Journal of Ambient Intelligence and Humanized Computing (2021) 12:911–921
https://doi.org/10.1007/s12652-020-02104-w

ORIGINAL RESEARCH

Smart city oriented optimization of residential blocks on intensive urban sensing data based on fuzzy evaluation algorithm

Jizhou Zhu[1] · Wenqian Liu[1] · Yuan Liu[1] · Di Wang[1] · Shan Qu[2] · Yaqiong Duan[1] · Jie Yao[3]

Received: 9 April 2020 / Accepted: 8 May 2020 / Published online: 19 May 2020

Abstract

The unreasonable planning of land use in residential blocks affects the quality of the city and the comfort and convenience of urban residents. How to improve the vitality of the street from the source is an urgent problem to be solved in urban and rural planning disciplines. This paper selects 18 residential districts in Xi'an, and uses a multivariate linear stepwise regression to establish a relationship model between street vitality and intensive land use indices in three different periods of non-commuting, weekly commuting, and weekend. Using fuzzy evaluation techniques, the degree of land use intensification in different residential blocks was analyzed. Using the relational model and evaluation conclusions, the appropriate range of street vitality in residential blocks was determined, and the constructed model was used to obtain the suitable index range for intensive land use under street vitality. The results show that the street vitality and building density, the proportion of commercial space along the street and the red line width of the street are most affected during the non-commuting period during the week. The street vitality during the commute period is most closely related to the building density, building mix and street network density. Street dynamics are most closely related to building density, building mix, and street red line width during weekends. The conclusions of the study provide theoretical support and data support for the optimization and transformation of land use in residential blocks, and ultimately aim to stimulate street vitality and promote the realization of intensive land use in residential blocks.

Keywords Smart city · Residential block · Intensive land use · Street vitality · Fuzzy evaluation algorithm

1 Introduction

As a public place where people live and interact, the block land is the main carrier of people's travel and activities, which integrates and restricts the development of the city. With the rapid development of urbanization, the "spreading" and "extensive" land development models have severely damaged the reasonable scale of street space and block texture, inhibited people's diverse living needs, and eventually led to the disappearance of street vitality. Studies have shown that the vitality of the street is closely related to the function, layout and scale of the blocks own land use (Hou et al. 2019). Resident travel activities increase the vitality of the street, and the increase in the vitality of the street can better meet the diverse and personalized needs of the residents and enhance the characteristics and cohesion of the neighborhood. As the main residential function, residential block is one of the urban areas with the highest frequency and longest time for residents to take walking activities. Street vitality has an interactive relationship with the intensive land use in this type of block. Therefore, from the perspective of residents' travel activities and internal needs, an in-depth study of the relationship between street vitality and land use characteristics of residential blocks in built-up areas is an issue worthy of in-depth study and discussion for stimulating street vitality and promoting intensive land use resources.

Research on the relationship between street vitality and land use in urban and rural planning has yielded fruitful results. In terms of theoretical research, first of all, the research on street space theory generally includes street

✉ Yaqiong Duan
duanyaqiong@chd.edu.cn

[1] School of Architecture, Chang'an University, Xi'an 710061, China

[2] Xijing University, Xi'an 710123, China

[3] Urban Planning and Design Institute of Chang'an University, Xi'an 710061, China

diversity theory, street place theory, and street behavior theory. These theories form the basis of street space environment research (Lynch 1990; Jacobs 2005; Bentley Waits 2002; Nobshutz 2010; Gaier 1986). Secondly, in terms of the relationship between street vitality and land use, the study found that street vitality has an impact on the land use characteristics such as space and scale, accessibility, mixed land use, street environmental quality, and public infrastructure (Bowen 2016; Duan et al. 2020; Ye and Zhuang 2017; Hou et al. 2018). In terms of research methods, the research mainly quantitatively evaluates and measures street vitality, and explores key land use factors that affect vitality. Among them, Ewing and Cervero used photographic records and expert scoring methods to quantitatively study urban vitality through analysis of urban space creation, walkability and pleasantness (Ewing and Cervero 2001). Grant took Canada as an example to study the impact of mixed land use on street vitality, and gave a detailed introduction to the theoretical development of land use (Grant 2002). Gou and Wang (2011) used the technical methods of semantic differential (SD) satisfaction evaluation to evaluate the vitality of the street space. Through the questionnaire survey of pedestrians' satisfaction with the street space, they obtained functional diversity, environmental comfort and traffic accessibility. It is an important guarantee for the vitality of the street (Gou and Wang 2011). Lei constructed a set of street vitality assessment index system, considered land use as a vital component, and proposed to pay attention to the mix of street accessibility and function in urban design (Lei 2012). Hao et al. used spatial syntax, street attributes and surrounding environment and other index systems to make a preliminary exploration of the influencing factors of three different types of street vitality through multiple linear regression analysis (Hao et al. 2016).

