

Spatial Vitality Characteristics and Influencing Factors of Commercial Districts in Hangzhou—An Empirical Study of the Hubin Commercial District Based on Multi-Source Data

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ABSTRACT: Evidence-based research into the vitality characteristics of commercial districts and their influencing factors can help promote the prosperity and development of such districts. Taking the Hubin Commercial District in Hangzhou City as the study area, this study employs quantitative urban research methods and fine-grained multi-source data to construct a multidimensional indicator system and examine the relationship between built-environment characteristics and commercial-district vitality at the urban-block and land-parcel levels. The results show that vitality in the Hubin Commercial District exhibits a “one-core, one-axis” spatial pattern. With Yan’an Road as the dividing line, vitality in the eastern and western parts is dominated by everyday social activity and holiday-related consumption, respectively. Functional density, distance to the nearest metro station entrance or exit, functional mix, and morphological compactness are the main factors influencing the vitality of the Hubin Commercial District in Hangzhou. Building on evidence that the current redevelopment of key areas in the Hubin Commercial District can enhance vitality, the study further proposes promoting a more balanced spatial distribution of activity, relieving commercial and traffic pressure, and enhancing district-wide vitality.

KEY WORDS: the Hubin Commercial District; multi-source data; commercial-district vitality; vitality characteristics; influencing factors; influential indicators

Introduction

Commercial districts are important spatial units that accommodate urban functions and socioeconomic activities. They play significant roles in showcasing a city’s image, strengthening its economy, concentrating urban vitality, and enriching social life. As China’s urban development undergoes a transition, the 14th Five-Year Plan calls for efforts to “accelerate the transformation of urban development modes, coordinate urban planning, construction, and management, implement urban renewal initiatives, and promote the optimization of urban spatial structures and improvements in urban quality”. Accordingly, the planning

and development of commercial districts need to shift from a sole focus on creating the built environment to equal emphasis on the built environment and spatial vitality. As the physical setting for commercial district vitality, the built environment and its effects on vitality need to be examined more objectively, comprehensively, and precisely. Evidence-based research using fine-grained data can therefore help clarify the relationship between spatial vitality and the built environment in commercial districts, thereby providing an empirical basis for people-centered design and urban socioeconomic development.

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nologies and methods for measuring urban vitality have continued to emerge in recent years, providing new approaches to fine-grained analysis and research in urban design [1-3]. Against this background, the use of multi-source data and multiple analytical models to assess urban vitality has complemented research on the spatial form of commercial districts and also has important practical implications for smart-city development [4]. Scholars in China and elsewhere have used emerging data sources, including mobile phone signaling data [5-7], heat-map data [8-10], public transit data [11, 12], GPS data [13], street-view imagery [14-16], data from Dianping [17, 18], and social media data [19-21]. Using built-environment indicators such as locational conditions, street-network morphology, urban-block size, parcel land use, functional mix, and transport accessibility, they have examined urban vitality at different scales and from different perspectives. Overall, research specifically focused on the vitality of commercial districts remains limited, and studies that examine it jointly from the two dimensions of human activity and commercial agglomeration are particularly scarce. Moreover, existing studies of urban vitality employ a wide variety of indicator systems, and indicator selection must account for regional and typological differences among study areas. Identifying and selecting indicators suited to the vitality and built-environment characteristics of the commercial districts in Hangzhou is therefore essential to establishing a localized and fine-grained research framework. Accordingly, this study focuses on commercial districts and conceptualizes commercial-district vitality in terms of two dimensions: social vitality and economic vitality. By examining the Hubin Commercial District, a representative commercial district with distinctive local characteristics of Hangzhou, the study seeks to identify indicators that are influential in the local context and provide a basis for targeted, context-sensitive design interventions and urban management.

Taking the Hubin Commercial District in Hangzhou as a case study, this research is grounded in relevant classical theories and combines new data and technologies with traditional data and methods. It quantitatively measures and analyzes the urban vitality characteristics and in-

fluencing factors of the Hubin Commercial District, identifies the underlying relationship between its built-environment characteristics and commercial-district vitality, and provides theoretical insights and empirical evidence for related research and context-sensitive planning and design.

1 Research Design

1.1 Study area and overview

The Hubin Commercial District is located in the core area of Shangcheng District, Hangzhou. It is one of the three zones in the “One Axis, Three Zones, and Multiple Subareas” spatial structure proposed in the *Master Plan for Creating a Vibrant, Culturally Rich, and Scenic Yan'an Road International Commercial Avenue*, prepared by Hangzhou Urban Planning and Design Institute in 2018. The study area is bounded by Middle Zhonghe Road to the east, Jiefang Road to the south, West Lake to the west, and Qingchun Road to the north. It covers approximately 1 km² and consists of land parcels that are relatively regular in shape (Figure 1).



