positively correlated with X1 (billboard density). In addition, Y5 (nighttime prolonged-dwelling proportion) was significantly and positively correlated with both X1 (billboard density) and X2 (illuminated signage density).

(3) With regard to the average pedestrian proportions, Y9 (average total pedestrian proportion) was significantly and positively correlated with X3 (street width-to-height ratio). Y7 (average brief-stopping proportion) was significantly and positively correlated with X1 (billboard density), X2 (illuminated signage density), and X4 (façade transparency). Y8 (average prolonged-dwelling proportion) was significantly and positively correlated with both X1 (billboard density) and X2 (illuminated signage density).

To provide a more intuitive representation of the correlations reported in Table 5, four variable pairs with relatively large correlation coefficients were selected and plotted as simple scatterplots (Figures 13–16). These included X1 (billboard density) and Y8 (average prolonged-dwelling proportion), X2 (illuminated signage density) and Y5 (nighttime prolonged-dwelling proportion), X3 (street width-to-height ratio) and Y1 (afternoon brief-stopping proportion), and X4 (façade transparency) and Y7 (average brief-stopping proportion). The scatterplots serve solely as visual supplements to the correlation analysis

by illustrating the overall direction of the relationships, the distribution of the data points, and the linear trends between the variables. They do not constitute additional statistical tests independent of the correlation analysis. Previous research has shown that scatterplots are appropriate for displaying the overall pattern of association between two quantitative variables. Moreover, in a simple linear relationship, R^2 is directly related to the square of Pearson's correlation coefficient. Therefore, because the correlation coefficients have already been reported, there is no need to interpret R^2 separately as an additional result [60].

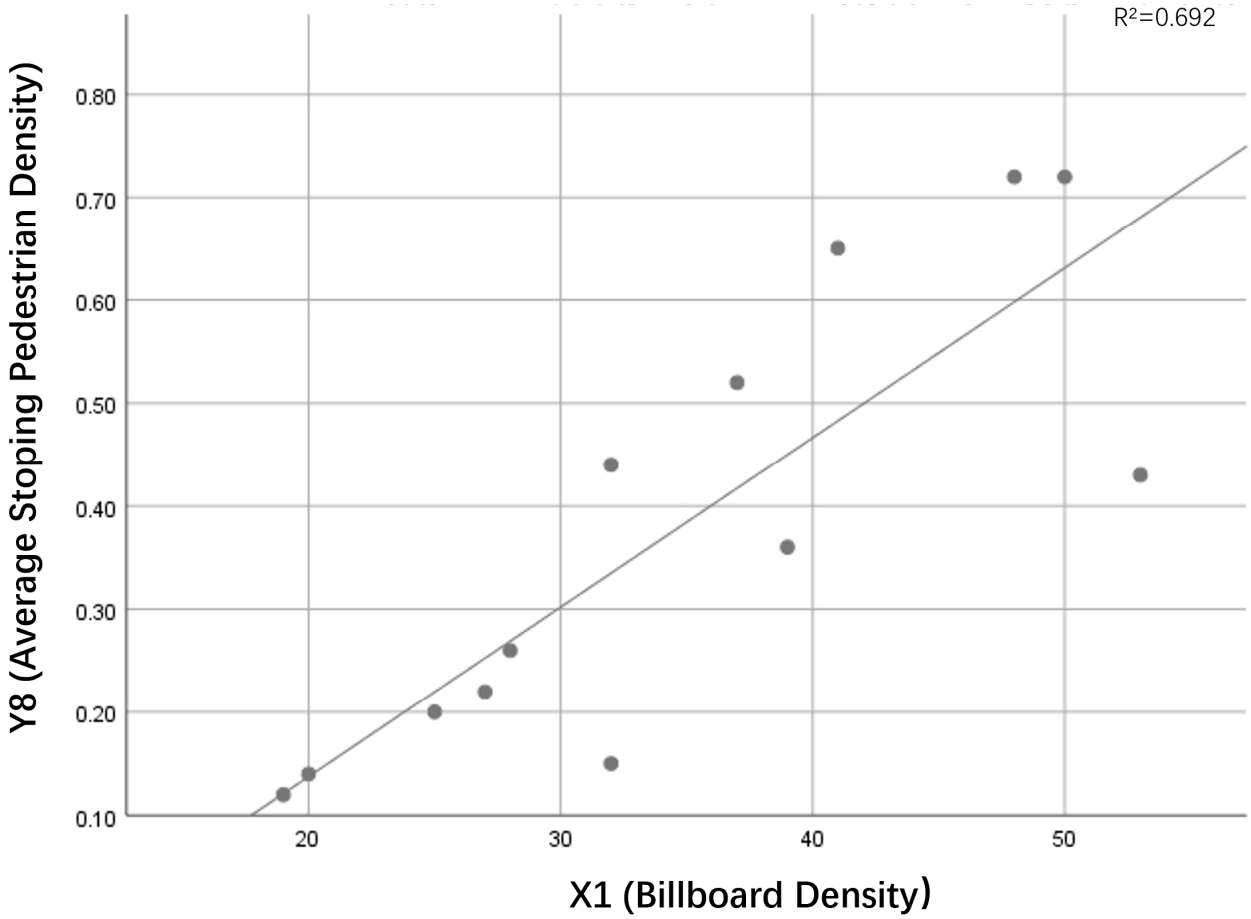


Figure 13. Scatter plot of X1 (billboard density) and Y8 (average stopping pedestrian share).