In recent years, with the development of information technology, research methods have turned to the use of POI, fuzzy matter-element analysis model, GPS and other technical means to explore the relevance of urban space vitality and land use. Among them, Ye and Zhuang (2017) used GPS to record the activity intensity of residents as a symbol of urban vitality. Through the analysis of the three spatial morphological elements such as street accessibility, building density and morphology, and functional mix, three element pairs It promotes the vitality of cities and provides urban design strategies for creating urban vitality (Ye and Zhuang 2017). Long and Zhou explored the influencing factors of street vitality through large-scale quantitative demonstration, but it was still limited to street vitality itself, and did not deeply study the relationship between it and land use (Long and Zhou 2016). Pei et al. used Pearson correlation analysis and multiple linear regression modeling methods to quantitatively study the relationship between various influencing factors and night street vitality (Pei et al. 2018). Xia et al. used Local Indicator of Spatial Association (LISA) to study the spatial relationship between land use intensity and urban vitality in five cities (Xia et al. 2020).

From the above research, it is clear that the study of spatial vitality at the block level is mostly a block of commercial blocks and historic blocks, and there is no research on the vitality of residential blocks at present. Most of the studies were evaluated for the vitality of specific subjects, and there was less quantitative analysis of both neighborhood vitality and land use. Therefore, it is of great practical significance to study the quantity dependence of street vitality and the use of land in the block, so as to rationally plan land use, it is of great practical significance to stimulate the vitality of urban streets and improve the intensive land use. This paper studies the use of quantitative analysis methods to integrate street vitality and intensive use of residential blocks from the perspective of neighborhoods, and quantitatively study the effects of street vitality and intensive land use. Therefore, supplementing the research on the intensive land use in residential blocks will help improve the street vitality of residential blocks and bring people back to humanized public places. So, this study is of great significance for reshaping the vitality of urban streets and improving the intensive land use in built-up areas. And it has a certain guiding role in the planning and construction of residential blocks.

2 Street vitality and land use characteristics of residential blocks

2.1 Research sample selection

In order to reflect the intensive land use and street vitality of different types of residential blocks, analyze how residents carry out various types of travel activities under the characteristics of this type of block, and explore the different types of residential blocks in the current socioeconomic and living conditions Due to factors such as the formation of vitality, we have identified 18 urban blocks with residential functions and complete and clear boundaries as the research object within the main urban area of Xi'an according to characteristics such as construction year, location, and spatial form of the block. Representation and universality Fig. 1.

Since the social economic strength, construction capacity, and development level of blocks in different generations are different, these factors directly affect the type of block construction, the characteristics of blocks, and the level of supporting facilities. However, the different planning and design theories and development status of the blocks in different years have affected the functional layout and spatial structure of the blocks. Therefore, this study divides 18 samples into two types according to age. The residential blocks before 2000 are old blocks, mainly concentrated in the old

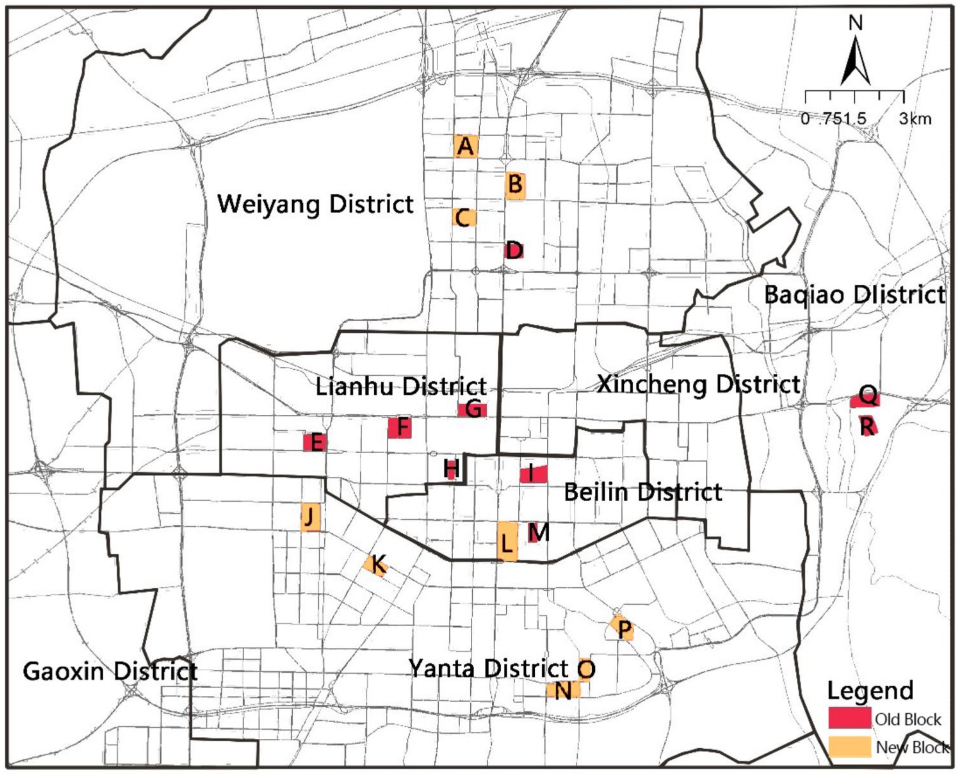

Fig. 1 Survey sample block distribution map

industrial areas of Xi'an Old Town, Textile City and Tumen, including the unit type. Residential areas, old residential areas and other types; residential blocks after 2000 (including 2000) are new blocks, mainly concentrated in various new technological development industrial areas in Xi'an, including villas and modern high-rise residential areas.