Figure 1 Modified model with standardized path coefficients

1.2 Research data

The base data used in this study mainly comprise geographic data and open-access online data and can be divided into the following four categories:

(1) Urban-block and land-parcel data: The boundaries and land-use classifications of the urban blocks and land parcels were digitized based on the *Regulatory Detailed Plan for the Hubin Planning Unit in Hangzhou*, prepared by Zhejiang Urban and Rural Planning and Design Institute in 2010, and were subsequently refined through field surveys.

(2) Building footprints and numbers of stories: Building footprints and numbers of stories were digitized using 2022 Amap data and subsequently refined through field surveys.

(3) Point-of-interest data: Point-of-interest (POI) data were obtained from the open data provided by Amap in 2022. Based on their type tags, the POIs were reclassified into seven categories: public services, business and office, commercial services, healthcare, residential, landscape and recreation, and transportation.

(4) Human activity data: Human activity data were derived from heat maps provided by online mapping platforms in 2022. Data were sampled during April 18-22 and May 16-22. Hourly heat-map data from 06:00 to 24:00 on weekdays and weekends were extracted and aggregated for analysis.

1.3 Analytical framework

Taking the Hubin Commercial District in Hangzhou as an empirical case, this study uses a series of multiple linear regression models to examine the relationship between the built environment and commercial-district vitality, which integrates social and economic vitality, and thereby identifies its vitality characteristics and influencing factors. The built-environment characteristics of the commercial district are organized into four dimensions for indicator construction: locational conditions, transport organization, spatial form, and land-use functions. First, social vitality, represented by human activity heat-map data, and economic vitality, represented by commercial establishment density, are weighted using the entropy weighting method to calculate composite vitality scores for each urban block and land parcel in the Hubin Commercial District. Second, built-environment indicators are specified under the four dimensions for each urban block and land parcel. These indicators are quantified using their corresponding calculation methods based on multi-source online data and field observations. Finally, a series of multiple linear regression models are used to identify the built-environment indicators associated with commercial-district vitality and to examine the magnitude and direction of their relationships with vitality.

1.4 Construction of the indicator system

In view of the characteristics of commercial districts,

this study conceptualizes commercial-district vitality in terms of two dimensions: social vitality and economic vitality. Social vitality is represented by human activity heat-map data, whereas economic vitality is represented by the density of commercial establishment POIs. The built-environment characteristics of the commercial district are organized into four dimensions—locational conditions, transport organization, spatial form, and land-use functions—and a total of 12 built-environment indicators are selected for analysis.

1.4.1 Commercial-district vitality indicators

(1) Social vitality: Social vitality in a commercial district mainly refers to the spatial concentration of human activity. In this study, human activity heat maps are used to measure social vitality. Given the differences in human activity patterns between weekdays and weekends, social vitality is divided into weekday social vitality, weekend social vitality, and average daily social vitality. Hourly heat-map data from 06:00 to 24:00 are compiled separately. Average daily social vitality is calculated as the mean of the weekday and weekend values.

(2) Economic vitality: Economic vitality in a commercial district mainly refers to the spatial density of commercial establishment POIs. The POI data obtained from open-access map data are reclassified to identify commercial POIs. Commercial establishment density is calculated as the ratio of the number of commercial POIs within an urban block or land parcel to its area and is used as the indicator of economic vitality.

(3) Composite vitality: Composite vitality refers to an integrated assessment of social and economic vitality within a commercial district. In this study, social and economic vitality are weighted using the entropy weighting method, and the resulting value is used as the indicator of composite commercial-district vitality. Given the differences in social vitality between weekdays and weekends, composite vitality is divided into weekday composite vitality, weekend composite vitality, and average daily composite vitality.

1.4.2 Commercial-district built-environment indicators

(1) Locational conditions: Locational conditions refer

primarily to the convenience of an urban block or land parcel for commercial agglomeration. The indicators selected in this study mainly include the distance to the nearest large-scale commercial complex.

(2) Transport organization: Transport organization mainly refers to the public transit accessibility of an urban block or land parcel. The indicators selected in this study mainly include the distance to the nearest metro station entrance or exit, the distance to the nearest bus stop, and the number of nearby bus stops.

(3) Spatial form: Spatial form mainly refers to the spatial dimensions and perceived scale of urban blocks or land parcels and their buildings. The indicators selected in this study mainly include urban-block or land-parcel size, morphological compactness, development intensity, build-

ing density, and average number of building stories.

(4) Land-use functions: Land-use functions mainly refer to the dominant functional types of urban blocks or land parcels. The indicators selected in this study include the primary functional type, functional density, functional mix, and business-format diversity.

1.5 Indicator quantification

Indicators with clear and directly measurable meanings, such as urban-block or land-parcel size and the number of building stories, are quantified from the base data using ArcGIS. More abstract indicators are operationalized and quantified using the corresponding calculation procedures. The methods used to quantify the indicator system are presented in Table 1.

