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Beyond greenery: exploring non-linear dynamics between socio-spatial integration and youth life satisfaction in community renewal

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Urban renewal initiatives grapple with a tripartite crisis in the community: resource allocation disparities, youth exclusion in participatory planning, and socio-spatial service degradation, all depressing life satisfaction among young residents. Despite extensive research on urban renewal and socio-spatial integration, the non-linear dynamics between these factors and life satisfaction, particularly in youth-oriented community renewal, remain underexplored, hindering effective decision-making. Furthermore, limited attention has been given to the combination of subjective perceptions and objective spatial metrics in assessing socio-spatial factors. This necessitates a move beyond simplistic analyses of singular urban amenities like greenery to a more comprehensive understanding of integrated socio-spatial dynamics. This study bridges these gaps by employing Gradient Boosting Decision Trees (GBDT) and eXtreme Gradient Boosting (XGBoost) models for non-linear exploration and Ordinary Least Squares (OLS) regression for subjective perception and objective spatial comparison, to explore how social and spatial factors influence youth life satisfaction in Suzhou, China. The results indicate that both subjective and objective factors significantly influence youth life satisfaction. GBDT prioritized Social Interaction and Commuting Environment as paramount. Subjective-objective comparative results revealed consistent positive linear impacts from both perceived and objective environmental and facilities accessibility factors. Crucially, XGBoost results indicate that Educational facilities density's contribution value sharply rises from -0.005 to -0.02 as density increases from -0.5 to -0.5 , and Medical facilities density's contribution value turns negative at higher densities. The findings not only advance socio-spatial integration theory but also contribute to the development of youth-oriented urban renewal strategies and governance mechanisms, aiming to enhance youth life satisfaction by holistically addressing the complex interplay of diverse socio-spatial elements, moving beyond a singular focus on green spaces to achieve balanced environmental quality and social equity.

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Introduction

The development of youth-oriented cities has gained significant global attention, aligning with broader efforts to achieve the United Nations Sustainable Development Goals (SDGs), particularly Goal 11 on sustainable cities and communities (Guterres, 2023; Li et al., 2021). As the world's urban population continues to rise, youth have emerged as a key demographic driving innovation and urban vitality (State Council of the PRC, 2021). Their well-being and development are crucial to ensuring that cities are not only sustainable but also inclusive and resilient (Fan et al., 2022). For example, in China, the "14th Five-Year Plan" emphasizes the importance of developing youth-oriented cities, highlighting the need for urban planning that directly addresses the diverse and evolving needs of young people (Kim et al., 2020; Liu et al., 2020; Mayer et al., 2019). Youth-oriented cities require not only physical transformations, but also the systematic integration and reconstruction of socio-spatial elements to achieve high-quality development and enhance life satisfaction (He et al., 2021). However, the rapid urbanization process led to significant changes in urban spatial structures, creating challenges in maintaining a balanced social and physical environment for young residents, particularly at the community level (Chen et al., 2022; Zeng et al., 2018). Urban community spaces often struggle with resource distribution asymmetry, youth participatory planning deficits, and facilities and ecosystem service myopia—factors that significantly lower life satisfaction among young residents (Colantonio and Dixon, 2011; Mualam et al., 2019). Consequently, integrating youth needs into urban planning has become a priority in cities and communities worldwide (Chen et al., 2024d). There is an urgent need to create environments that empower youth, promote inclusivity, and enhance life satisfaction. Despite growing interest in this area, research on how socio-spatial integration can be optimized to foster youth development in cities, especially within community renewal processes, remains limited (Jiang et al., 2020).

Decades of research confirm that socio-spatial environments sculpt life satisfaction, yet urban planners persistently misdiagnose the dose-response relationships between community socio-spatial factors and youth well-being (Alnaimat et al., 2024; Sun et al., 2024). While acknowledging the importance of both social and spatial dimensions, existing literature often examines them in isolation rather than as integrated socio-spatial phenomena. Extensive research has shown that a well-maintained social environment, encompassing factors such as neighborhood relations and communication frequency among friends, along with social perception including emotional stability and psychological well-being, contributes to better mental health (Bianchi et al., 2021; Korkmaz and Balaban, 2020) and reduces anxiety (Fan et al., 2022). Social environmental factors, such as neighborhood relations and communication frequency among friends, as well as social perception, including emotional stability and psychological well-being, have been linked to increased life satisfaction (Alnaimat et al., 2024). Similarly, spatial environmental factors, such as property services, landscape quality, and urban commuting conditions (e.g., transport facilities and accessibility services), play a significant role in shaping youth life satisfaction. A case study from Turkey has demonstrated a positive relationship between the socio-spatial characteristics of urban space and social sustainability, suggesting that education level, working conditions, and income, which may refer to socio-demographic variables, positively influence life satisfaction (Song et al., 2025). Personal attributes like age, gender, education, and income are also recognized as key determinants of life satisfaction (Sun et al., 2024). Despite this recognition of individual components, the current body of research largely lacks a comprehensive study of the truly integrated socio-spatial environment in which

residents, particularly youth, experience their daily lives (Cao, 2013).

Additionally, the "socio-spatial" integration paradox unfolds that urban renewal operates not through linear cause-and-effect chains but via multi-loop feedback systems (Alnaimat et al., 2024). However, much of the current research on urban environments and life satisfaction has predominantly focused on exploring linear relationships between physical-spatial dimensions (e.g., residential or urban environmental features) and well-being. Similarly, the linear role of social factors and individual characteristics on life satisfaction often remains either under-explored or is treated in isolation from spatial context (Arundel and Ronald, 2021). This reliance on linear correlation analyses, which frequently utilize non-spatial divergence indices, inherently limits the capture of complex, non-linear interactions and thresholds, making the intrinsic correlation between socio-spatial integration, demographic social characteristics, and life satisfaction still in dispute (Wang et al., 2023). Consequently, such linear approaches hinder accurate and timely attention to the nuanced needs of community renewal and sustainable urban development, especially concerning the satisfaction of youth groups during the dynamic urban renewal process, where non-linear responses are highly probable (Rosenthal et al., 2022). Therefore, exploring the potential non-linear effects and complex interdependencies within the socio-spatial integration environment is crucial for a more precise understanding of youth well-being, necessitating the application of advanced methodologies like machine learning algorithms, such as Gradient Boosting Decision Trees (GBDT) and eXtreme Gradient Boosting (XGBoost), which are specifically designed to uncover these intricate non-linear relationships (Alnaimat et al., 2024).

This study investigates the non-linear dynamics between socio-spatial integration and youth life satisfaction, with a focus on community renewal in youth-oriented cities. Employing GBDT, a method well-suited for identifying complex interactions in urban renewal, offers valuable insights into how various socio-spatial elements interact to influence youth life satisfaction (Lin et al., 2021). Then, ordinary least squares (OLS) regression is employed to make a comparison between subjective and objective influential factors on youth life satisfaction. Additionally, an additional layer of predictive refinement offered by XGBoost is crucial for uncovering the non-linear dynamics between socio-spatial factors and youth life satisfaction, providing deeper insights that might be overlooked (Zhou et al., 2024). The research questions are as follows:

1. How to investigate the relationship between socio-spatial environment and youth life satisfaction, using multi-dimensional metrics and analytic techniques?
2. How do socio-spatial factors (community environment, commuting environment, social interaction, expressed sentiment) interact non-linearly to influence youth life satisfaction for sustainable community renewal?
3. How to create a youth-oriented urban renewal and governance mechanism to enhance youth life satisfaction from a socio-spatial integration perspective?

Our study contributes to the theoretical development of socio-spatial integration, providing actionable insights for urban renewal strategies that aim to enhance youth satisfaction and well-being in youth-oriented cities. Practically, the findings offer data-driven support and policy recommendations to address challenges related to attracting and retaining youth in urban environments, advancing youth-oriented cities sustainably and inclusively. This study employs a cross-sectional dataset for an exploratory analysis of associations and non-linear characteristics. It aims to reveal the associative structures and threshold features

between subjective perceptions and objective metrics. The findings do not constitute the identification or inference of causal effects.