2.2 Xi'an city residential street district vitality index

The Street Vitality Index should include the number of people walking by, the number of people staying in the activity and the time of staying. Considering the influence of the three influencing factors on the street vitality, the weight of the indexes is analyzed by the Delphi method for the three influencing factors, and the weighted sum of the influencing factors is used as the vitality index of the street (SVI_s), as shown in the following formula (1):

$$SVI_s = \alpha N_p + \beta N_s + \gamma T \tag{1}$$

In the formula: SVI_s is the street vitality index for a particular road; N_p is the number of people passing by in unit time ($\mathrm{P{\cdot}h^{-1}}$); N_s is the number of people who stayed in the unit time ($\mathrm{P{\cdot}h^{-1}}$); T is the time of staying (h); α, β, γ are the weight coefficient, the importance of each influencing factor is characterized. According to the survey of relevant experts in the urban planning field, after three rounds of consultation, the opinions of relevant experts tend to be consistent. Calculated based on the survey results $\alpha = 0.26,\ \beta = 0.39,\ \gamma = 0.35$.

In order to ensure the comparability of indexes, the block street vitality index should be able to reflect the average state of all the street vitality contained in the block, so each block has multiple pedestrian streets with different areas. The block street vitality index is defined as the ratio between the sum of all the pedestrian streets in the block and the pedestrian area of the block, namely:

$$SVI_B = \left(\sum_i SVI_{s,i} \right) / A \tag{2}$$

In the formula, SVI_B is the street vitality index of a specific block; $SVI_{s,i}$ is the vitality index of the Ith street in the block; A is the area of the pedestrian street (km^2).

In order to facilitate the subsequent analysis, according to the non-commuting time during the week, the commute time during the week, and the weekend time, the street vitality index of the dynamic neighborhood is recorded as SVI_{B1}, SVI_{B2}, SVI_{B3}.

2.3 Land use characteristic indexes of residential blocks in Xi'an

Specific factors and methods for measuring land use are diverse, including population density, occupational and housing balance, land mix, accessibility, quality of walking environment, public facilities, and street environment (Ren and Lv 2011). The function, density, shape, accessibility and street design of the block are the main characterization factors of land use. In this paper, residential blocks are taken as the research object. Therefore, three categories and ten categories of indicators, such as land use intensity, land use mix, and land use form, are selected to describe the land use characteristics of the blocks:

(1) Land use intensity

Land use intensity refers to the development and utilization rate of land in the process of urban development, which mainly includes the building development capacity and building coverage density of the land. The performance forms are three indexes (Zheng 2009): floor area ratio, building height and building density. Due to the complicated construction situation of urban built-up areas, the building volume ratio and density of residential blocks are quite different. However, considering the influence of building height on vitality is not essential, the volume ratio and building density are selected as the land strength indexes among them:

The calculation formula of the floor area ratio is:

$$F = \frac{S_a}{L} \tag{3}$$

In the formula, F is block area ratio; S_a is the total floor area of the block (m^2); L is the total land area of the block (m^2).

Building density is calculated as:

$$B = \frac{S_f}{L} \tag{4}$$

In the formula, B is the building density for the block; S_f is the floor area of the block building (m^2); L is the total land area of the block (m^2).

(2) Land use mix

According to literature review and on-site investigation, the land use mix in the block includes the mix of building mix, functional form mix, and spatial form. In this paper, the calculation methods of land use mix degree indexes such as building mix degree, functional business mix degree, functional business density, commercial proportion along the street and open space proportion are as follows:

The calculation formula for building mixing degree is:

$$M = -\sum_i \left[\left(\frac{b_i}{a} \right) \ln \left(\frac{b_i}{a} \right) \right] \tag{5}$$

In the formula, M is the building mix for the block; a is the total area of all types of buildings in the area (m^2); b_i refers to the area of i_{th} building in the area (m^2).

The calculation formula of the commercial mode mixing degree is:

$$C = \sum_i \left(P_i ln P_i \right) \tag{6}$$

In the formula, C is the functional business mix degree of the block; P_i represents the proportion of Ith POI in the total number of POI in the block, $(i = 1, \cdots, n)$。

The calculation formula of the commercial mode density is:

$$D = \frac{N}{L} \tag{7}$$

In the formula, N is the total number of neighborhood POI; L is the total land area of the block (m^2).

The calculation formula for street commerce proportion is:

$$R_c = \frac{S_c}{S_a} \tag{8}$$

In the formula, R_c is the proportion of commercials along the street; S_c is the floor area for construction (m^2); S_a is the total floor area of the block (m^2).

The calculation formula for open space proportion is:

$$O = \frac{S_g}{L} \tag{9}$$

In the formula, O is the proportion of commercials along the street; S_g is the area of the public green space square (m^2); L is the land area of the block (m^2).

(3) Land use form

According to literature review and on-the-spot investigation, most scholars use the length and width of the street as the scale measure of the street. Because the block selection criteria are enclosed by the main and secondary trunk roads of the city, the street network density is selected as the scale of the horizontal latitude of the street index. When the block area is the same, the more street networks inside the block and the smaller the area that the block is divided. In addition, the scale of the street is also one of the factors affecting people's activities on the street. Therefore, the pedestrian area density and the street red line width are used as the characterization indexes that affect the street's own scale. The calculation methods are as follows:

The calculation formula for street network density is:

$$\rho = \left(\sum_i l_i\right)/L \tag{10}$$

In the formula, ρ is the street network density ($m \cdot m^{-2}$); l_i is the neighborhood i is the length of the street (m); L is the land area of the block (m^2).