To maintain consistency between the analytical method and the interpretation of the findings, the correlation analysis was used primarily to identify statistical associations between the simplified environmental indicators and the observed proportions of pedestrian activities and to provide an exploratory basis for subsequent modeling. Specifically, X1–X4 represent the numerical distribution of billboards, the numerical distribution of illuminated signage, street-space proportions, and the openness of ground-floor interfaces, respectively, whereas Y1–Y9 represent the proportions of pedestrian activities across different observation periods and behavioral categories. Table 5 and Figures 13–16 therefore primarily present the direction and strength of the associations and the distributional characteristics of the data points. Recent research on commercial pedestrian streets has shown that street vitality and pedestrian dwell behavior are jointly shaped by temporal conditions, spatial structure, functional configuration, and street-level elements. These relationships should therefore be examined further using larger samples, observations across multiple time periods, and multisource data [10,18,19].

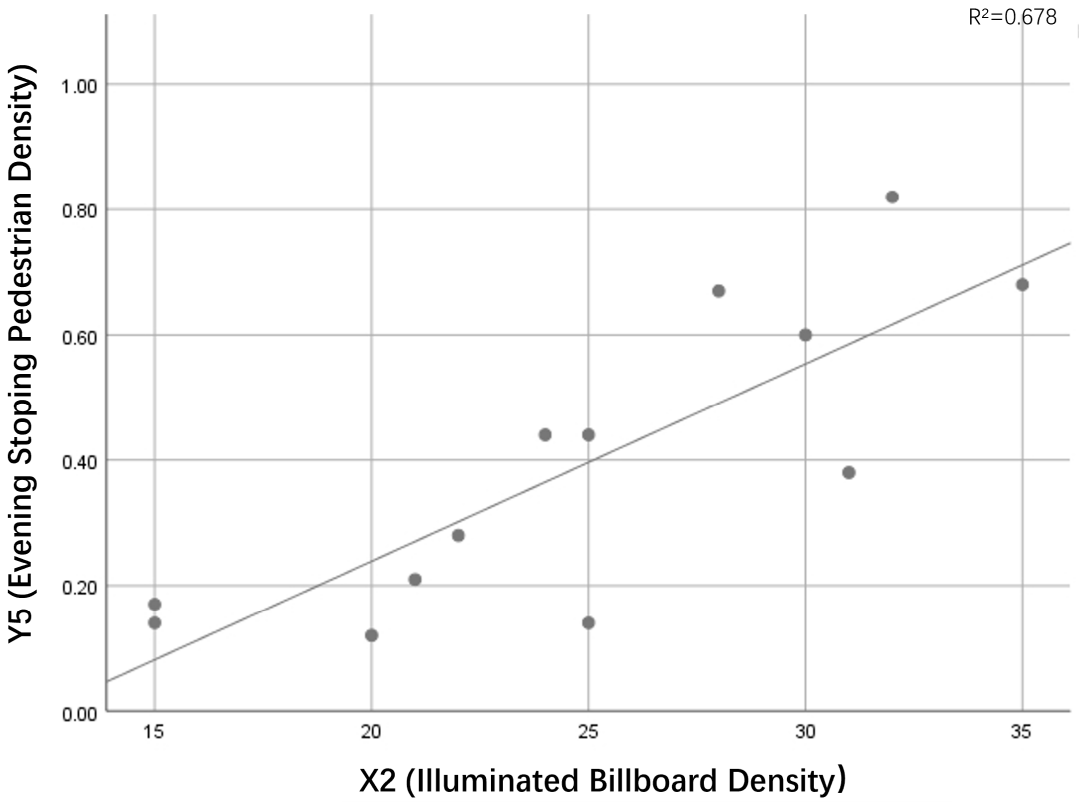


Figure 14. Scatter plot of X2 (illuminated billboard density) and Y5 (evening stopping pedestrian share).