Table 1 Indicator system and quantification methods for the Hubin Commercial District

Category	Dimension	Indicator	Calculation method	Formula and notes
Commercial-district vitality	Social vitality	Weekday human activity concentration	Ratio of the total weekday heat-map value to urban-block/land-parcel area	$CA = \frac{1}{S} \sum_{i=1}^n MT_i$ Where i denotes an hourly time point from 06:00 to 24:00, MT_i is the vectorized map heat value at the ith time point, and S is the urban-block/land-parcel area.
		Weekend human activity concentration	Ratio of the total weekend heat-map value to urban-block/land-parcel area	$CA = \frac{1}{S} \sum_{i=1}^n MT_i$ Where i denotes an hourly time point from 06:00 to 24:00, MT_i is the vectorized map heat value at the ith time point, and S is the urban-block/land-parcel area.
		Average daily human activity concentration	Mean of weekday and weekend human activity concentration	$CA_{av} = \frac{(CA_{wd} + CA_{we})}{2}$ Where CA_{av} is average daily human activity concentration, CA_{wd} is weekday human activity concentration, and CA_{we} is weekend human activity concentration.
	Economic vitality	Commercial establishment density	Ratio of the number of commercial establishment POIs to urban-block/land-parcel area.	$SA = \frac{ST_{poi}}{S}$ Where ST_{poi} is the total number of commercial establishment POIs within the urban block/land parcel, and S is the urban-block/land-parcel area.
Built-environment characteristics of the commercial district	Locational conditions	Distance to the nearest commercial complex	Euclidean distance between the centroid of the urban block/land parcel and that of the nearest commercial complex	$shm_d = \sqrt{(x_s - x_{ho})^2 + (y_s - y_{ho})^2}$ Where x_s and y_s are the longitude and latitude coordinates of the urban-block/land-parcel centroid, respectively, and x_{ho} and y_{ho} are the longitude and latitude coordinates of the centroid of the nearest commercial complex, respectively.

(Continued)

Category	Dimension	Indicator	Calculation method	Formula and notes
Built-environment characteristics of the commercial district	Transport organization	Distance to the nearest metro station entrance/exit	Euclidean distance between the urban-block/land-parcel centroid and the nearest metro station entrance/exit.	Calculated in the same manner as the distance to the nearest commercial complex
		Distance to the nearest bus stop	Euclidean distance between the urban-block/land-parcel centroid and the nearest bus stop	Calculated in the same manner as the distance to the nearest commercial complex
		Number of nearby bus stops	Number of bus stops within a five-minute walking distance of the urban-block/land-parcel centroid	A five-minute walking distance is defined as 400 m.
	Spatial form	Urban-block/land-parcel area	Area of urban block/land parcel	—
		Morphological compactness	Measure of the compactness of urban-block/land-parcel shape	$NCI = \frac{\sqrt{\pi S}}{V}$ Where S is the urban-block/land-parcel area and V is its perimeter
		Development intensity	Ratio of total building floor area to land area, i.e., floor area ratio (FAR).	$FAR = \frac{A_r}{A_l}$ Where A_r is the total floor area of all buildings within the urban block/land parcel, and A_l is the urban-block/land-parcel area
		Building density	Ratio of total building footprint area to urban-block/land-parcel area	$building_{den} = \frac{1}{S} \sum_{i=1}^n m_i$ Where i denotes a building within the urban block/land parcel, m_i is the footprint area of the i th building, and S is the urban-block/land-parcel area
	Land-use functions	Average number of building stories	Mean number of stories of all buildings within the urban block/land parcel	$building_f = \frac{1}{n} \sum_{i=1}^n bf_i$ Where bf_i is the number of stories of the i th building, and n is the number of buildings within the urban block/land parcel
		Functional density	Ratio of the total number of POIs to urban-block/land-parcel area	$fun_{mix} = \frac{c_i}{S_i}, (i = 1, 2, 3, \dots, n)$ Where C_i is the total number of POIs within the urban block/land parcel, and S_i is the urban-block/land-parcel area.
		Functional mix	Information entropy of all POI functional types	$fun_{mix} = -\sum_{i=1}^n (p_i \times \ln p_i), (i = 1, 2, 3, \dots, n)$ Where i denotes a POI functional category, p_i is the proportion of POIs in category i relative to the total number of POIs within the urban block/land parcel, and n is the number of POI categories
		Business-format diversity	Simpson index of the different POI functional types	$FDI = 1 - \sum_{i=1}^n \left(\frac{N_i}{N}\right)^2$ Where i denotes a POI functional category, N_i is the number of POIs in category i , and N is the total number of POIs within the urban block/land parcel.