The calculation formula for pedestrian area proportion is:

$$R_w = \frac{A_w}{L} \tag{11}$$

In the formula, R_w is the proportion of pedestrian area in the block; A_w is a pedestrian area (m^2); L is the land area of the block (m^2).

The calculation formula for street width is:

$$W = \frac{\sum_i w_i}{n} \tag{12}$$

In the formula, W is the street width (m); w_i is the width of the i_{th} street in the block (m); n is the total number of streets in the neighborhood.

3 Relationship model of street vitality and intensive land use of residential blocks

3.1 Determination of the index system

For the relevant land use characteristics obtained in the above survey, are they related to the neighborhood vitality index? Therefore, this paper uses Pearson correlation analysis to judge the degree of association between land use characteristics and street vitality index. According to the non-commuting time, the week commute time and the weekend time period, the correlation matrix between the street vitality index and the sample block land use characteristic index is calculated as shown in Table 1.

According to the correlation analysis of street vitality index and land use indexes mentioned above, it is concluded that street vitality of residential blocks in Xi'an has no significant correlation with volume ratio, degree of functional business mix and proportion of walkable area. Therefore, these three indexes can be excluded in the establishment of the model. Through pairwise correlation analysis, it can be concluded that building mix degree is significantly correlated with functional commercial density (sig value is 0.008), and functional commercial density is also significantly correlated with open space proportion (sig value is 0.005). It can be judged that there is a correlation among the three indexes of building mix degree, functional density and proportion of open space, and the approximate index should be excluded. Therefore, building density, building mix degree, commercial proportion along the street, road network density and street red line width were finally determined to participate in the regression analysis as explanatory variables, denoted as $X_i = (i = 1, 2, \cdots, 5)$.

3.2 Relationship model

Through comprehensive analysis of multiple variables, the study is most relevant to the land use indexes of non-commuting time during the week under the influence of various factors, and comprehensive analysis is carried out

Table 1 Related matrices of street vitality index and land use intensity elements

	Non-commuting vitality index		Commuting vitality index		Weekend vitality index	
	Pearson correlation	Significant (two-tailed)	Pearson correlation	Significant (two-tailed)	Pearson correlation	Significant (two-tailed)
Strength						
Volume rate	0.081	0.75	0.03	0.906	0.04	0.874
Building density	0.806**	0	0.818**	0	0.831**	0
Mixing degree						
Building mix	0.436	0.07	0.519*	0.023	0.46	0.055
Functional business mix	0.401	0.099	0.443	0.066	0.438	0.069
Functional density	0.649**	0.004	0.763**	0	0701**	0.001
Business share along the street	0.748**	0	0.748**	0	0.729**	0.001
Open space ratio	−0.622**	0.006	−0.627**	0.005	−0.611**	0.007
Form						
Street network density	0.743**	0	0.818**	0	0.745**	0
Street red line width	−0.751**	0	−0.712**	0.001	−0.754**	0
Percentage of pedestrians' area	0.234	0.35	0.427	0.077	0.322	0.192

**The correlation is significant when the confidence (double test) is 0.01

through multiple variables. Therefore, multiple linear stepwise regression is adopted to select independent variables that have significant influence on dependent variables and construct the regression equation:

(1) Non-commuting hours during the week

The three variables selected for the model are building density (X_1), commercial proportion along the street (X_3), street red line width (X_5), the significant value of the index to the model coefficient test meets the requirements (sig < 0.05), as shown in Table 2.

According to Table 2, the regression equation of weekly non-commuting street activity index Y_1 and land use index (building density X_1, commercial proportion along the street X_3, width of street red line X_5) was obtained as follows:

$$Y_1 = 0.417 + 1.868X_1 + 5.218X_3 - 0.015X_5 \quad (13)$$

From formula (13), it can be seen that street vitality has the closest relationship with building density, commercial proportion along the street, and the width of the red line of the street during non-commuting periods during the week. It can be seen from Table 2 that the degree of influence from high to low is building density, commercial proportion along the street, and street red line width. But the impact of the three on street vitality is similar, and it is positively correlated with building density and business along the street, and negatively correlated with the width of the street red line.

Building density is an indicator of the land use intensity constructed in this paper, and also a characteristic index of different types of blocks. The higher the building density of old blocks, the higher the street vitality and vice versa. And for the non-commuter activities during the week, most of the people are attracted by the business along the street. The survey also found that the majority of the elderly who are active during the week are precisely the business activities along the street that attract people. In addition, people also prefer street activities where the width of the street red line is narrow, and the width of the street red line affects the comfort of people's activities.

(2) Commute hours during the week

The three variables selected for the model are building density (X_1), mixing of building floor area (X_2), street network density (X_4), and the significant values of the indexes for the model coefficient test are consistent. Requirements (sig < 0.05), as shown in Table 3.

According to the results of regression coefficient given in Table 3, the weekly commuting street activity index Y_2 and land use index (building density X_1, building mix X_2, street network density X_4) were obtained as follows:

$$Y_2 = -0.799 + 1.550X_1 + 0.540X_2 + 90.762X_4 \quad (14)$$

From formula (14), it can be seen that street vitality has the closest relationship with building density, building area mixing degree, and street network density during commuting during the week. It can be seen from Table 3 that the degree of influence from high to low is the street network density, building density, and building mix degree. The degree of influence of the street network density is much greater than the other two indicators, and it is positively correlated with the street network density, building mix, and building density. When the street network density, building mix, building density is higher, the non-commuter period during the week the more vibrant the street.