Literature review

Socio-spatial integration and community renewal. Socio-spatial integration is an evolving concept in urban studies and is usually defined as the spatial proximity of different social groups and their integration in terms of functions, relationships, and social symbols. It emphasizes interaction, communication, and the sharing and use of common space among social groups and aims to eliminate social segregation and spatial differentiation and promote social harmony within urban environments (Cao et al., 2020; Sepe, 2021). Theoretically, socio-spatial integration bridges traditional spatial theories, such as Lefebvre's conceptualization of space as a social product, and modern urban sociology's focus on how space mediates social inequalities (Harvey, 2010; Sassen, 1996). This framework posits that the built environment—including housing quality, public spaces, and infrastructure—intersects with social practices such as community attachment, social interaction, and feelings of belonging, collectively influencing individual and collective outcomes (Arundel and Ronald, 2021). The integration of socio-spatial dimensions has gained prominence in community renewal, particularly in cities experiencing rapid urbanization and demographic shifts (Delmelle, 2016). While urban renewal initiatives often entail the redevelopment of physical infrastructure and public spaces, a lack of attention to socio-spatial integration can exacerbate social inequalities, undermining the very goals of inclusivity and sustainability (Heyes and Zhu, 2019). This is particularly evident in the phenomenon of gentrification, where urban redevelopment driven by economic imperatives may lead to spatial fragmentation and the erosion of social cohesion, disproportionately affecting marginalized communities (Freihardt, 2020). Conversely, integrating socio-spatial principles into planning and renewal decision-making can mitigate these risks, fostering inclusive, resilient, and vibrant neighborhoods (Guo et al., 2023).

Socio-spatial integration in youth-oriented cities. Youth-oriented cities present a unique context for examining socio-spatial integration, as they are characterized by dynamic social structures and evolving spatial needs (Rosenthal et al., 2022). However, these cities also face challenges related to housing affordability, social disconnection, and uneven access to community resources (Jia et al., 2018). Therefore, socio-spatial integration becomes critical for ensuring that urban renewal strategies align with the needs and aspirations of young residents (Heyes and Zhu, 2019). And in youth-oriented cities is particularly relevant in addressing life satisfaction, as research suggests that community attributes—such as housing quality, public facilities, and social interaction—directly influence well-being (Tian et al., 2024). Yet, the relationship between these factors is often non-linear, with diminishing returns evident as basic needs are met. For instance, while high-quality housing and accessible public amenities enhance satisfaction, their impact plateaus beyond a threshold, highlighting the importance of balanced and context-sensitive renewal strategies (Hao et al., 2023).

This study focuses on the intersection of socio-spatial factors and life satisfaction in youth-oriented cities, particularly the influence of social interaction, community, and commuting environments during the urban renewal process. As urban renewal advances, the needs and spatial characteristics of young people show dynamic changes, making it particularly important to understand the non-linear relationships among these factors. The research indicates that while high-quality housing and public

facilities significantly improve life satisfaction, their effects show a saturation point after basic needs are met. This is crucial for a balanced urban renewal strategy, which should consider the diverse needs and emotional resonance of the youth population.

The impact of socio-spatial integration on youth life satisfaction. Life satisfaction of urban youth is often examined factors such as mental health, residential community dynamics, and spatial aspects of urban living (Yu et al., 2024). For example, research has highlighted the importance of mental health and life satisfaction among unmarried urban youth, as well as the role of community culture in concentrated youth housing arrangements (Liang, 2021). Moreover, the non-linear relationship between community characteristics and life satisfaction emphasizing that community features—when prioritized based on their relative significance—significantly influence life satisfaction and urban renewal outcomes (Li, 2024).

In resource-limited settings, identifying and improving the most impactful community characteristics for youth satisfaction is crucial, and how urban renewal strategies can enhance youth satisfaction in rapidly evolving cities (Fan et al., 2022). Meanwhile, life satisfaction follows an inverted U-shaped curve with age, yet the specific needs and perspectives of the youth demographic remain insufficiently addressed in the literature (Shen et al., 2021). Research from Shanghai supports a positive correlation between income and life satisfaction, but it fails to consider the broader influence of the community environment (Sdino et al., 2020), and the relationship between youth life satisfaction and community-related factors remains underdeveloped (Middel et al., 2019). These factors include personal attributes, social support, social interaction, open spaces, and accessibility (Nakano and Washizu, 2018). At the community level, personal attributes such as age, gender, education, and income are key determinants of life satisfaction (Sun et al., 2024). For example, higher-income youth may have greater access to resources, leading to higher community satisfaction (Cao, 2020), while more educated individuals tend to have higher expectations regarding community infrastructure (Tabales et al., 2013). Given these findings, we hypothesize that:

H1. *Personal attributes significantly influence youth life satisfaction, with household income being the most critical determinant.*

The socio-spatial integration theory suggests that factors such as spatial layout, resource distribution, social interaction, and identity recognition collectively shape youth life satisfaction (Nakano and Washizu, 2018). Among these, the community environment—including housing quality, public facilities, and services—is crucial for improving satisfaction (Tian et al., 2024). Studies have shown that high-quality housing and comprehensive community services, such as commercial and educational resources, significantly enhance youth satisfaction (Li et al., 2022). Under the context of community renewal, this mechanism exhibits more complex and dynamic characteristics (Hui et al., 2021). Community renewal involves not only the improvement of the physical environment but also the redistribution of resources and the reorganization of spatial order, which has a dual impact on youth residential experience and satisfaction (Chahardowli and Sajadzadeh, 2022; Gu and Zhang, 2021). When renewal efforts lead to an overall enhancement of housing quality, public spaces, and service facilities, youth life satisfaction increases significantly (Kim et al., 2020). However, when the renewal process results in rising housing costs or weakened neighborhood relationships, its marginal effect may diminish or even turn negative, forming a typical threshold effect (Navarrete-Hernandez et al., 2023). Additionally, within this context, the commuting

environment also plays a crucial role in shaping youth satisfaction. Renewal often improves travel efficiency by optimizing road networks and enhancing non-motorized and public transportation systems, thereby significantly influencing the daily routines and social engagement opportunities of young people (Zhang et al., 2021). However, the impact of commuting time on life satisfaction is non-linear. Poor commuting conditions can lead to a significant decline in satisfaction, but once commuting conditions improve beyond a certain point, the effect on satisfaction diminishes (Leontiev and Osin, 2014). Thus, we hypothesize that:

H2. *Community environment is a key determinant of youth life satisfaction, with housing quality (H2a) and public facilities (H2b) being the most significant factors.*

H3. *The commuting environment is a major factor influencing youth life satisfaction, with commuting time (motorized/non-motorized) being the most significant determinant.*

Meanwhile, as a central element of the theory of socio-spatial integration, social interaction profoundly impacts the ways young people engage socially and their satisfaction levels. This is because community renewal reshapes existing social networks and interaction spaces (Chen et al., 2024c). On one hand, renewal promotes the revitalization of public spaces and community activities, offering young people more opportunities for social engagement (Cao, 2020). Positive social engagement, such as neighborhood relationships, social networks, and interaction frequency, fosters a sense of belonging and increases satisfaction (Wang and Zhao, 2021). On the other hand, spatial restructuring and population turnover may weaken the stability of neighborhood interactions, leading to new social adaptation processes (Guo et al., 2022). Research has also shown that beyond a certain threshold, the marginal benefits of social interaction may decrease, indicating a non-linear effect (Boyce and Wood, 2011). This dual mechanism makes the relationship between social interaction and satisfaction more non-linear within the context of renewal.

Furthermore, through social perception, people can make preliminary identification and understanding of other people's emotions, behaviors, intentions, etc., thus providing a basis for further social cognition and judgment (Ma et al., 2018). Social perceptions, including safety, social support, and belongingness, are key factors influencing satisfaction. Low social safety, for instance, significantly reduces youth satisfaction, but when safety reaches a certain level, its influence on satisfaction levels off (Chen et al., 2024b). Similarly, the effects of community belongingness and social support tend to diminish after a certain threshold is reached (Ma et al., 2018). Therefore, we propose the following hypotheses:

H4. *Social interaction significantly impacts youth life satisfaction, with physical health being the most significant factor within this category.*

H5. *Social perceptions, such as safety and social support, positively correlate with youth life satisfaction.*

Overall, we identify the critical factors influencing youth life satisfaction within urban communities, particularly in urban renewal and socio-spatial integration (Fig. 1). By integrating these factors into a coherent framework, we aim to explore the non-linear relationships between various socio-spatial components and youth satisfaction, using advanced methods such as GBDT and XGBoost. This approach offers an innovative pathway for developing effective urban renewal strategies that prioritize the diverse needs of the youth demographic. Additionally, this study uses OLS regression and GBDT/XGBoost simultaneously to verify the robustness of non-linear relationships and to supplement the explanation of linear trends for certain variables. For example, the impact of physical health and work status on life satisfaction is

well-validated linearly in the OLS regression, which effectively strengthens our confidence in the results of the non-linear analysis. Therefore, OLS regression is not used to identify causal relationships but rather as a comparative tool to provide additional explanatory perspectives within the non-linear analysis framework. Simultaneously, GBDT/XGBoost is used in this paper to characterize the non-linear associations and marginal contributions (SHAP) between variables and youth life satisfaction. It is also used to identify potential thresholds and inflection points to provide evidence for setting "appropriate" policy ranges. The results should not be interpreted as causal relationships.