1.6 Analytical method

In this study, commercial-district vitality is used as the dependent variable, while the built-environment indicators are used as independent variables. A series of multiple linear regression models are constructed to identify the built-environment indicators associated with commercial-district vitality. The equation is as follows:

$$\text{VIT} = \beta_0 + \beta_1 \times \text{shm}_d + \beta_2 \times \text{metro}_d + \beta_3 \times \text{bus}_d + \beta_4 \times \text{bus}_{\text{qty}} + \beta_5 \times S + \beta_6 \times \text{NCI} + \beta_7 \times \text{FAR} + \beta_8 \times \text{building}_{\text{den}} + \beta_9 \times \text{building}_f + \beta_{10} \times \text{fun}_{\text{den}} + \beta_{11} \times \text{fun}_{\text{mix}} + \beta_{12} \times \text{FDI}$$

where VIT denotes the composite commercial-district vitality score; shm_d denotes the distance to the nearest commercial complex; metro_d denotes the distance to the nearest metro station entrance or exit; bus_d denotes the distance to the nearest bus stop; bus_{qty} denotes the number of nearby bus stops; S denotes urban-block or land-parcel size; NCI denotes urban-block or land-parcel morphological compactness; FAR denotes the floor area ratio (development intensity); $\text{building}_{\text{den}}$ denotes building density; building_f denotes the average number of building stories; fun_{den} denotes the functional density; fun_{mix} denotes the functional mix; and FDI denotes business-format diversity.

2 Results

2.1 Spatial distribution patterns of vitality in the Hubin Commercial District

2.1.1 Spatial distribution of social vitality

In this study, social vitality in the Hubin Commercial District is represented by the spatial concentration of human activity. The results reveal marked variations across urban blocks and land parcels and across time periods, together with substantial temporal fluctuations.

The spatial distributions at the urban-block and land-parcel levels are broadly similar. On weekdays, human activity in the Hubin Commercial District is concentrated primarily in the urban blocks and land parcels surrounding Affiliated Hangzhou First People's Hospital, School of Medicine, Westlake University and the School of Obstetrics and Gynecology, Zhejiang University School of Medicine, both of which are Grade-A tertiary hospitals. The ur-

ban blocks and land parcels near Xingyuanli, Quanyeli, Daqingli, and the Hangzhou Workers' Cultural Palace in the northern section of the Hubin Commercial Pedestrian Street exhibit the lowest levels of human activity. Overall, the concentration of human activity is slightly higher in the urban blocks and land parcels between Yan'an Road and Huansha Road, whereas it is substantially lower in those adjoining the Hubin Road Pedestrian Street than in other parts of the commercial district. On weekends, the main concentrations of human activity expand to include the urban blocks and land parcels near Dongpo Road and the Hubin Road Pedestrian Street, with the most pronounced increase occurring near Zone C of Hubin Yintai in 77. The urban blocks and land parcels near Pingyuanli, Huixingli, and the Hangzhou Workers' Cultural Palace exhibit the lowest levels of human activity. Overall, the concentration of human activity in the urban blocks and land parcels along the Hubin Road Pedestrian Street increases markedly, approaching or even exceeding that in other parts of the commercial district. The most substantial increase occurs in the urban blocks and land parcels between Xueshi Road and Pinghai Road. In terms of average daily human activity, the main concentrations extend from the two Grade-A tertiary hospitals to the area surrounding the Gonglian Mansion City Center (Gonglian CC). The urban blocks and land parcels near Xingyuanli, Quanyeli, Daqingli, and the Hangzhou Workers' Cultural Palace in the northern part of the Hubin Commercial District exhibit the lowest levels of human activity. Overall, the urban blocks and land parcels between Yan'an Road and Huansha Road show higher concentrations of human activity than those in other parts of the commercial district (Figure 2).

2.1.2 Spatial distribution of economic vitality

In this study, economic vitality in the Hubin Commercial District is represented by the density of commercial establishment POIs. The results show that areas with high commercial POI densities form an approximately linear north-south pattern along major roads. They are concentrated primarily along Yan'an Road and secondarily along Middle Zhongshan Road.