During commuting, the vitality of the street is mainly pedestrians. When the density of the road network increases, the number of paths that the street can traverse

Table 2 Coefficient list

Model		Non-standardized coefficient		Standard coefficient	T	Significant	Collinear statistics	
		B	Standard error	Beta			Allow	VIF
1	(Constant)	−0.334	0.196		−1.709	0.107		
	Building density x_1	3.570	0.656	0.806	5.443	0.000	1.000	1.000
2	(Constant)	−0.251	0.164		−1.535	0.146		
	Building density x_1	2.494	0.653	0.563	3.818	0.002	0.684	1.462
	Commercial proportion along the street x_3	6.526	2.228	0.432	2.929	0.010	0.684	1.462
3	(Constant)	0.417	0.334		1.247	0.233		
	Building density x_1	1.868	0.646	0.422	2.891	0.012	0.554	1.806
	Business share along the street x_3	5.218	2.069	0.345	2.522	0.024	0.628	1.591
	Street red line width x_5	−0.015	0.007	−0.315	−2.221	0.043	0.585	1.709

Dependent variable: non-commuting street vitality index Y_1

Table 3 Coefficient list

Model		Non-standardized coefficient		Standard coefficient	T	Significant	Collinear statistics	
		B	Standard error	Beta			Allow	VIF
1	(Constant)	−0.605	0.239		−2.529	0.022		
	Street network density X_4	148.357	26.032	0.819	5.699	0.000	1.000	1.000
2	(Constant)	−0.815	0.212		−3.850	0.002		
	Street network density X_4	132.719	22.290	0.732	5.954	0.000	0.940	1.064
	Building Mix X_2	0.710	0.248	0.352	2.866	0.012	0.940	1.064
3	(Constant)	−0.799	0.189		−4.217	0.001		
	Street network density X_4	90.762	27.722	0.501	3.274	0.006	0.486	2.056
	Building mix X_2	0.540	0.235	0.268	2.300	0.037	0.837	1.195
	Building density X_1	1.550	0.712	0.352	2.179	0.047	0.435	2.301

Dependent variable: commute vitality index Y_2

increases, so the number of people walking on the street increases, and the vitality also increases. The building mix degree represents the mix degree of residential and commercial office buildings in the block. The higher the building mix degree, the more it will promote the walking behavior of the people in the block, so the performance of the street vitality during commuting time is more obvious.

(3) Weekends

The three variables selected for the model are building density (X_1), street red line width (X_5), mixing of building floor area (X_2), and the significant values of the indexes for the model coefficient test are consistent. Requirements (sig < 0.05), as shown in Table 4.

According to the results of the regression coefficients given in Table 4, the commuter street vitality index Y_3 and land use index within the week (building density X_1, building area mix X_2, street red line width X_5). The regression equation is:

$$Y_3 = 0.672 + 2.123X_1 + 0.642X_2 - 0.026X_5 \tag{15}$$

It can be seen from formula (15) that street vitality is most closely related to building density, street red line width, and street network density during the weekend. It can be seen from Table 4 that the degree of influence from high to low is the street red line width, building density, and building mixing degree. The three indicators have similar influence degrees and are positively related to the building mixing degree and building density. When the street network density, building mix and building density are higher, the street vitality is higher during the non-commuter period during the week. It is negatively correlated with the width of the street red line. The wider the street red line, the lower the vitality value.

On weekends, the higher the degree of building mix, the more balanced the three types of buildings in the block. People's living needs can be met in the block. When they can't be met, long-distance travel activities will occur, and the lower the vitality of the block. As with non-

Table 4 Coefficient list

Model		Non-standardized coefficient		Standard coefficient	T	Significant	Collinear statistics	
		B	Standard error	Beta			Allow	VIF
1	(Constant)	−0.387	0.211		−1.831	0.086		
	Building density x_1	4.177	0.708	0.828	5.899	0.000	1.000	1.000
2	(Constant)	0.594	0.413		1.439	0.171		
	Building density x_1	2.972	0.757	0.589	3.924	0.001	0.637	1.571
	Street red line width x_5	−0.021	0.008	−0.396	−.641	0.019	0.637	1.571
3	(Constant)	0.672	0.365		1.840	0.087		
	Building density x_1	2.123	0.763	0.421	2.785	0.015	0.488	2.049
	Street red line width x_5	−0.026	0.007	−0.491	−3.545	0.003	0.581	1.723
	Building mix x_2	0.642	0.279	0.278	2.303	0.037	0.766	1.305

Dependent variable: weekend street vitality index Y_3

commuting hours, when people move, the width of the appropriate street red line will increase people's activity and comfort, so the wider the street red line, the lower the vitality index.