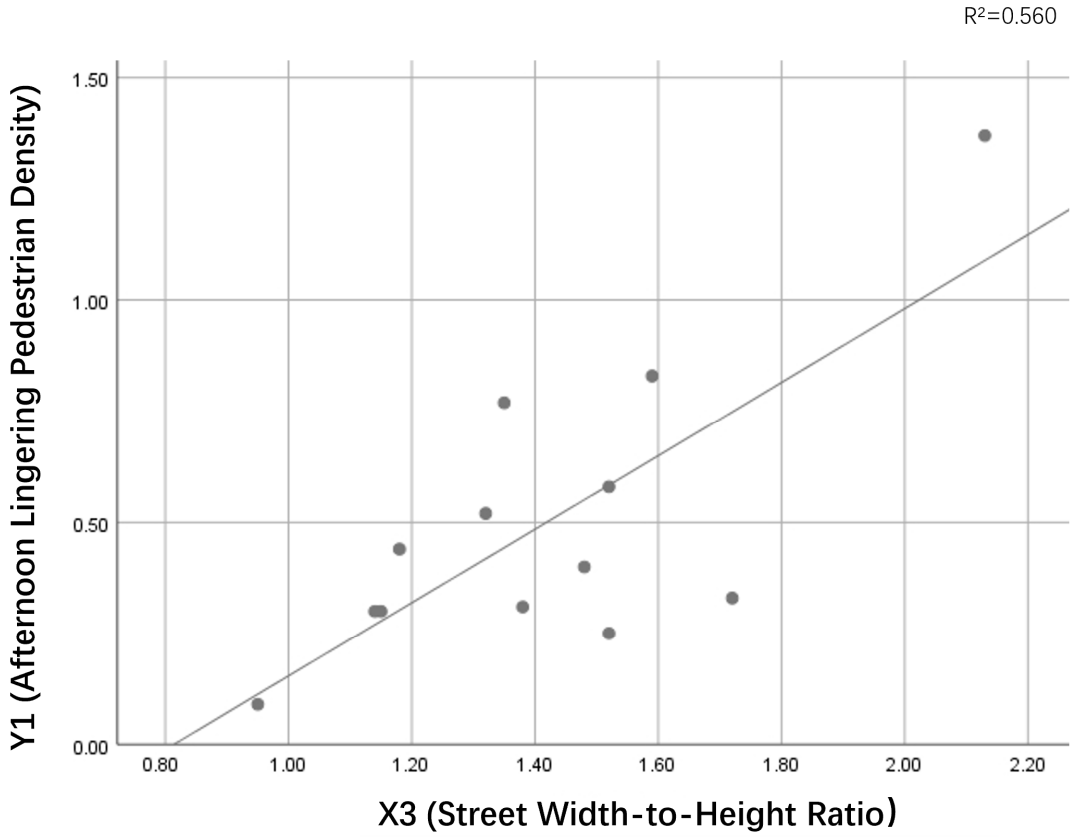


Figure 15. Scatter plot of X3 (street width-to-height ratio) and Y1 (afternoon lingering pedestrian share).

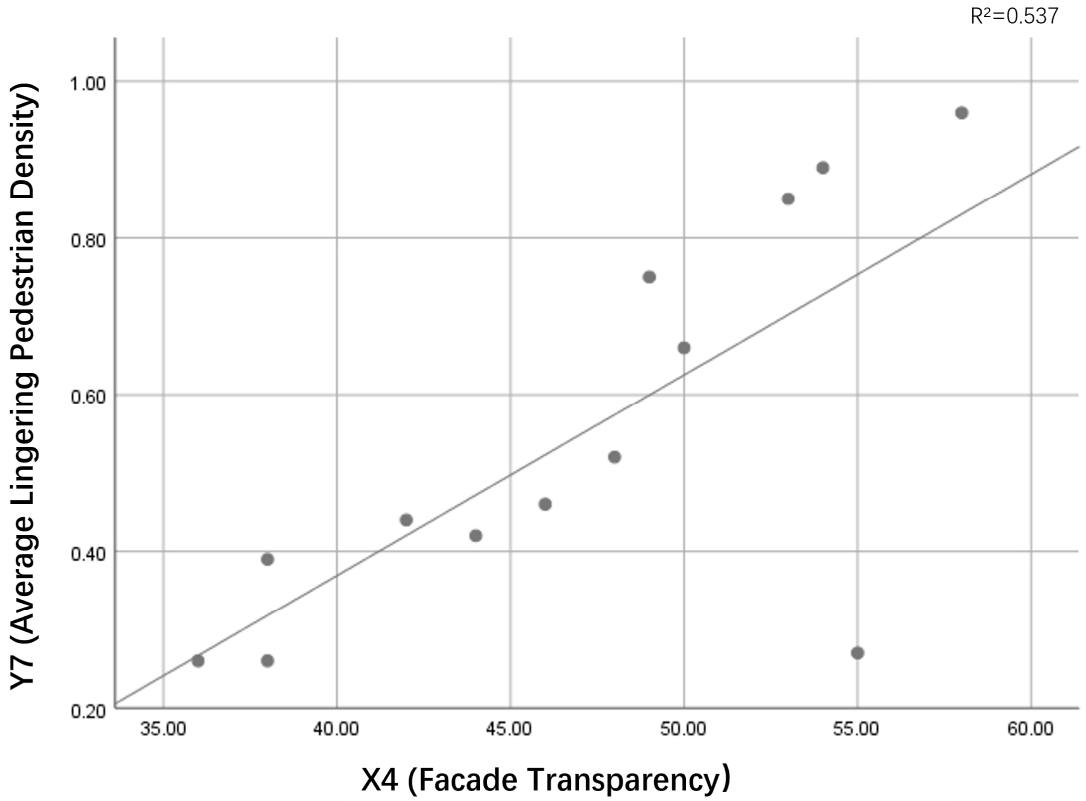


Figure 16. Scatter plot of X4 (facade transparency) and Y7 (average lingering pedestrian share).