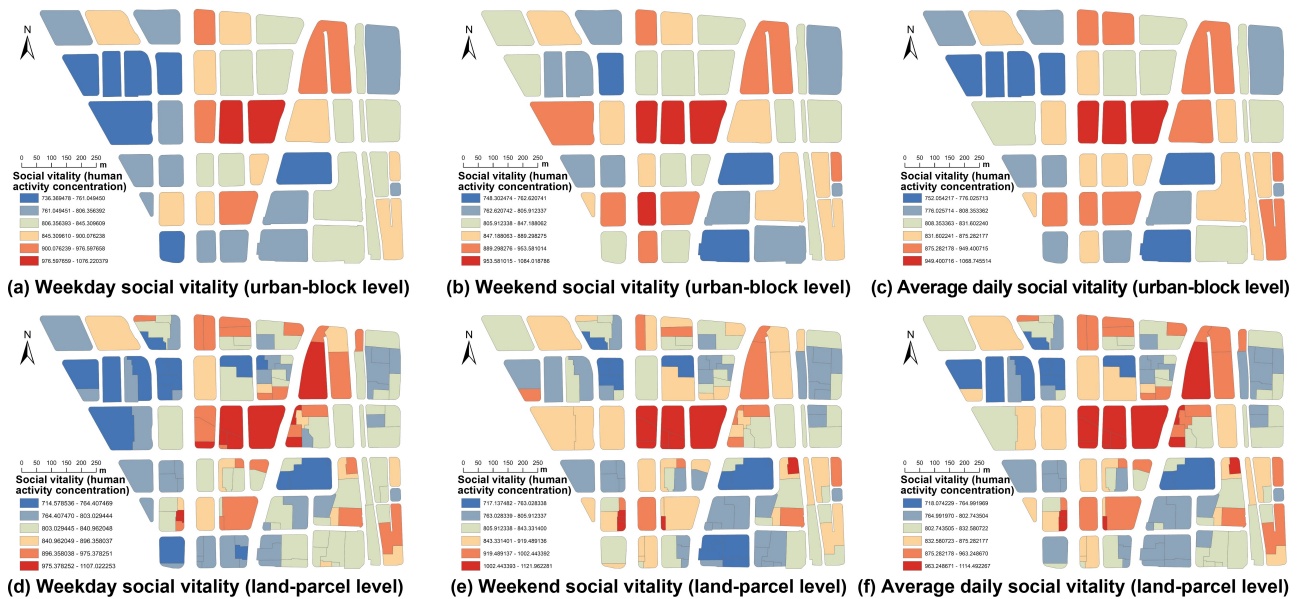


Figure 2 Spatial distribution of social vitality (urban-block & land-parcel levels)

At both the urban-block and land-parcel levels, commercial POI densities are generally higher to the east of Yan'an Road than to the west. The highest concentrations occur around the Gonglian CC and Longxiang Building, although the detailed distribution patterns differ between the two spatial levels. At the urban-block level, high commercial POI density is also observed in the urban block containing Zone B of Hubin Yintai. Among the urban blocks near Middle Zhongshan Road, commercial establishments are more evenly distributed on the west side than on the east side. Overall, the urban blocks containing the Gonglian CC and Zone B of Hubin Yintai in form the principal concentration cores. By contrast, markedly low commercial POI densities are observed in the predominantly residential urban blocks between Putishi Road and Huansha Road, as well as in the urban blocks containing Affiliated Hangzhou First People's Hospital, School of Medicine, Westlake University and the Hangzhou Workers' Cultural Palace. At the land-parcel level, commercial POI densities in the northern parcels east of Yan'an Road are higher than those in the southern parcels, whereas the opposite pattern is observed to the west of this road. The highest concentration occurs in the northern parcels east of the road. Along Middle Zhongshan Road, commercial establishments are located mainly in the land parcels on the west side, with no marked difference between the northern and southern sections (Figure 3).

2.1.3 Spatial distribution of composite vitality

In this study, composite commercial-district vitality is represented by an integrated assessment of social and economic vitality. The results show that composite vitality is concentrated around the Gonglian CC, extends along Yan'an Road as a north-south axis, and radiates outward into the surrounding areas.

Overall, the areas east and west of Yan'an Road exhibit markedly different distributions of composite vitality on weekdays and weekends. On weekdays, composite vitality is also concentrated, to a lesser extent, in the urban blocks and land parcels on both sides of Middle Zhongshan Road, forming a north-south linear pattern. Composite vitality is generally higher and more evenly distributed to the west of Middle Zhongshan Road than to the east. The urban blocks and land parcels near the northern section of the Hubin Road Pedestrian Street and the Hangzhou Workers' Cultural Palace have the lowest composite vitality. On weekends, composite vitality increases markedly in the western urban blocks and land parcels near the Hubin Road Pedestrian Street. At the urban-block level, a continuous east-west linear distribution of composite vitality forms across the urban blocks between Xueshi Road and Pinghai Road. Composite vitality in this area exceeds that in the urban blocks on both sides of Middle Zhongshan Road and is second only to that of the urban blocks east of

Yan'an Road. In terms of average daily composite vitality, the urban blocks and land parcels on both sides of Yan'an Road exhibit the highest values. With the area surrounding the Gonglian CC as the core, vitality extends north-south along Yan'an Road and east-west through the urban blocks and

land parcels between Xueshi Road and Pinghai Road, forming a cross-shaped spatial pattern. Composite vitality in the urban blocks and land parcels between Xueshi Road and Pinghai Road tends to be slightly higher than that in those on both sides of Middle Zhongshan Road (Figure 4).

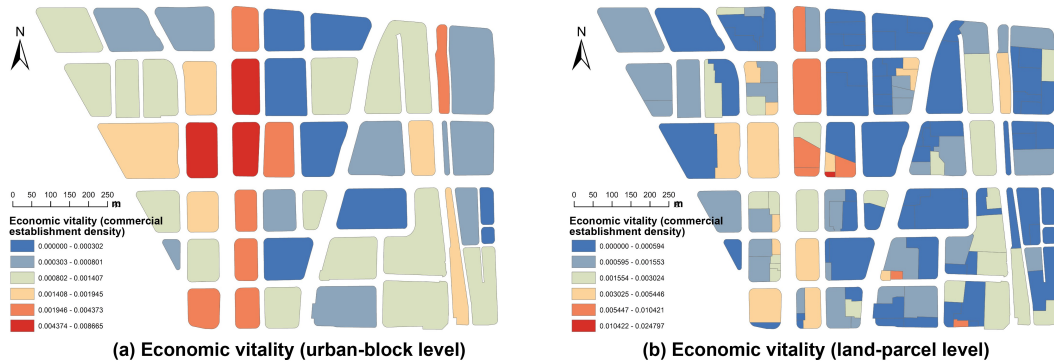


Figure 3 Spatial distribution of economic vitality (urban-block & land-parcel levels)