4 Evaluation of land use intensity of residential blocks

Since the intensity of land use is not an absolute concept with relative uncertainty, the evaluation of the intensity of land use can be regarded as a fuzzy problem. Therefore, the evaluation method selected is fuzzy comprehensive evaluation method, which avoids the process of subjective weighting and scoring and makes the evaluation results more objective and scientific. This paper divides the evaluation of land use intensification into three-level indexes, which belongs to the second-level fuzzy comprehensive evaluation. The calculation principle is as follows:

(1) The weight matrix is constituted according to the second-level index weights of the three subsystems. A_i and a_{ij} are the weight values of the j_{th} factor in factor A_i. According to the five-level membership function, the membership matrix can be constructed to r_i.
(2) The product of the weight matrix and the membership matrix: $C_i = A_i \times R_i$. C_i is the evaluation matrix for each index in the subsystem, $C_i = \left(c_{i1}, c_{i2}, \cdots, c_{ik}\right)$.
(3) The evaluation results of each subsystem constitute a total evaluation matrix $R = \left(C_1, C_2, \cdots, C_n\right)$ to determine the final weight matrix of each subsystem to the whole system: $A = \left(A_1, A_2, \cdots, A_n\right)$, among them A_i is the weight value of the i_{th} subsystem for the whole system. Multiply the evaluation matrix by the weight matrix: $D = A * R$, among them D is a matrix of evaluation results of the degree of intensive land use in the block, $D = \left(d_1, d_2, \cdots, d_k\right)$.

4.1 Evaluation criteria

Because the indicator of land use is very similar to the indicator of intensive land use, it is more conducive to systematic analysis to use the same indicator system. Therefore, the block land use indicator system constructed in the above is regarded as the indicator system of land intensive evaluation. Because the residential street in Xi'an was divided into old blocks and new blocks in the previous article, under the social development background of the built-up area, different types of residential areas have formed an established land use pattern, and the streets under different land use patterns also have different Vitality characteristics, therefore, the two types of blocks should have different evaluation criteria.

In this paper, the evaluation standards for new and old blocks are determined by the overall trend method, that is, under the premise of reasonable norms, based on the economic development status of Xi'an city and the technical management standards of urban planning, combined with the current construction of the old and new blocks and the statistical data of each indicator Calculate the average growth rate of the indicator, and then determine the indicator value. The final evaluation criteria are shown in Tables 5 and 6.

4.2 Calculating membership

The membership function formula of the positive index constructed in this paper is shown in Eq. (16):

$$r_i\left(x_i\right)=\begin{cases} 0 & x_i \le x_{i,j-1} \\ \frac{x_{ij} - x_{i,j-1}}{x_{ij} - x_{i,j-1}} & x_{i,j-1} \le x_i \le x_{ij} \\ 1 & x_i \ge x_{ij} \end{cases} \tag{16}$$

In the formula, x_{ij} is the value of the i_{th} factor for the evaluation criteria of intensive degree 1, 2, 3, 4 and 5. x_i is the evaluation eigenvalue of the i_{th} factor, $r_i\left(x_i\right) - x_i$ is the membership degree of evaluation eigenvalue pair intensity j.

Table 5 Evaluation criteria for land use intensiveness in old blocks

Secondary finger Standard (u_i)	Three-level index (u_{ij})	Extensive (1)	More extensive (2)	Basic intensive (3)	Intensive (4)	Excessive intensive (5)
Strength	Building density (%)	[0,10]	(10,15]	(15,25]	(25,35]	(35,45]
Mixing degree	Building mix	[0,0.2]	(0.2,0.4]	(0.4,0.6]	(0.6,1.2]	(1.2,1.5]
	Business share along the street (%)	[0,2]	(2,4]	(4,6]	(6, 15]	(15,25]
Form	Street network density (km/km^2)	[0,5]	(5,7.5]	(7.5,12]	(12,25]	(25,35]
	Street red line width (m)	(55,45]	(45,35]	(35,28]	(28,15]	(15,0]

Table 6 Evaluation criteria for land use intensification in new block

Secondary finger Standard (u_i)	Three-level index (u_{ij})_	Extensive (1)	More extensive (2)	Basic intensive (3)	Intensive (4)	Excessive intensive (5)
Strength	Building density (%)	[0,10]	(10,15]	(15,20]	(20,30]	(30,40]
Mixing degree	Building mix	[0,0.2]	(0.2,0.35]	(0.35,0.5]	(0.5,1]	(1,1.5]
	Commercial space along the street (%)	[0,2]	(2,3.5]	(3.5,5]	(5, 12]	(12,20]
Form	Street network density (km/km^2)	[0,5]	(5,7]	(7,10]	(10,20]	(20,30]
	Street red line width (m)	(60,50]	(50,40]	(40,32]	(32,15]	(15,0]

4.3 Determine index weights

To determine the index weight is to determine the degree of influence of single factor in the overall evaluation. The method adopted in this paper is the coefficient of variation method, which eliminates the uncertainty of subjective experience. The importance of each factor in the overall evaluation is different:

$$A_i=\left(a_1, a_2, \cdots, a_n\right) \tag{17}$$

In the formula, A_i is the measure of the influence degree of factor u_i on the total evaluation. *A* is the fuzzy subset of factor importance degree of *u*.

The index weight calculation steps are as follows.

(1) Calculate the mean square error of each index

$$D_i = \sqrt{\frac{\sum_{j=1}^{n}\left(u_{ij} - \overline{u_i}\right)^2}{n}} \tag{18}$$

In the formula,D_i is the mean square deviation of the i_{th} index, n is the number of samples,u_{ij} is the j_{th} sample value of the i_{th} index, which can be calculated as follows.

$$\overline{u_i} = \frac{1}{n}\sum_{j=1}^{n} u_{ij} \tag{19}$$

In the formula,$\overline{u}_i$ is the mean value of the i_{th} index.