5. Discussion

5.1. Key Findings and Interpretation of the Results

The results revealed several case-specific statistical associations between signage- and street-related variables and pedestrian activity variables, providing exploratory evidence for understanding the relationship between signage configuration and pedestrian dwell behavior in commercial streets. These findings can be interpreted within the environment–behavior analytical framework outlined above. Billboard density and illuminated signage density correspond more closely to the informational-stimulus dimension, primarily representing the quantitative distribution of commercial-information exposure and nighttime legibility. By contrast, street width-to-height ratio and façade transparency correspond more closely to the spatial-interface dimension, principally reflecting perceived street enclosure, spatial openness, and the perceptibility of the ground-floor interface. In other words, in the present case, signage quantity, nighttime illuminated signage, street width-to-height ratio, and façade transparency exhibited interrelated statistical patterns with brief stopping and extended dwell behavior. Billboard density and illuminated signage density primarily capture the quantity of visual exposure at the street-segment level, whereas signage size, luminance, contrast, repetitive rhythm, spatial frequency, content complexity, and dynamic presentation collectively constitute the qualitative dimension of façade visual complexity. From a neurodesign perspective, greater visual-information richness may enhance the salience and perceptual interest of street interfaces, while highly regular repetition, intense contrast, and multilayered graphic superimposition may increase visual-processing demands [20,21]. The observed associations with dwell behavior can therefore be interpreted as case-specific manifestations of the combined effects of the quantity of visual exposure, the richness of commercial information, and the structure of visual complexity.

In moving from statistical associations to the interpretation of the findings, this study adopts a context-sensitive approach. More specifically, the observed associations between

billboard density, illuminated signage density, street width-to-height ratio, façade transparency, and pedestrian-activity proportions may co-occur with variations in tourist flows, seasonal conditions, promotional activities, the composition of business types, brand attractiveness, and pedestrians' travel purposes. The following discussion therefore focuses primarily on the direction, strength, and spatial distribution of the associations observed during the study periods on Shangxiajiu Pedestrian Street. The findings are treated as preliminary, locally grounded references for understanding the governance of visual interfaces in historic commercial streets.

(1) Billboard density

Billboard density was significantly and positively correlated with both the mean proportion of brief stops and the mean proportion of extended dwell. This finding indicates that commercial-information exposure and storefront-interface concentration, as represented by the number of billboards, are closely associated with pedestrian dwell behavior. Across the 13 street segments examined in this case study, data points with relatively high mean proportions of extended dwell were concentrated around a density of approximately 50 billboards per 100 m. This value is more appropriately interpreted as an exploratory reference point specific to Shangxiajiu Pedestrian Street, with its potential applicability largely limited to streets characterized by comparable historic urban morphology, street-facing commercial interfaces, and tourism-oriented commercial functions. In light of previous research on street elements and pedestrian dwell in commercial pedestrian streets, higher billboard density may frequently coincide with more finely subdivided storefronts, richer street-facing information, and stronger commercial attraction [10].

From a pattern-language perspective, higher billboard density in the present case can also be understood as a concomitant indicator of more finely subdivided storefronts, a greater number of street-facing entrances, and richer interface information. Interrelated interface patterns, including storefront entrances, "street windows," commercial displays, and arcades, help create continuous, legible, and activity-intensive pedestrian environments, thereby providing spatial conditions that support storefront observation, entry into commercial premises, and dwell activities [2,4]. This interpretation is also consistent with recent research on commercial pedestrian streets, which has identified significant associations between commercial-display density, ground-floor transparency, interactive street elements, and pedestrian stopping and engagement behavior [10].

A neurodesign perspective further suggests that increases in billboard density are generally accompanied by greater informational richness, while also altering the repetitive rhythm, contrast energy, and graphic layering of street-facing façades. Within the range observed in this study, the positive association between billboard density and the proportion of dwell behavior may be interpreted as reflecting the combined enhancement of commercial-information salience, storefront legibility, and visual interest. At the same time, façade-related visual experience is jointly moderated by signage regularity, luminance contrast, spatial frequency, and material reflectance. These attributes provide an additional neurodesign-based pathway for explaining differences in dwell behavior among street segments [20,22].