Study area

In recent years, Suzhou, China, has consistently advanced its urban planning and construction, with a particular focus on fostering a youth-friendly city environment to attract and retain young talent (Fig. 2). This study concentrates on the city's primary districts, including Gusu District, the Industrial Park, and the High-tech Zone, aiming to explore the non-linear effects of socio-spatial factors on youth life satisfaction within the context of urban renewal. Notably, the young people's questionnaire samples of this research are collected in the red highlighted communities.

Research methods

GBDT methods. To assess the influence of various socio-spatial factors on youth life satisfaction, this study employs GBDT to investigate the impact of individual factors at different hierarchical levels. The model is expressed as:

$$r_{mi} = \left[\frac{\partial L(y, f(x_i))}{\partial f(x_i)} \right]_{f(x)=f_{m-1}(x)}, \theta_{mj} = \arg \min_{x_i \in R_{mj}} \sum L(y_j f_{m-1}(x) + \theta) \quad (1a)$$

$$f_m(x) = f_{m-1}(x) + \sum_{j=1}^J \theta_{mj} I(x \in r_{mi}) \quad (1b)$$

$$\hat{f} = f_m(x) = \sum_{m=1}^M \sum_{j=1}^J \theta_{mj} I(x \in r_{mi}) \quad (1c)$$

Where N represents the number of subjective questionnaires, M denotes the number of regression trees, and J is the number of leaf nodes in each regression tree. The function $I(x)$ is an indicator function for determining whether x belongs to a particular set, and θ represents hyperparameters.

OLS analysis method. OLS is a fundamental statistical method used in linear regression analysis to estimate the relationship between one or more independent variables and a dependent variable. The OLS regression model can be expressed as:

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_i x_i + \varepsilon \quad (2)$$

where: y_i is the dependent variable for observation i ; x_i are the independent variables for observation i ; β_0 is the intercept; β_j are the coefficients for the independent variables; ε_i is the error term for observation i .

XGBoost analysis method. This study applies the XGBoost algorithm for data modeling and prediction, leveraging its efficiency and strong performance in regression and classification tasks. The specific formula is as follows:

$$\text{Obj}(\Theta) = \sum_{i=1}^n I(y_i, \hat{y}_i) + \sum_{k=1}^K \left[\gamma T + \frac{1}{2} \sum_{j=1}^T w_j^2 \right] \quad (3a)$$

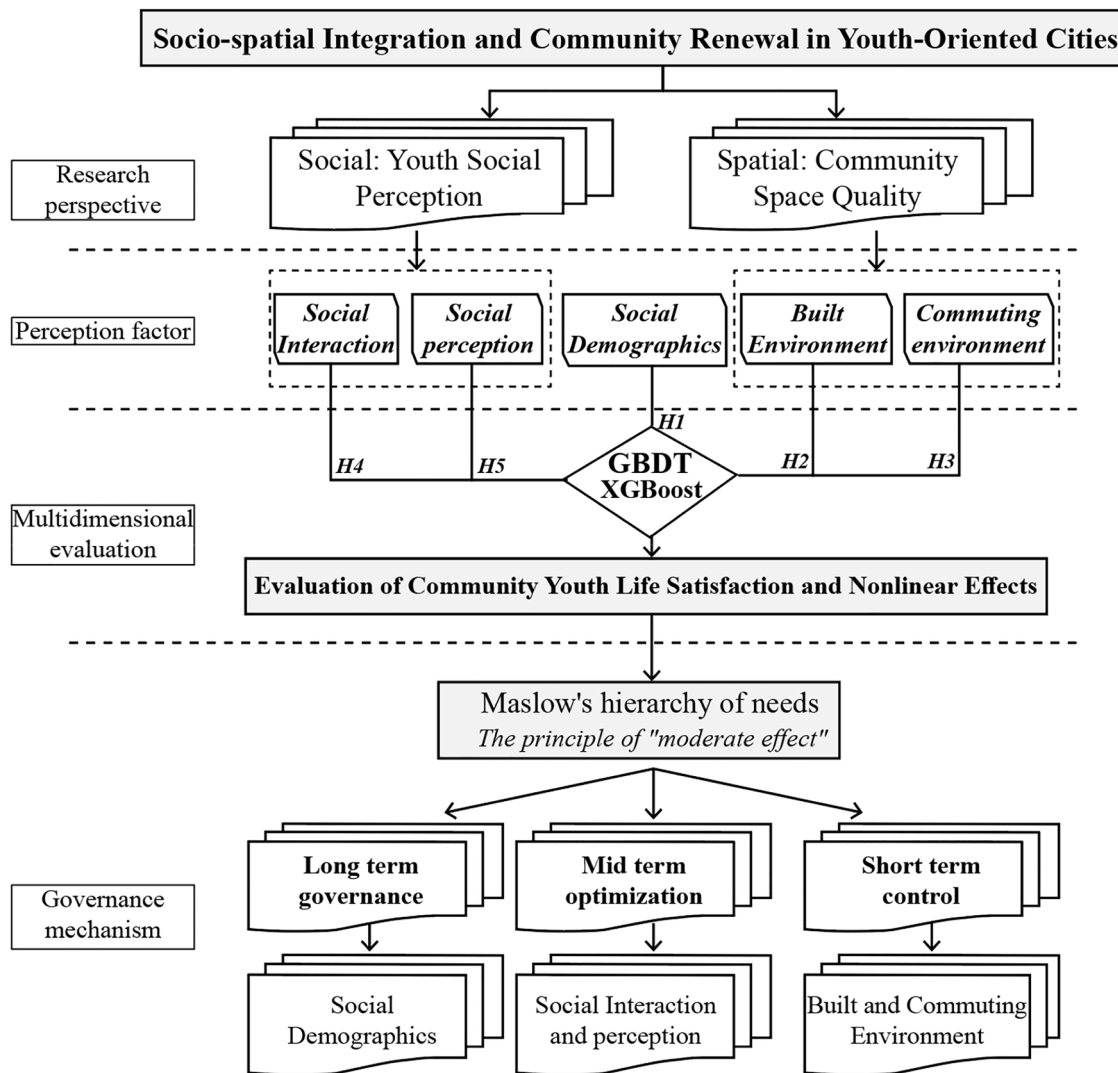


Fig. 1 Research framework.

$$\hat{y}_i^{(t)} = \hat{y}_i^{(t-1)} + f_t(x_i) \tag{3b}$$

$$Gain = \frac{1}{2} \left[\frac{G_L^2}{H_L + \partial} + \frac{G_R^2}{H_R + \partial} - \frac{(G_L^2 + G_R^2)}{H_L + H_R + \partial} \right] - \gamma \tag{3c}$$

The objective function (Eq. 3a) combines a loss function, $l(y_i, \hat{y}_i)$, to evaluate the discrepancy between actual (y_i) and predicted (\hat{y}_i) values, along with regularization terms γ and ∂ to control model complexity. Equation 3b describes how predictions are updated using the regression tree $f_t(x_i)$ constructed in each iteration. Equation 3c optimizes node splitting by maximizing the "Gain", calculated from the gradient statistics (G_L , G_R , H_L , H_R) for the left and right child nodes post-split.