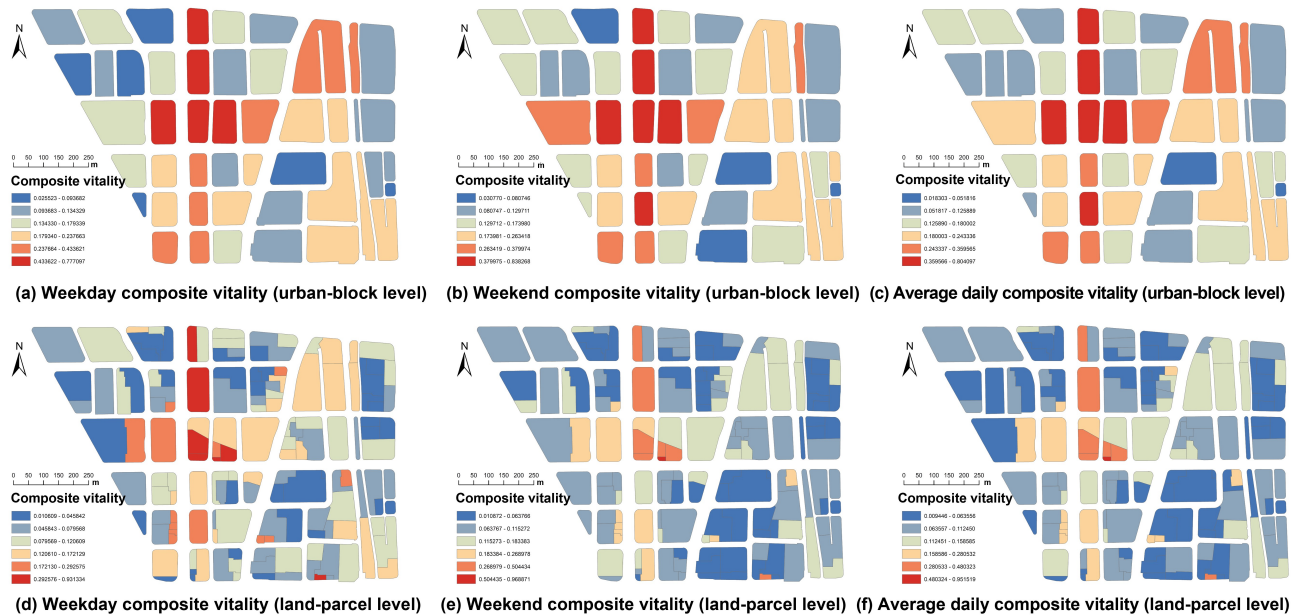


Figure 4 Spatial distribution of composite vitality (urban-block & land-parcel levels)

2.2 Analysis of influential indicators for commercial-district vitality

To assess the relationships between individual built-environment indicators and the vitality of the Hubin Commercial District and to identify the key influential indicators, Pearson correlation analysis was first conducted in SPSS between composite vitality and the 12 built-environment indicators. Indicators without statistically significant correlations were excluded, and the remaining indicators were subsequently entered into a series of multiple linear regression models. Weekday, weekend, and average daily-

composite vitality were separately specified as dependent variables, while the built-environment indicators that passed the correlation significance test were specified as independent variables. Overall, the urban-block-level and land-parcel-level regression models exhibit similar goodness of fit, although the urban-block-level models perform slightly better.

2.2.1 Urban-block-level analysis of influential indicators

Based on the 3 regression models for weekday, weekend, and average daily composite vitality at the urban-block level, indicators that failed the significance test ($p \geq$

0.05) were excluded. The remaining variables entered into the three models included distance to the nearest metro station entrance or exit, number of nearby bus stops, urban-block area, morphological compactness, average number of building stories, functional density, and functional mix. The adjusted R^2 values of the three models were 0.803, 0.806, and 0.803, respectively, indicating good model fit. The overall F-tests were statistically significant for all three models ($p < 0.05$), demonstrating that all 3 regression models were statistically significant. All selected independent variables had statistically significant regression coefficients ($p < 0.05$), indicating that each of the indicators included in the models was statistically significant.

In terms of the relative contributions of the influential indicators to composite vitality, the 5 influential indicators of weekday composite vitality, in descending order

of contribution, were functional density, functional mix, number of nearby bus stops, urban-block area, and morphological compactness. The 4 influential indicators of weekend composite vitality were functional density, distance to the nearest metro station entrance or exit, functional mix, and morphological compactness. The 5 influential indicators of average daily composite vitality were functional density, distance to the nearest metro station entrance or exit, morphological compactness, average number of building stories, and functional mix. Functional density, functional mix, and morphological compactness were included in all 3 models, with functional density exerting the strongest influence in each. These results indicate that urban-block functional density is the most important factor associated with composite vitality in the Hubin Commercial District, with a substantially greater contribution than the other indicators (Table 2).