(2) Illuminated signage density

Illuminated signage density was significantly and positively correlated with the nighttime proportion of extended dwell, indicating that the visibility and visual salience created by illuminated signage at night are closely associated with nighttime dwell behavior. In the present case, data points with higher nighttime proportions of extended dwell were concentrated around a density of approximately 32 illuminated signs per 100 m. This finding may serve as an exploratory reference for managing the nighttime visual environment

of historic commercial streets. Previous research on commercial pedestrian streets has shown that pedestrian vitality varies according to temporal, spatial, and built-environment conditions, and that nighttime vitality is jointly shaped by the street environment and commercial functions [19]. From a neurodesign perspective, illuminated signage creates a nighttime visual field structured by luminance contrast, repetitive rhythm, spatial frequency, graphic layering, and dynamic content updating. The positive association observed between illuminated signage density and the nighttime proportion of extended dwell suggests that nighttime visibility, the salience of commercial information, and dwell activity vary in parallel. Future research could integrate signage quantity with actual luminance, color temperature, contrast, repetition, dynamic frequency, and content complexity, while incorporating façade-image analyses conducted at different viewing distances, to develop a comprehensive assessment of nighttime visual salience, perceived complexity, and visual comfort [20,21].

(3) Street width-to-height ratio

The street width-to-height ratio was significantly and positively correlated with both the afternoon proportion of brief stops and the afternoon proportion of total pedestrian activity, indicating that daytime pedestrian activity is closely associated with street cross-sectional scale, spatial enclosure, and interface legibility. The "street as a room" concept regards continuous building façades and rows of trees as the walls of street space and interprets the experience of enclosure as the combined outcome of proportional relationships, absolute width, boundary continuity, and specific contextual conditions [2,3]. Observations from related street cases similarly emphasize the combined role of absolute street width, continuous street walls, trees, and pedestrian presence in shaping comfortable walking environments [5]. In the present case, after excluding the substantially larger S4 plaza, the width-to-height ratios of most street segments, calculated with the visual influence of signage incorporated into the street profile, ranged from 1.1 to 1.8, while higher proportions of brief stops were concentrated around a ratio of approximately 1.6. In the context of Shangxiajiu's continuous qilou arcades, street-facing storefronts, and intensive commercial activity, this result may be interpreted as suggesting that moderate spatial openness and clearly defined boundaries jointly enhance street-space legibility and provide conditions that support storefront observation, brief stopping, and entry into commercial premises. This value may serve as an exploratory spatial reference for Shangxiajiu Pedestrian Street, with its applicability primarily limited to streets characterized by comparable historic morphology, continuous qilou interfaces, and commercial functions. Recent studies have likewise shown that street width, ground-floor interfaces, advertising area, retail density, and functional configuration are jointly associated with pedestrian stopping and spatial vitality in commercial streets [10,18].

(4) Façade transparency

Façade transparency was significantly and positively correlated with both the afternoon proportion of brief stops and the mean proportion of brief stops, indicating that the openness, visibility, and visual permeability of ground-floor interfaces are closely associated with brief stopping behavior. In the pattern language developed by Alexander et al., "street windows," "opening to the street," "arcades," and "building edges" are treated as interrelated patterns that support public life in pedestrian streets [2]. Park's network analysis [4] further identifies interface spaces as an important component of urban-center design. In the context of Shangxiajiu's qilou streets, transparent storefronts and open entrances strengthen visual continuity between indoor commercial activities and street-level public space, making merchandise displays, human activity, and routes of entry more readily legible to pedestrians. Together with signage, these elements create an information-rich

and legible street "wall." In the present case, higher proportions of brief stops were concentrated around a façade transparency level of approximately 60%. This value may serve as an exploratory reference for the renewal of ground-floor interfaces in historic commercial streets. Related empirical studies have likewise identified significant associations between commercial-display density, ground-floor transparency, interactive street elements, and pedestrian stopping and engagement behavior [10,18].

From the perspective of visual-attention mechanisms, transparent storefronts, entrances, and display windows transform indoor merchandise and activities into visual targets that can be perceived from the street and, together with signage, create a continuous sequence of attentional anchors. Mobile eye-tracking research has shown that the segmentation and organization of openings at ground-floor level can prolong pedestrians' visual engagement with street edges [26,27], while research on cognitive architecture emphasizes the role of window openings, edges, and face-like configurations in rapid orientation and visual anchoring [28,29]. The positive association between façade transparency and the proportion of brief stops observed in this study may therefore be further interpreted as the combined outcome of interface visibility, visual anchoring, and the acquisition of storefront information.

5.2. Comparison with Previous Research and Case-Specific Contributions

Compared with previous research, the contribution of this study lies primarily in providing supplementary case-based empirical evidence. First, this study examines street visibility, human-scale interfaces, and pedestrian dwell behavior within the context of signage governance in a historic commercial street, thereby further clarifying the relationship between ground-floor visual interfaces and the vitality of public life. Second, by incorporating nighttime illuminated signage into the analysis of pedestrian dwell behavior, this study extends research on the nighttime visual environments of commercial streets from perceptual evaluation to directly observable dwelling behavior. Third, based on correlation analyses of 13 street segments, the study identifies several case-specific numerical concentration ranges that provide testable hypotheses for subsequent research involving observations across multiple time periods, samples from multiple locations, and multisource data. Recent studies of commercial pedestrian streets have similarly shown that street vitality is jointly influenced by temporal, spatial, and built-environment factors, indicating that the stability of the present findings requires continued examination across a broader range of contexts [18,19]. This perspective may also help explain the apparent paradox whereby brighter lighting and denser signage cease to generate additional pedestrian dwelling in certain street segments [10,61]. Overall, these comparisons indicate that the present study helps address the limited quantitative evidence connecting advertising elements, interface attributes, and pedestrian dwell behavior from the perspective of collective behavioral responses. It should also be noted that the billboard-density and illuminated-signage-density thresholds identified in this study essentially correspond to a commercial-street advertising environment dominated by traditional signs, light boxes, neon signage, and conventional LED displays.