Variable construction. Table 1 systematically outlines the construction and categorization of the various subjective and objective indicators employed in this study to assess their influence on youth life satisfaction. The table is structured into five overarching categories: personal attributes (A), social interaction (B), social perception (C), community environment (D), and commuting environment (E). For each category, specific variables are delineated as either subjective indicators, which capture

individual perceptions and self-reported experiences (e.g., educational background, physical health, psychological well-being, landscape quality, motorized commuting time), or objective indicators, which represent quantifiable characteristics of the urban environment or demographic features (e.g., housing price, population density, medical facilities density, educational facilities density, park facilities density, greening rate).

In this study, physical health is categorized under Social Interaction because the health status of young residents is not solely determined by individual physiological attributes but is closely connected to their social engagement, neighborhood relationships, and participation in community activities. According to socio-spatial integration theory, social interaction and spatial behaviors exert significant influences on individuals' health and overall life satisfaction (Guo et al., 2022). Particularly within the context of community renewal, the reconstruction of public spaces and social networks enables health to function as a socially embedded indicator that reflects the strength and quality of social connections and interactions.

To avoid confusion, this study distinguishes between two sets of features: Table 3 reports the relative importance based on subjective questionnaire variables constructed by GBDT, and thus does not include the objective spatial measure, medical facilities density. The corresponding subjective dimension in the

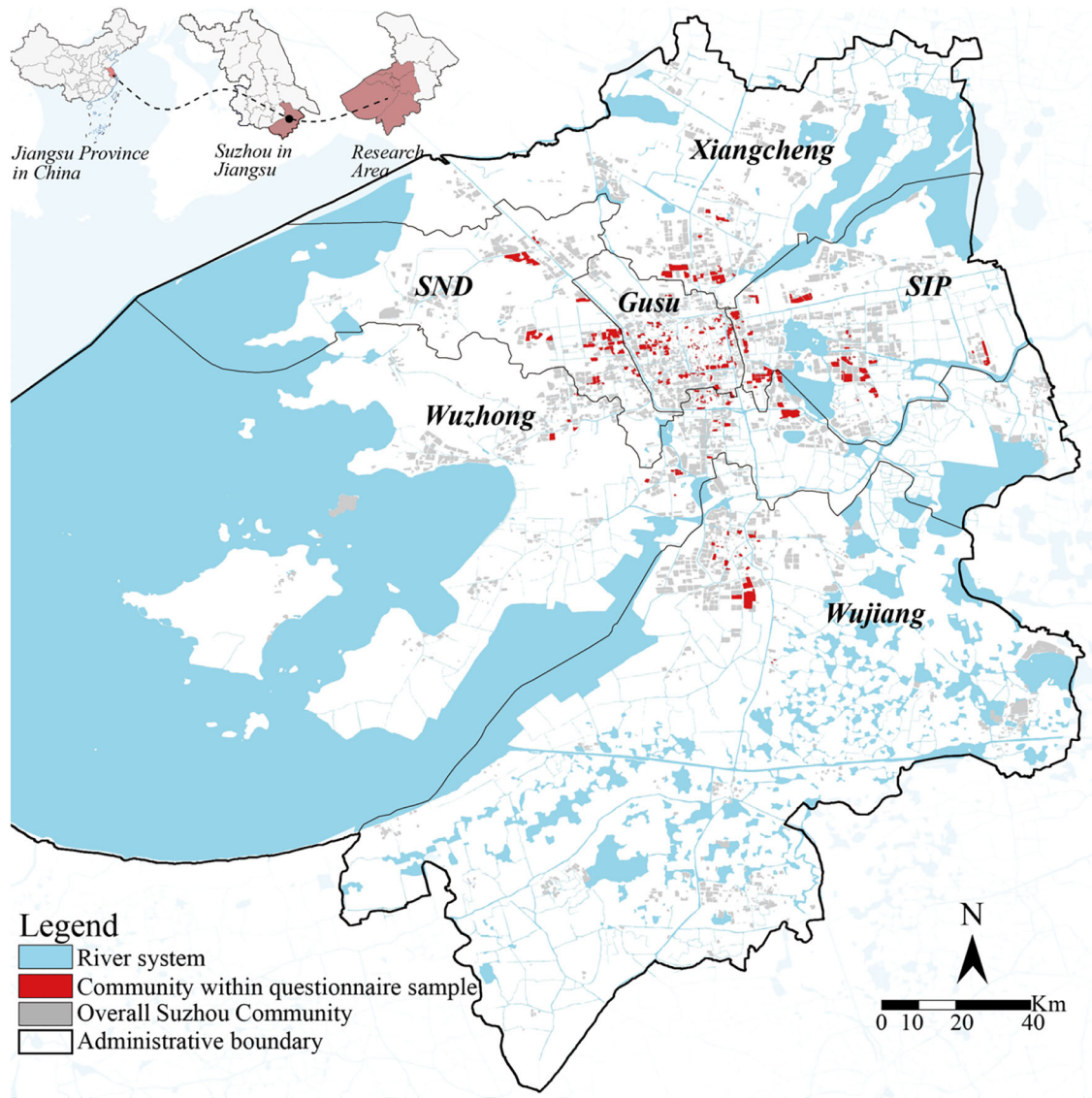


Fig. 2 Study area.

Table 1 Subjective and objective indicator factors construction.

Category	Subjective indicator	Objective indicator
Personal attributes (A)	Educational background, Family structure, Household income, Identity, Household registration type, Age	Housing price, Population density
Social interaction (B)	Physical health, Work status, Neighborhood relations, Exercise frequency, Communication frequency	Medical facilities density
Social perception (C)	Psychological well-being, Emotional state, Emotional stability	/
Community environment (D)	Landscape quality, Educational facilities accessibility, Property services, Urban park accessibility, Community greenery, Commercial facilities convenience	Plot ratio, Greening rate, Educational facilities density, Commercial facilities density
Commuting environment (E)	Motorized commuting time, Accessibility services, Traffic condition, Transport greenery, Non-motorized commuting time, Transport facilities, Environmental safety, Transportation mode	Park facilities density, Public facilities density, Transport facilities density

questionnaire is Physical health. XGBoost results are presented in two parts: Fig. 10 refers to objective factors, and Fig. 11 refers to subjective factors. Therefore, Medical facilities density does not appear in Table 3, which pertains to subjective variables, and is only shown in Fig. 10 under objective factors.

Data acquisition. Appendix 1 presents a summary of variable measurements. Personal attributes scales were developed following Li et al. (2022), including household income, household registration type, educational background, age, identity, and family structure. The life satisfaction scale was adopted from Sun

et al. (2024). The scales of community environment and commuting environment were adapted from Zhang et al. (2021) and adjusted according to the research situation. Social interaction scale and social perception scale were adapted from Chen et al. (2024d), respectively, incorporating urban renewal and socio-spatial integration context.

A comprehensive random sampling survey was conducted within Suzhou’s six districts. The data collection spanned from May 2024 to July 2025. A total of 1380 questionnaires were collected. To ensure the focus on the youth demographic, respondents aged under 18 or over 50 were systematically excluded from the analysis. Following a rigorous screening process to filter for the target youth population and ensure data validity, 1039 valid questionnaires were retained for subsequent analysis. The demographic characteristics of the sampled participants are presented in Table 2. To avoid definitional ambiguity, this study adopts a context-specific operational definition of the target population as youth and young adults aged 18–50. This choice is not intended to equate with the United

Nations’ statistical definition of “youth”; rather, it is tailored to the policy and practice context of youth-oriented community renewal in urban China, focusing on individuals in the early-to-mid career and family-formation stages who are most exposed to commuting conditions and public-service accessibility. Given that local “youth/young-talent” and hukou-related policies often extend upper age bounds beyond 35–40, depending on education and occupation, we use 18–50 to span the policy-served population. All inferences are therefore interpreted within this operational scope.

Figure 3 effectively illustrates the distribution of self-reported life satisfaction levels among two distinct youth age groups: 18–35 and 36–50 years old. The x-axis quantitatively represents the life satisfaction score, typically measured on a Likert scale ranging from 1 (indicating very dissatisfied) to 5 (indicating very satisfied). Concurrently, the left y-axis denotes the absolute number of respondents within each category, while the right y-axis presents the percentage frequency for each respective age group. For the 36–50 age group, the highest percentage of respondents (28.8%) reported a life satisfaction score of 4, followed by 19.1% at score 3, with a notable 9.9% indicating the highest satisfaction level of 5. Analogously, the 18–35 age group’s peak percentage (23.8%) is observed at a satisfaction score of 4, alongside a significant proportion at satisfaction level 3 (10.4%).