Table 2 Standardized coefficients for the urban-block- and land-parcel-level regression models

	Urban-block-level composite vitality			Land-parcel-level composite vitality		
	Weekday	Weekend	Average daily	Weekday	Weekend	Average daily
Distance to the nearest metro station entrance/exit	—	—0.328	—0.474	—0.194	—0.200	—0.214
Distance to the nearest bus stop	0.270	—	—	—	—	—
Urban-block/land-parcel area	0.192	—	—	—	0.131	—
Morphological compactness	—0.142	—0.186	—0.282	—	—	—
Average number of building stories	—	—	0.222	—	—	—
Functional density	0.859	0.776	0.721	0.825	0.823	0.819
Functional mix	—0.295	—0.208	—0.178	—0.134	—0.147	—0.134
Business-format diversity	—	—	—	—	—0.107	—
Adjusted (R^2)	0.803	0.806	0.803	0.749	0.751	0.753

Notes: The standardized coefficient reflects the influencing relationship between vitality-constituting elements and vitality values. A larger absolute value indicates a greater contribution to the influence on vitality. A positive value means a positive effect on vitality, whereas a negative value denotes a negative effect on vitality.

Regarding the direction of the relationships between the urban-block-level indicators and composite vitality in the Hubin Commercial District, functional density, number of nearby bus stops, and urban-block area were positively associated with weekday composite vitality, whereas functional mix and morphological compactness were negatively associated with it. In the weekend model, functional density showed a positive association, whereas distance to the nearest metro station entrance or exit, functional mix, and morphological compactness showed negative associations. In the average daily model, functional density and average number of building stories were positively associ-

ated with composite vitality, whereas distance to the nearest metro station entrance or exit, morphological compactness, and functional mix were negatively associated with it. Across all 3 models, functional density was consistently positively associated with composite vitality, while functional mix and morphological compactness were consistently negatively associated with it. Thus, urban blocks with higher functional density tend to exhibit greater vitality, whereas those with an excessively mixed functional composition or greater morphological compactness tend to exhibit lower vitality (Table 2).

2.2.2 Land-parcel-level analysis of influential indicators

Based on the 3 regression models for weekday, weekend, and average daily composite vitality at the land-parcel level, indicators that failed the significance test ($p \geq 0.05$) were excluded. Across the three models, the retained variables included distance to the nearest metro station entrance or exit, land-parcel area, functional density, functional mix, and business-format diversity. The adjusted (R^2) values of the three models were 0.749, 0.751, and 0.753, respectively, indicating good model fit. The overall (F)-tests were statistically significant for all three models ($p < 0.05$), demonstrating that all three regression models were statistically significant. In addition, all selected independent variables had statistically significant regression coefficients ($p < 0.05$), indicating that each of the indicators included in the models was statistically significant.

In terms of the relative contributions of the influential indicators to composite vitality, the 3 influential indicators of weekday composite vitality, in descending order of contribution, were functional density, distance to the nearest metro station entrance or exit, and functional mix. The 5 influential indicators of weekend composite vitality were functional density, distance to the nearest metro station entrance or exit, functional mix, land-parcel area, and business-format diversity. The 3 influential indicators of average daily composite vitality were functional density, distance to the nearest metro station entrance or exit, and functional mix. Functional density, distance to the nearest metro station entrance or exit, and functional mix were included in all 3 regression models, and functional density exerted the strongest influence in each. These results indicate that land-parcel functional density is the most important factor associated with composite vitality in the Hubin Commercial District, with a substantially greater contribution than the other factors (Table 2).

Regarding the direction of the relationships between the land-parcel-level indicators and composite vitality in the Hubin Commercial District, functional density was positively associated with weekday composite vitality, whereas distance to the nearest metro station entrance or exit and functional mix were negatively associated with it. In the weekend model, functional density and land-parcel

area showed positive associations, whereas distance to the nearest metro station entrance or exit, functional mix, and business-format diversity showed negative associations. In the average daily model, functional density was positively associated with composite vitality, whereas distance to the nearest metro station entrance or exit and functional mix were negatively associated with it. Across all 3 models, functional density was consistently positively associated with composite vitality, while distance to the nearest metro station entrance or exit and functional mix were consistently negatively associated with it. Thus, land parcels with higher functional density tend to exhibit greater vitality, whereas parcels located farther from metro station entrances or exits and those with an excessively mixed functional composition tend to exhibit lower vitality (Table 2).