5.3. Research Limitations and Future Research

First, this study used 13 street segments within Guangzhou's Shangxiajiu Pedestrian Street as the units of analysis. This design facilitated the identification of spatial variation within a single historic commercial street and enabled exploratory comparisons at the street-segment level. At the same time, the use of 13 spatial units means that the statistical inferences are primarily intended to identify associations within this specific case. The correspondence between sample size and model complexity affects the stability of correlation

coefficients, significance tests, and regression estimates [55,56]. Future research should increase the number of street segments examined and include historic commercial streets, modern commercial streets, and open-air retail streets surrounding commercial complexes. Repeated observations should also be accumulated across weekdays and weekends, daytime and nighttime periods, and different seasons. Such data would support multivariable regression, robustness testing, internal validation, and external validation across cities. Subsequent multisite studies could additionally collect pedestrian activity proportions, PLOS and SUMI-QPS scores, and Visit Potential estimates simultaneously for the same street segments, thereby enabling comparisons of the consistency and complementarity among actual behavior, perceptual evaluations, and spatial-use potential [31,33]. Parallel evaluations conducted in real streets and immersive virtual environments could also be used to examine changes in walking quality, spatial attractiveness, and propensity to dwell before and after design interventions, thereby supporting the ex ante evaluation of regeneration proposals for historic commercial streets [31,62]. Recent research on commercial pedestrian streets has likewise demonstrated substantial temporal, spatial, and urban-contextual variation in street vitality, indicating that multisite and multi-period data are required to assess the stability and scope of applicability of the observed associations [19,48].

Second, as an open-access historic commercial district, Shangxiajiu Pedestrian Street is shaped simultaneously by seasonal conditions, microclimate, tourist flows, commercial promotions, the composition of business types, brand attractiveness, and pedestrians' travel purposes. Previous research has shown that the vitality of commercial pedestrian streets varies according to temporal, spatial, and built-environment factors [19], while the effects of the built environment also differ across cities and between daytime and nighttime conditions [48]. Marketing activities in commercial districts can likewise alter the distribution of consumer behavior by changing patterns of cross-store visitation [47]. The present study improved the consistency of comparisons across street segments through the selection of contiguous segments, synchronized observations, standardized counting procedures, and relative proportional indicators. Nevertheless, these external contextual variables collectively define the interpretive boundaries of the correlational findings. Within these boundaries, the observed strengths of association and numerical concentration ranges are interpreted as preliminary local indications under the specific observational conditions, while tourism intensity, seasonal differences, commercial-activity cycles, and the composition of business types are identified as priorities for future research. The findings should therefore primarily be understood as correlational evidence derived from a specific temporal context, and caution is required when extending them across seasons, activity cycles, and levels of tourism intensity. In addition, the study employed anonymous group-level observations at the street-segment level, with tourists and local residents jointly constituting the overall pedestrian sample. The findings therefore reflect the aggregate dwelling patterns of a mixed population. Recent research has shown that tourists and local residents may perceive safety, interest, relaxation, and streetscape elements differently in historic districts [63]. Future research could combine field-based behavioral observations with brief intercept surveys or anonymous self-reports and conduct stratified analyses of tourists, local residents, and other user groups. This approach would enable comparisons of dwelling and passing-through behavior among different populations under varying advertising stimuli, nighttime environments, and street-interface conditions.

Third, the field observations covered only two days. Although the research design included one weekday and one weekend day and employed synchronized counting within identical observation periods, the temporal sample remained limited. Long-term street monitoring has shown that walking behavior exhibits pronounced spatiotempo-

ral dynamics [64]. Future research should therefore adopt multiday, cross-seasonal, or continuous monitoring designs to verify the present findings.

Fourth, this study relied on behavioral correlation analysis and threshold fitting rather than intervention-based causal identification. Consequently, the potential confounding effects of covariates such as the composition of retail types, price levels, and brand strength cannot be fully excluded.

Fifth, billboard density and illuminated signage density were used as street-segment-level quantitative indicators representing the numerical distributions of billboards and illuminated signs across the analytical units. Previous studies have shown that cumulative advertising area, color content, actual luminance, contrast, and the dimensions of individual signs jointly influence visual comfort, visual salience, and the allocation of attention in street environments [15,17,65]. The correlational findings of the present study therefore primarily reflect case-specific associations among the numerical distribution of advertisements, the spatial characteristics of the street, and the proportions of pedestrian activities.