This study conducted reliability and validity tests on the scale to ensure data quality. The results showed that the Cronbach’s alpha coefficient of the questionnaire was 0.815, indicating good internal consistency; The KMO test value is 0.934, and the significance level of Bartlett’s sphericity test is $P = 0.000^{***}$, indicating strong correlation between variables. The factor analysis results are reliable, and the scale structure has good validity. Detailed scale items and test results can be found in Appendices S2 and S3.

Results

Objective spatial analysis and visualization. Figure 4 illustrates the objective spatial indicators in Suzhou, revealing distinct distribution patterns. The figures for medical facilities (a), education facilities (b), commercial facilities (c), transport facilities (e), and public facilities (f) consistently demonstrate a pronounced concentration of higher densities within the central urban core of Suzhou, gradually diminishing outwards towards the periphery. Specifically, commercial facilities (c) exhibit the highest degree of spatial clustering in the core, reflecting major economic and activity hubs. In contrast, the park density (d) showcases a more varied distribution, with higher percentages of green space observed in the less densely built-up areas and along the city’s

Table 2 The demographic characteristics of the sample.

Variables	Items	Sample size	Percentage
Gender	Male	535	51.5
	Female	504	48.5
Age	18-35	623	60.0
	36-50	416	40.0
Household income (Note: 1 RMB = 0.14 USD)	≤50,000 RMB	248	23.9
	50,001- 250,000 RMB	375	36.1
	250,001-450,000 RMB	266	25.6
	450,001-650,000 RMB	103	9.9
	≥650,001 RMB	47	4.5
Household registration status	Urban local	307	29.5
	Rural local	347	33.4
	Urban migrant	269	25.9
	Rural migrant	39	3.8
	Others	77	7.4

To evaluate sample representativeness, the gender ratio, education level, and occupational structure were compared with official statistics from the *Suzhou Statistical Yearbook (2023)* and the *Seventh National Population Census*. The results show that the sample’s gender composition (male: 49.6%; female: 50.4%) and occupational distribution closely align with the citywide youth population (differences <3%), while the proportion of respondents holding a bachelor’s degree or above (62.7%) is moderately higher than the official figure (58.3%). This indicates a slight overrepresentation of higher-educated youth, which is common in voluntary survey data but does not materially affect the validity or generalizability of the analysis.

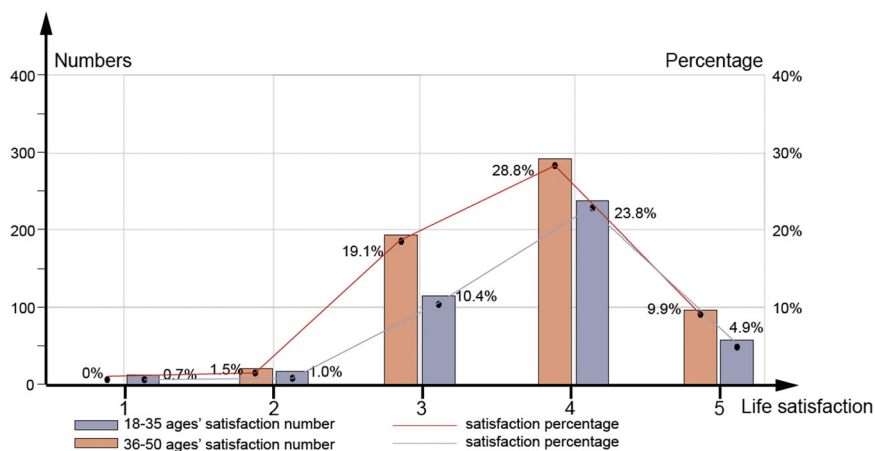


Fig. 3 Numbers and frequency distribution of satisfaction.

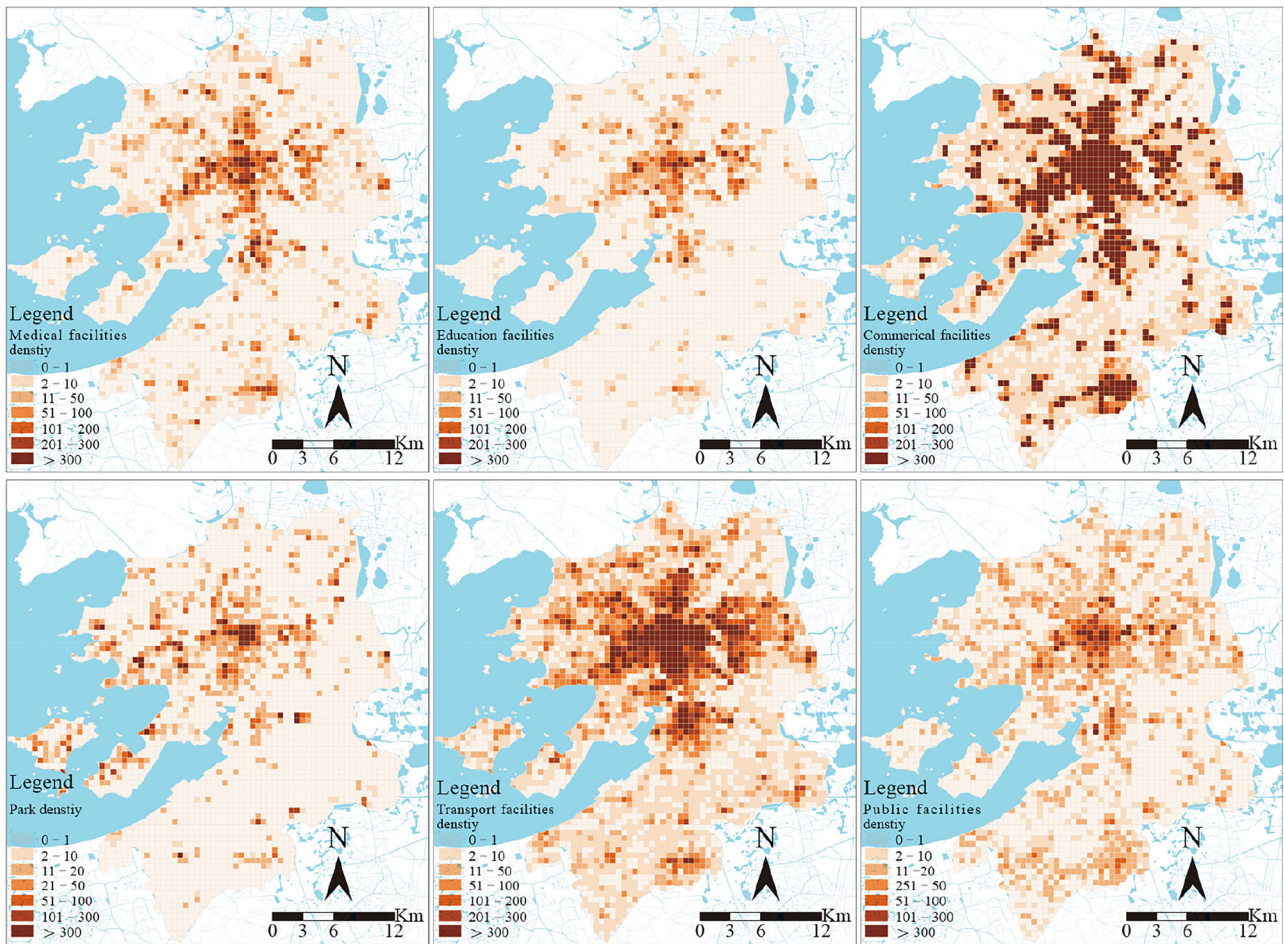


Fig. 4 Spatial density distribution of key objective socio-spatial indicators.

Table 3 The relative importance of predictive factors on life satisfaction.