(2) Calculate the coefficient of variation of each index

$$m_i = \frac{D_i}{\overline{u_i}} \tag{20}$$

In the formula, m_i is the coefficient of variation of the i_{th} index.

(3) Calculate the weight of each index

$$a_i = \frac{m_i}{\sum_{i=1}^{n} m_i} \tag{21}$$

In the formula, a_i is the weight of the i_{th} index.

According to the current situation of 18 blocks, the weight coefficients of the index in the old and new block are as follows.

$$A_i = (0.13, 0.22, 0.37, 0.11, 0.17) \tag{22}$$

$$A_i = (0.14, 0.24, 0.43, 0.11, 0.08) \tag{23}$$

4.4 Evaluation results

According to the current distribution of the intensity of land use in each block, as shown in Fig. 2, it can be seen that blocks with basic intensive land use include E, G, H, I and B,extensive use includes R, D, F, K, C, L, A; extensive use includes Q, J, M, N, O, and P. It reflects that the land use of most of the blocks in Xi'an is in the state of extensive use to basic intensive use, and there is a waste of land use. Moreover, most of the old blocks before 2000 belong to the scope of basic intensive use, while most of the new blocks after 2000 belong to the state of extensive use.

4.5 Appropriate value estimation of intensive land use index

According to the evaluation results of the intensive land use of the blocks in Fig. 2, comparing the intensive degree of the sample blocks with the vitality of the streets, it can be seen that the correlation between the intensive degree of land use and the vitality of the streets in the three periods is very high. The higher the vitality of the street, which indicates that the vitality of the street is at an ideal value when the block is in intensive use. Therefore, on the basis of the intensive land use target, this paper defines the ideal value of the street vitality value of the current block, and then determines the appropriate index value of the land use of each block according to the ideal target vitality value, according to the three different time determined above The regression model of street vitality and land use in each segment determines the optimized estimation results of the land use indicators of the blocks under the guidance of street vitality:

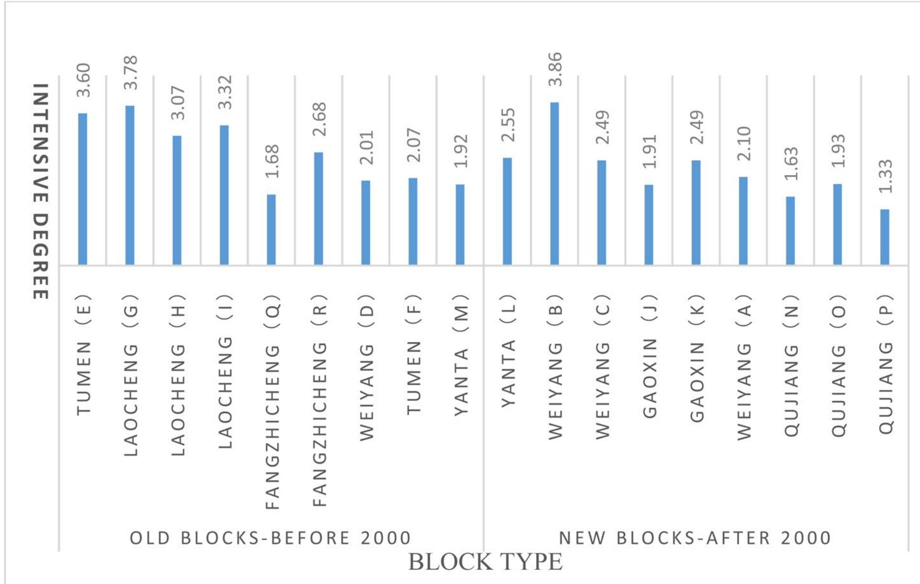

Fig. 2 Evaluation results of intensive land use in the sample block

(1) Appropriate development intensity. In the stage of detailed and controlled planning of the block, the overall urban design should be carried out on the rational layout of the land and the construction intensity, which can accurately control various indicators and is more conducive to the formation of intensive use of the block. The plot ratio of the old block is between 2.0 and 2.5, and the building density is between 25 and 35%. The plot ratio of new block is between 2.5 and 3.5, and the building density is between 20 and 30%.

(2) Mixed street function. Meet the needs of people as much as possible within the space of the residential block, enrich the functions of the block, and reduce the time and energy for people to travel between the various functional areas. The old block is a long-term residential block. The functions of the block are mixed. The functional blocks with low utilization rate should be integrated in the block. The building mix of the block should be between 0.62 and 1.2; the newer residential block and block land the nature and function are relatively simple, and the land use is extensive. Therefore, in planning and construction, efforts should be made to improve the mix of the land use properties of the blocks, and at the same time, the diversity of the building functions of the blocks should be improved. As an integrated comprehensive block, the building mix degree should be between 0.5 and 1.0.

(3) Open street interface. Since the interface along the street is the easiest to attract people's visual attention and is also a place where people use frequently, the residential street along the street should provide people with more open access spaces. The common practice is to arrange bottom merchants along the street in the residential area. The proportion of businesses along the street should be between 6.5 and 15% for old blocks, and 5.5–12% for new blocks.