3 Conclusion and Discussion

3.1 Main findings

Based on the overall results, the main findings are as follows:

(1) Composite vitality in the Hubin Commercial District exhibits a “one-core, one-axis” spatial pattern. The core is centered on the area surrounding the Gonglian CC, while Yan’ an Road forms the primary north-south axis, from which vitality radiates into the surrounding areas. A weaker north-south axis of activity is also formed along Middle Zhongshan Road. On weekends, social vitality increases substantially along the east-west axis formed by Xueshi Road and Pinghai Road. The core and the primary north-south axis intersect near metro station entrances and exits, and the east-west axis that experiences a marked increase in weekend social vitality also passes through areas served by metro entrances and exits. The regression results show that distance to the nearest metro station entrance or exit generally ranks as the second most influential indicator, except in the weekday urban-block-level model, in which it is not statistically significant. These findings suggest that vitality in the Hubin Commercial District depends strongly on the pedestrian flows generated by the metro system and that metro accessibility plays a crucial role in shaping its spatial distribution.

(2) With the primary north-south vitality axis as the dividing line, the western part of the commercial district

exhibits a marked difference in the concentration of social vitality between weekdays and weekends, whereas the eastern part shows broadly similar levels on weekdays and weekends. The western part, owing to its proximity to major commercial complexes and the West Lake Scenic Area, exhibits a clear holiday effect generated by concentrations of consumers and tourists. By contrast, the eastern part contains a more heterogeneous mix of parcel uses and POI functions and therefore exhibits relatively stable everyday vitality supported by diverse forms of social life. Moreover, the concentration of human activity around the Grade-A tertiary hospitals in the eastern part is comparable to that in the core commercial area. The healthcare functions and related commercial facilities clustered around these hospitals are also important contributors to the high vitality of the surrounding areas.

(3) Among the indicators associated with composite vitality, functional density is the most important and shows a strong positive association with composite vitality. Distance to the nearest metro station entrance or exit, functional mix, and morphological compactness are secondary indicators and show negative associations with composite vitality. These findings suggest that greater functional concentration increases the range of activity destinations available to people within a given activity area. Metro services perform the most important transport function in supporting commercial activity in the Hubin Commercial District. A highly diverse functional mix may, to some extent, weaken the commercial identity of the district and disperse the focus of consumer activity, thereby reducing the concentration of economic vitality. Although compact and intensive urban-block forms improve spatial efficiency, the resulting lower per-capita availability of space may compromise spatial quality and consequently reduce vitality to some extent.

3.2 Discussion and future research

The findings indicate that the development of a landmark identity around the entrances and exits of Longxian-qiao Metro Station, together with the quality-oriented upgrading of Yan'an Road—the primary north-south axis—and the Hubin Road Pedestrian Street adjoining West Lake following the G20 Summit, has helped maintain and en-

hance urban vitality within the “one-core, one-axis” area of the Hubin Commercial District. Measures such as integrating street spaces with new retail, developing smart streets, and creating shared street spaces have also contributed to this improvement. At the same time, however, the strong concentration of pedestrian activity around the Gonglian CC and along Yan'an Road has resulted in excessive pressure from concentrated commercial activity and traffic flows in this “one-core, one-axis” area, adversely affecting shopping and travel experiences. To enhance district-wide vitality, greater attention should therefore be given to strengthening commercial vitality east of Yan'an Road. Building on the secondary north-south axis along Middle Zhongshan Road and the weekend east-west axes along Xueshi Road and Pinghai Road, this area could develop a more distinctive commercial identity, enhance its international appeal and attractiveness to younger consumers, improve spatial quality, further increase the density of commercial facilities, moderately reduce business-format diversity along the commercial axes, and reinforce the overall commercial atmosphere. These measures could promote coordinated development between the two north-south axes of Yan'an Road and Middle Zhongshan Road and ultimately form a grid-like four-axis network incorporating Xueshi Road and Pinghai Road. Such a spatial structure could redistribute vitality away from areas of excessive concentration, relieve pressure from highly concentrated commercial and traffic flows, and extend commercial-district vitality from the principal axes into a broader surrounding area.

By integrating the two dimensions of social and economic vitality, this study highlights the distinctive characteristics of commercial districts and allows their vitality to be measured more precisely. It also integrates multi-source data through new technologies to conduct a fine-grained, multidimensional quantitative analysis. In doing so, the study clarifies the spatial vitality patterns of the commercial district, identifies locally relevant influential indicators, and reveals the underlying relationship between built-environment characteristics and commercial-district vitality. The findings provide a context-sensitive reference for locally distinctive design interventions and urban management.

This study nevertheless has several limitations that warrant further investigation. First, the analysis of human activity concentration does not account for the types or purposes of activities. Future research could integrate additional techniques to distinguish people who linger in a space from those who are merely passing through. Second, the present study relies on objective data on human activity, while the subjective perceptions and evaluations of space users remain to be incorporated. Finally, because the study is limited to the Hubin Commercial District, the identified indicators and underlying mechanisms of influence have explanatory relevance only within the study area. Further investigation and validation are required before the findings can be applied to commercial districts across a broader area of Hangzhou.

Sources of Figures and Tables

Fig. 1: Prepared by the author based on information from Baidu Maps.

All other figures and tables were produced by the authors.

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