Influencing factors	Weight	Level	Influencing factors	Weight	Level
Personal attributes (A)	7.50	/	Community environment (D)	13.0	/
Educational background	1.80	15	Landscape quality	3.40	10
Family structure	1.70	16	Educational facilities accessibility	3.20	11
Household income	1.20	21	Property services	2.90	13
Identity	1.10	24	Urban park accessibility	1.20	22
Household registration type	1.00	26	Community greenery	1.20	23
Age	0.70	27	Commercial facilities convenience	1.10	25
Social interaction (B)	27.6	/	Commuting environment (E)	30.5	/
Physical health	18.10	1	Motorized commuting time	6.70	3
Work status	4.00	8	Accessibility services	5.60	4
Neighborhood relations	2.70	14	Traffic condition	5.60	5
Exercise frequency	1.50	19	Transport greenery	5.50	6
Communication frequency	1.30	20	Non-motorized commuting time	3.10	12
Social perception (C)	21.3	/	Transport facilities	1.70	17
Psychological well-being	12.40	2	Environmental safety	1.60	18
Emotional state	5.40	7	Transportation mode	0.70	28
Emotional stability	3.50	9			
Adjusted-R ²	0.339				

natural water bodies, indicating the distribution of recreational and ecological infrastructure.

Relative importance and non-linear analysis results via GBDT. Table 3 presents the relative importance of various subjective factors in predicting youth life satisfaction, as determined through

the GBDT model. The model’s overall explanatory power, as indicated by an Adjusted-R² of 0.339, suggests that these subjective factors collectively account for a substantial portion of the variance in youth life satisfaction.

The findings reveal a nuanced hierarchy of influencing factors, categorized into personal attributes (A), social interaction (B), social perception (C), community environment (D), and

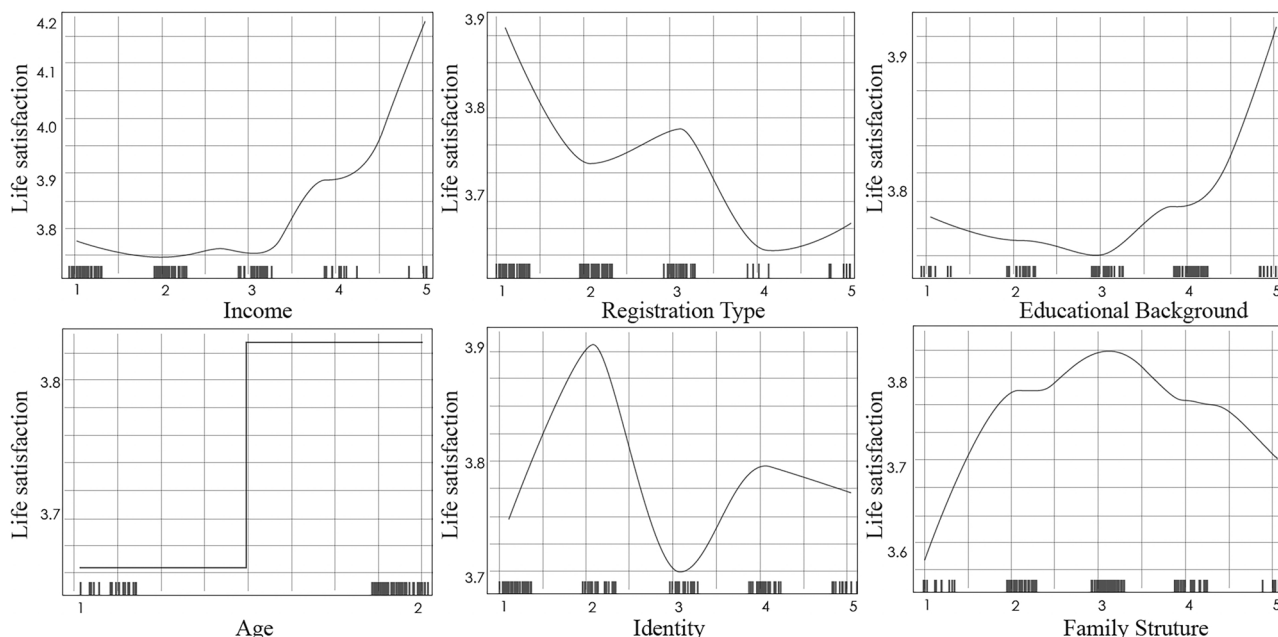


Fig. 5 Non-linear analysis of personal attributes and life satisfaction.

commuting environment (E). Notably, social interaction (B) and commuting environment (E) emerge as the most influential overarching categories, with total weights of 27.6 and 30.5, respectively, underscoring their significant impact on youth life satisfaction. Within these, Physical health (Weight: 18.10, Rank: 1) stands out as the single most critical predictor, followed closely by Psychological well-being (Weight: 12.40, Rank: 2) from the Social Perception category. Commuting-related factors also demonstrate high importance, with Motorized commuting time (Weight: 6.70, Rank: 3), Accessibility services (Weight: 5.60, Rank: 4), and Traffic condition (Weight: 5.60, Rank: 5) all ranking within the top six. Conversely, factors like Age, Household registration type, and Transportation mode show comparatively lower relative importance, suggesting a lesser direct influence on youth life satisfaction within this model’s framework.

Figure 5 illustrates the non-linear relationships between personal attributes and youth life satisfaction. Income and education levels show a clear positive trend in satisfaction, with income increasing from 3.7 to 4.2 and education rising from 3.75 to 4.0. Notably, age exhibits a distinct threshold effect, where older groups report significantly higher satisfaction (3.85) than younger groups (3.65), aligning with existing literature. These non-linear patterns suggest that urban renewal projects should focus on tailored interventions for different demographic groups, particularly for those at younger stages in their careers and education (Freihardt, 2020; Rosenthal et al., 2022).

Figure 6 shows the non-linear relationship between social interaction factors and life satisfaction. Both physical health and work status demonstrate a strong positive trend, with life satisfaction increasing from 2.0 to 4.2 as physical health improves. However, exercise frequency shows a peak effect, with satisfaction rising to 3.95 before slightly declining to 3.9, suggesting an optimal level of exercise. These findings indicate that urban renewal projects should optimize social spaces and health-related facilities to ensure a balanced environment for physical activities (Chen et al., 2024a), avoiding the over-provision of services that could lead to diminishing returns (Im and Hong, 2018).

Figure 7 illustrates how social perception factors such as emotional stability and psychological well-being relate to youth

life satisfaction. Satisfaction increases steeply from 1.0 to 3.0–3.5 as these factors improve, but the rate of increase slows as they reach higher levels, with a plateau at around 4.0–4.1. This pattern suggests diminishing returns in the impact of these factors on satisfaction, which indicates that interventions should focus on improving emotional and psychological support for young residents, particularly at lower levels of emotional stability (Azizian and Polich, 2007).

Figure 8 shows the non-linear relationships between community environment factors like property services and urban park accessibility. Life satisfaction rises steadily as the quality of services improves, with property services causing a significant increase from 2.0 to 4.1 between levels 1 and 3. However, at higher levels, the rate of increase becomes less sharp, indicating diminishing returns in service provision. These findings suggest that urban renewal policies should focus on optimizing services in areas with lower satisfaction levels and avoid over-providing in already high-satisfaction areas.

Notably, the observed non-linear dip in life satisfaction at intermediate levels of community greenery points to a threshold effect within the urban renewal process. Life satisfaction begins at approximately 3.9 at level 1, then declines significantly to about 3.6 at level 3. This temporary decrease likely reflects the short-term disruption and reduced access to green spaces that residents face due to ongoing renewal projects or uneven resource redistribution (Tian et al., 2024). Satisfaction subsequently rises again to 3.8 at level 5 as the renewal process stabilizes and green resources become more integrated. This pattern suggests that greenery’s impact is not a simple monotonic increase but rather a more complex, context-dependent effect (Dye et al., 2005).

Figure 9 illustrates the non-linear relationships between commuting environment factors and youth life satisfaction. Satisfaction rises from 2.0 to 4.0 as the quality of transport facilities improves, but transportation mode displays a unique dip at intermediate levels, suggesting discomfort with specific commuting modes. This emphasizes the need for tailored transportation solutions in urban planning, where policies should ensure multiple options are available to cater to the diverse commuting preferences of young residents (Hassan et al., 2021).