More specifically, billboard density and illuminated signage density principally capture quantitative distributions at the street-segment level. Future research could combine these measures with signage area, individual sign dimensions, installation height, actual luminance, color temperature, color contrast, content complexity, dynamic variation, and subjective evaluations of visual comfort to construct a more comprehensive system of indicators for the visual intensity of street advertising. Recent studies of visual pollution and outdoor advertising have shown that advertising scale, color, lighting, location, and content format jointly shape the quality of the urban visual environment and users' perceptions [16,17,23]. Subsequent research could therefore supplement quantitative counts with measurements of the lighting environment, image recognition, eye tracking, and questionnaire-based evaluations to provide a more detailed explanation of the relationship between advertising-related visual environments and pedestrian dwell behavior.

In addition, this study used a 1 min threshold to distinguish brief stopping from prolonged dwelling and operationalized pedestrian activity into three categories: brief stopping, prolonged dwelling, and passing through. This approach facilitated consistent field recording across the 13 street segments but inevitably simplified the internal diversity of complex dwelling behavior. The conclusions are therefore more applicable to comparisons of dwelling intensity at the street-segment level than to the interpretation of more specific behavioral categories, such as social interaction, window-shopping, or digital engagement. Future studies could employ video coding, computer vision, or mobile-sensing methods to identify the purposes of dwelling and patterns of interaction in greater detail.

The behavioral analysis also focused on dwelling duration and passing-through status within the overall pedestrian population. Pedestrians with sensory sensitivities or neurodivergent characteristics constitute an important population for subsequent stratified research. Stimuli such as high luminance, dynamic imagery, dense visual information, crowding, and noise may affect their spatial choices, dwelling duration, route planning, and community participation [66,67]. Future research could combine sensory-profile questionnaires, participatory walking interviews, accessibility audits, and route tracking to evaluate the navigational experiences of groups with different sensory needs in historic commercial streets. Visual-stimulus intensity, quiet buffer spaces, the clarity of wayfinding, and the predictability of information could then be incorporated into assessments of inclusive street environments.

Finally, the street width-to-height ratio and façade transparency were both calculated using street-segment averages and therefore did not capture fine-grained variations along the street. Future research could employ computer vision and mobile-

sensing technologies to enable an integrated assessment of continuous and momentary environmental characteristics.

Future research could proceed in four main directions. First, quasi-experimental or natural-experimental designs could be implemented. For example, advertising spacing and the proportion of illuminated advertisements could be adjusted in stages within controlled street segments, after which a difference-in-differences approach could be used to estimate causal effects. Second, future research could develop a multiscale measurement framework for the visual complexity of street façades and signage by integrating neurodesign and visual-attention perspectives. Along representative walking routes and at typical viewing distances, mobile eye-tracking devices could be used to define ground-floor storefronts, entrances, display windows, signage, upper façades, and roadway space as areas of interest. Time to first fixation, fixation count, fixation duration, scan paths, and transitions between areas of interest could then be recorded and spatiotemporally matched with walking trajectories, movement speed, brief stopping, and extended dwell. Standardized façade images could also be analyzed in terms of luminance, color temperature, contrast, repetition, spatial frequency, orientation distribution, graphic layering, material reflectance, and the frequency of dynamic updating. This approach would enable comparisons of visual-engagement levels across different street frontages and help identify interface configurations that support continuous walking, storefront information acquisition, and transitions from movement to dwelling [26,27,30]. Eye-tracking indicators could additionally be analyzed in conjunction with subjective assessments of visual comfort and heart-rate variability to construct a relational pathway linking visual complexity, visual attention, perceptual experience, and behavioral responses. Third, the analysis could be extended to multiple cities and different types of commercial environments. With larger samples, quadratic regression, segmented regression, generalized additive models, or analyses of spatial heterogeneity could be employed to identify the specific forms of the observed relationships and to test the stability and applicability of the value-concentration ranges identified in this study across different urban morphologies, cultural environments, and consumption structures. Through these extensions, the value ranges identified in the present study could serve as hypotheses for subsequent cross-regional validation and, with support from multicase, longitudinal, and multisource data, could gradually be developed into more generalizable design references. Recent research on commercial pedestrian streets has similarly indicated that pedestrian-street vitality is jointly shaped by temporal, spatial, and built-environment factors, and that cross-city comparisons under daytime and nighttime conditions can enhance the explanatory power of research findings [19,48]. Finally, by increasing the number of street segments, street types, and observation periods, future research could develop multivariable regression or machine-learning models linking signage configuration to pedestrian behavior. The stability and transferability of these models could then be evaluated through internal validation, external validation across locations, and sensitivity analysis.

Within the research boundaries described above, the findings concerning billboard density, illuminated signage density, street width-to-height ratio, and façade transparency are defined as exploratory, context-specific, and case-based evidence. The numerical concentration ranges reported in this study are intended primarily to describe the patterns observed across 13 street segments of Shangxiajiu Pedestrian Street during one weekday and one weekend observation window and to provide testable hypotheses for subsequent research. Future studies could further examine the stability of these associations across different street types, seasonal conditions, levels of tourism intensity, and cycles of commercial activity by using samples from multiple commercial districts, cross-city comparisons,

continuous temporal monitoring, cross-seasonal surveys, quasi-experimental designs, and more refined measurements of the visual environment.