(4) Appropriate block size. The development of high road network density and small-scale development should be promoted within the residential block, which increases the permeability of the block, thereby providing people with more choices and opportunities to stimulate exchanges during travel activities. The street density of the old block is 12–25 km/km^2, and the red line width of the street is between 15 and 28 m. The street network density of new block is between 10 and 20 km/km^2, and the red line width of the street is suitable between 15 and 32 m.

5 Conclusions

According to the actual survey data of residential blocks in Xi'an city, an index is defined to show the block vitality. According to three aspects of land use intensity, mixing degree and scale, ten land use characteristic indices are constructed to comprehensively describe the land use status of residential blocks. On the basis of the above data investigation and analysis, a statistical regression model between the block vitality and land use characteristics was constructed by using the multiple linear stepwise regression technique and dividing the three periods of non-commuting within a week, commuting within a week and weekends. According to the results of the model, it can be found that the building density, building mix degree, commercial proportion along the street and street network density of the block land use index all promote the block vitality in different time periods, while the width of the street red line has an inhibitory effect on the street vitality in different time periods. By using the fuzzy comprehensive evaluation method to evaluate the land intensification degree of the current block, the land intensification degree of the current sample block was obtained, the suitable range of residential block street vitality was determined, and the suitable range of land intensification use index under the guidance of street vitality was obtained by using the model constructed.

The vitality of residential blocks is influenced by a wide range of complex factors, and the indices covered in this article are only part of the problem. Further research may consider incorporating more land use characteristics indices, street facilities, street environmental quality, and so on. In addition, due to the difficulty of sample data research, the number and type of sample blocks can be further expanded in subsequent research, and more profound results can be obtained by increasing the amount of survey data.

Acknowledgements This research was funded by the Shaanxi Key Research and Development Projects, grant number 2020SF-407 and 2020SF-395.

Compliance with ethical standards

Conflict of interest The authors declare that they have no known conflict of interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Bentley Waits I (2002) Architectural environment resonance design (transl: Ji X). Dalian University of Technology Press, Dalian

Bowen T (2016) Inquiring into the influence mechanism of mixedness on spatial vitality in neighborhood renewal. In: China Urban Planning Society, Shenyang municipal ‘government. Planning 60 years: achievements and challenges—proceedings of 2016 China urban planning annual conference. China Urban Planning Association, Shenyang municipal people’s government, p 13

Duan Y, Fan X, Liu J, Hou Q (2020) Operating efficiency-based data mining on intensive land use in smart city. IEEE Access 08(01):17253–17262

Ewing R, Cervero R (2001) Travel and the built environment–synthesis. Transp Res Rec J Transp Res Board 1780(1):265–294

Gaier Y (1986) Communication and space (transl: He). China Building Industry Press, Beijing

Gou A, Wang J (2011) Research on street space vitality evaluation based on SD method. Planner 27(10):102–106

Grant J (2002) Mixed use in theory and practice: Canadian experience with implementing a planning principle. J Am Plan Assoc 68(1):71–84

Hao X, Long Y, Shi M, Wang P (2016) Influencing factors and planning design inspiration of Beijing street vitality measurement. Shanghai Urb Plan 03:37–45

Hou Q, Zhang X, Li B, Zhang X, Wang W (2018) Identification of low-carbon travel block based on GIS hotspot analysis using spatial distribution learning algorithm. Neural Comput Appl 31(09):4703–4713

Hou Q, Fan X, Liu W, Duan Y, Zhang L (2019) Environmental study on intensive land use mechanism of residential blocks in Xi’an under the direction of street vitality. Ekoloji 28(107):4415–4422

Jacobs J (2005) The death and birth of Jinhengshan in the big cities of the United States. Yilin Press, Beijing

Lei J (2012) A preliminary study on the quantitative evaluation method of urban street vitality. In: China Urban Planning Society. Diversity and inclusion—proceedings of 2012 China urban planning annual conference (05. Urban road and transportation planning). Chinese cities Planning Society, p 12

Long Y, Zhou Y (2016) Quantitative evaluation of street vigor and analysis of influencing factors——taking Chengdu as an example. New Build 01:52–57

Lynch K (1990) City imagery (transl: Xiang B). China Building Industry Press, Beijing

Nobshutz (2010) The spirit of the place (transl: Shi Z). Huazhong University of Science and Technology Press, Wuhan

Pei Y, Wu H, Tang Y, Li T, Long Y (2018) Analysis of night street vitality and influencing factors in Beijing second ring road based on spatial data. Urb Archit 09:111–116

Ren J, Lv B (2011) The impact of land use on traffic travel. Urb Plan J 05:63–72

Xia C, Yeh AGO, Zhang A (2020) Analyzing spatial relationships between urban land use intensity and urban vitality at street block level: a case study of five Chinese megacities. Landsc Urb Plan 193:103669

Ye Y, Zhuang Y (2017) The evolution hypothesis of spatial form and vitality in the new district: an integrated analysis based on street accessibility, building density and morphology, and functional mixture. Int Urb Plan 32(02):43–49

Zheng H (2009) Discussion on the control of land development intensity in controlled detailed planning—taking the controlled detailed planning of Maoqiao and Donggouling areas in nanning as an example. Planner 25(11):48–52