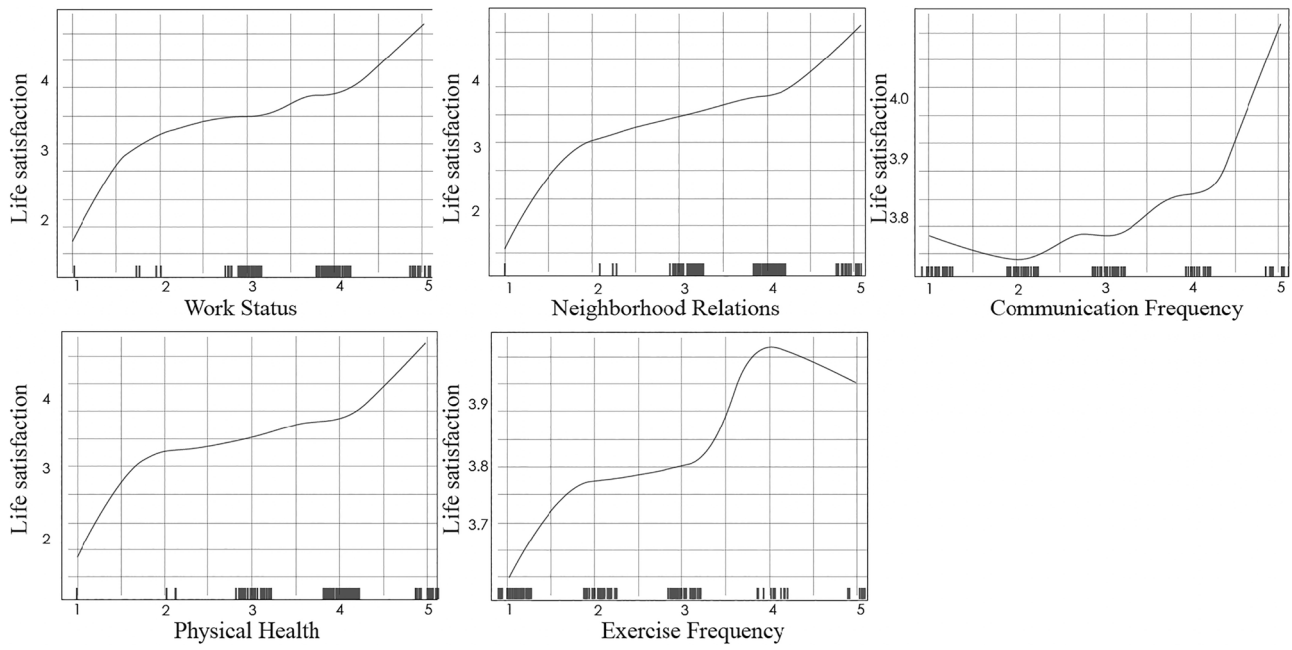


Fig. 6 Non-linear analysis of social interaction factors and life satisfaction.

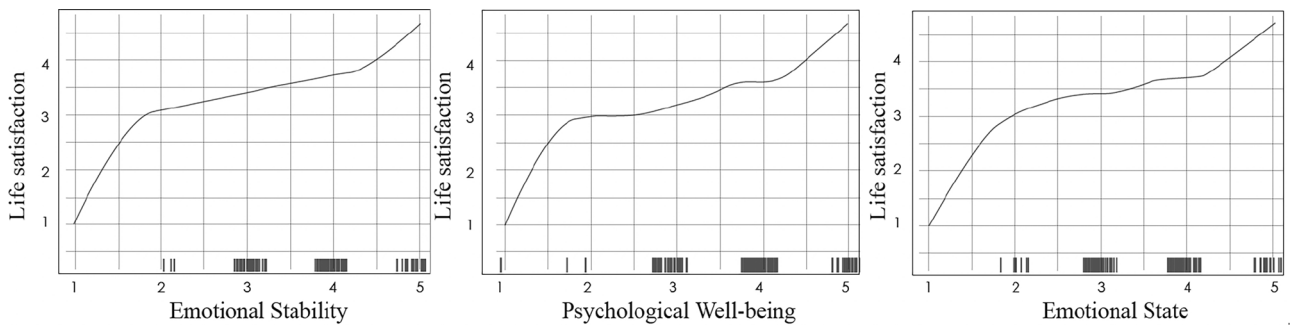


Fig. 7 Non-linear analysis of social perception factors and life satisfaction.

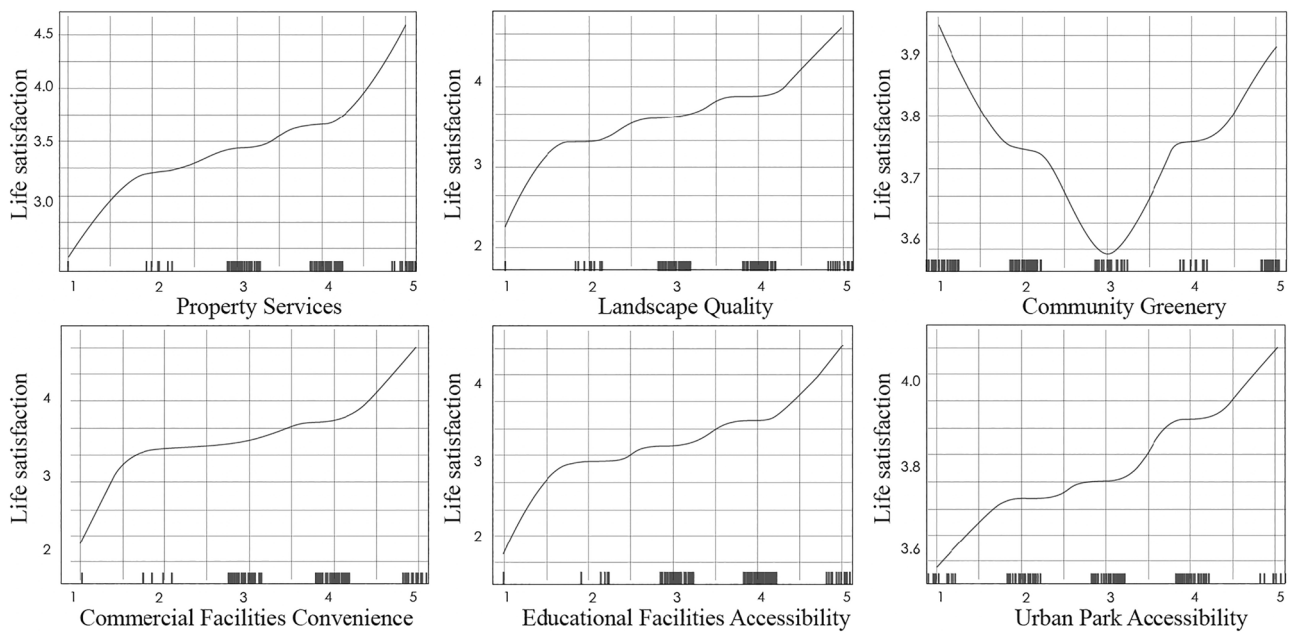


Fig. 8 Non-linear analysis of community environment factors and life satisfaction.