5.4. Exploratory Policy and Design Implications

5.4.1. Signage Governance and the Nighttime Visual Environment

The findings provide exploratory guidance for signage governance in Shangxiajiu Pedestrian Street. The positive associations between billboard density and illuminated signage density and several indicators of brief stopping and extended dwell suggest that, within the existing local regulatory framework, management practices could incorporate street-segment-level assessments of the nighttime visual environment. Such assessments could consider signage quantity, operating hours, overall luminance, size, spacing, and relationships with historic building interfaces. Neurodesign principles further support extending signage governance beyond the regulation of quantity and scale to include the management of visual structure. More specifically, assessments could address the distribution of high-contrast elements, the frequency of regular repetition, graphic overlap among adjacent signs, the reflective properties of illuminated materials, and variations in spatial frequency across different viewing distances. By creating moderate contrast, varied compositional rhythms, and clear visual hierarchies, historic commercial streets may enhance visual comfort and environmental inclusiveness while maintaining commercial visibility and interface vitality [20,22]. Guangzhou's current regulatory documents already incorporate electronic display devices, dynamic lighting, operating hours, and light-pollution control into the governance framework [34,35]. As digital advertising continues to develop, future assessments could also examine how dynamic content, update frequency, and modes of interaction shape pedestrian experience [24,25]. These implications should primarily be regarded as preliminary, case-specific guidance for the local context and as practical propositions requiring validation across multiple sites.

5.4.2. Spatial Enclosure and Ground-Floor Interfaces

The associations of street width-to-height ratio and façade transparency with several indicators of pedestrian dwell provide integrated implications for spatial enclosure and ground-floor interface renewal in historic commercial streets. Drawing on the "street as a room" concept and the pattern-language framework, renewal strategies can treat qilou street frontages, building façades, rows of trees, storefront openings, signage configurations, and small-scale spaces that support dwelling as interconnected design patterns. Continuous street walls, clearly legible entrances, moderate transparency, and human-scale design can thereby be combined to create a sequence of recognizable street "rooms" [2–4]. This integrated approach can simultaneously enhance spatial enclosure, ground-floor visibility, visual connections between indoor and outdoor spaces, and the interface order of historic districts. Specific interventions can be contextually adjusted according to absolute street width, width-to-height ratio, qilou continuity, tree configuration, and activity intensity, allowing spatial scale and commercial interfaces to jointly support pedestrian movement, observation, and dwelling. Because the vitality of commercial pedestrian streets is jointly shaped by temporal conditions, spatial characteristics, the built environment, and the broader urban context, these strategies may serve as a starting point for comparative research and design practice in Shangxiajiu Pedestrian Street and other historic commercial streets with similar spatial morphologies.

For specific interface-renewal projects, street frontages may be classified into high, medium, and low levels of visual engagement on the basis of eye-tracking indicators, with particular attention paid to the legibility of entrances and display windows, the rhythm of ground-floor segmentation, the informational hierarchy of signage, the composition

of window openings, and human-scale details. Interfaces characterized by continuous visual anchors and a clear informational hierarchy can support spatial orientation, storefront information acquisition, and route selection while pedestrians are moving, thereby facilitating smooth transitions among continuous walking, brief stopping, and extended dwell [27,28,30].

6. Conclusions

This study examined 13 street segments in Shangxiajiu Pedestrian Street as the units of analysis and employed field measurements, synchronized behavioral observations, and correlation analyses to investigate the relationships of billboard density, illuminated signage density, street width-to-height ratio, and façade transparency with the proportions of brief stopping, prolonged dwelling, and total pedestrian activity. Within the present case and the specified observation periods, the correlation analyses showed that billboard density was significantly and positively associated with the average proportions of brief stopping and prolonged dwelling; illuminated signage density was significantly and positively associated with the proportion of nighttime prolonged dwelling; street width-to-height ratio was significantly and positively associated with the proportions of afternoon brief stopping and total afternoon pedestrian activity; and façade transparency was significantly and positively associated with the afternoon and average proportions of brief stopping. These findings indicate case-specific statistical associations between pedestrian dwelling behavior and the numerical distribution of billboards, the numerical distribution of illuminated signage, street width-to-height ratio, and ground-floor façade transparency across the street segments of Shangxiajiu Pedestrian Street.

Based on these findings, the study provides exploratory local references for signage configuration, nighttime visual-environment management, the adjustment of spatial enclosure, and the regeneration of ground-floor interfaces in Shangxiajiu Pedestrian Street. The identified associations and numerical concentration ranges describe the spatial and behavioral characteristics of this case under the specified observation conditions and may be developed into testable hypotheses for subsequent multicase research. Future studies could further assess the stability, contextual variation, and applicability of these associations by expanding the sample of street segments, extending the observation period, conducting repeated observations across seasons, and incorporating cases from multiple cities.

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