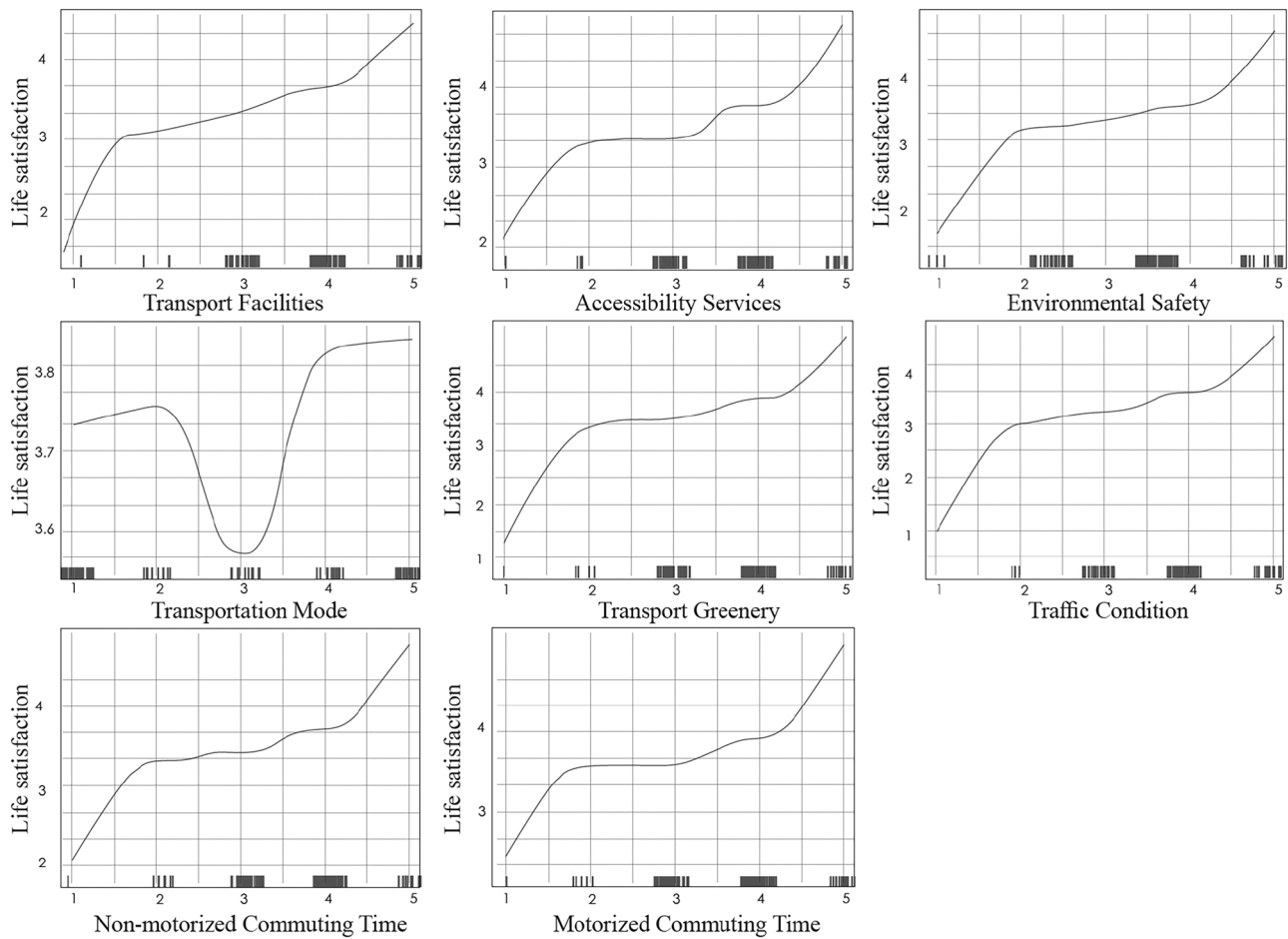


Fig. 9 Non-linear analysis of commuting environment factors and life satisfaction.

Table 4 The impact of factors on life satisfaction via OLS regression results.

Variables	M1-Subjective		Variables	M2-Objective	
	Coff (sd)	VIF		Coff (sd)	VIF
Social Interaction			Medical facilities density	0.021 (0.021)	1.972
Physical health	0.609*** (0.073)	3.870	Park facilities density	0.346*** (0.025)	1.002
Community Environment			Educational facilities density	0.431*** (0.017)	1.037
Landscape quality	0.110 + (0.075)	4.141	Commercial facilities density	0.07 (0.007)	2.145
Educational facilities accessibility	0.080 (0.097)	6.876			
Commercial facilities convenience	-0.031 (0.092)	6.269	Public facilities density	0.142** (0.04)	1.016
Commuting Environment			Transport facilities density	-0.037 (0.019)	1.528
Transport facilities	0.091** (0.028)	1.231	Const	2.313*** (0.174)	
Trafáfic condition	0.142* (0.071)	3.812	N	142	
Const	0.167 (0.148)		R ²	0.362	
N	142				
R ²	0.812				

***<0.001, **<0.01, *<0.05, +<0.15. Although some VIF values (e.g., for Educational facilities accessibility, VIF = 6.876) slightly exceed the conventional threshold of 5, further diagnostics indicate that these variables are conceptually distinct and do not exhibit problematic levels of collinearity. Following Related research on VIF (Crane and Surlis, 2002), VIF values below 10 are generally considered acceptable for social survey data, particularly when theoretical distinctions justify variable inclusion. Therefore, multicollinearity is unlikely to distort the estimated relationships or model interpretations.

Objective and subjective satisfaction influential factors comparison. Table 4 presents the OLS regression results, Model 1 (M1), focusing on subjective perceptions, exhibits a substantially higher explanatory power ($R^2 = 0.812$) compared to Model 2 (M2), which analyzes objective spatial densities ($R^2 = 0.362$), suggesting that self-reported experiences often account for a larger portion of perceived well-being in a linear framework.

Both models underscore the importance of the Community Environment and Commuting Environment in shaping life satisfaction. For instance, in the subjective model (M1), landscape quality shows a marginally significant positive influence ($\beta = 0.110$), which finds a stronger corroboration in the objective model (M2) where its counterpart, park facilities density, exerts a highly significant positive impact ($\beta = 0.346$). Similarly, in M1,

transport facilities ($\beta = 0.091$) and traffic condition ($\beta = 0.142$) are significant positive predictors, broadly aligning with the general importance of transportation-related infrastructure captured in the objective model, where public facilities density also shows a significant positive effect ($\beta = 0.142$). This suggests a fundamental agreement that the perceived and objective quality of the environment and accessibility are beneficial.

Conversely, the analysis highlights significant divergences in the specific factors and the magnitude of their linear impacts. The most striking difference lies in the Social Interaction category, where physical health in M1 exhibits an exceptionally strong and highly significant positive effect ($\beta = 0.609$), making it the most influential subjective factor. However, its objective correlate, medical facilities density in M2, shows a much smaller and statistically insignificant positive coefficient ($\beta = 0.021$). This stark contrast indicates that the perception of one's physical health linearly impacts life satisfaction far more profoundly than the mere density of medical facilities. Furthermore, while subjective perceptions of commercial facilities convenience have a negligible linear impact in M1 ($\beta = -0.031$), its objective counterpart, Commercial facilities density, also remains insignificant in M2 ($\beta = 0.07$).

The substantial difference in explanatory power between the subjective and objective models raises an important issue related to cognitive biases, particularly social expectation effects. Social expectation effects often lead individuals to provide responses they believe are socially acceptable or expected, which may inflate their self-reported life satisfaction. In our study, subjective ratings may be influenced by the desire to align with societal norms or positive self-image, thus resulting in higher reported satisfaction levels compared to objective measures of environmental factors.

Prediction analysis between influential factors and life satisfaction via XGBoost. The non-linear analysis utilizing XGBoost, comprehensively presented in Figs. 10 and 11, offers crucial insights into how both subjective and objective socio-spatial factors dynamically influence youth life satisfaction. A key finding is that objective factors frequently exhibit thresholds, saturation points. For instance, Medical facilities density demonstrates its SHAP value (contribution) shifting from a positive ~ 0.003 to a negative ~ -0.005 at higher densities, suggesting potential disutility beyond a certain point. Similarly, Educational facilities

density shows its contribution sharply increasing from ~ -0.005 to ~ 0.02 before plateauing, indicating diminishing returns. In contrast, subjective factors often manifest consistent positive increases with perceived quality. For example, Physical health's SHAP value consistently rises from approximately -0.4 at lower levels to ~ 0.0 at higher levels, reflecting a strong positive monotonic impact. Furthermore, perceived Traffic condition sees its SHAP value surge from ~ 0 to $\sim 0.015-0.02$ at the highest levels, indicating a particularly strong positive contribution when conditions are perceived as excellent.

Specifically, Fig. 10 specifically illustrates the non-linear impact of objective socio-spatial factors. For Educational facilities density, its SHAP value (contribution) sharply rises from around -0.005 to $\sim 0.015-0.02$ as density increases from approximately $-0.5-0.5$, indicating a significant increase in positive influence before plateauing. Conversely, Medical facilities density initially shows an increasing positive contribution (SHAP value rising from ~ 0 to $\sim 0.003-0.004$ as density increases from 0 to ~ 0.5), which then sharply declines to around -0.005 as density approaches 4, suggesting that excessively high densities may become detrimental. Commercial facilities density exhibits a similar pattern of initial positive contribution followed by a decrease at higher densities. Transport facilities density also demonstrates a non-linear effect, with its positive contribution peaking around ~ 0.004 at low densities (~ 0.5) before a pronounced drop to ~ -0.002 at density ~ 2 , then a gradual rise again.

Figure 11 illustrates Physical health, a generally positive and increasing contribution to life satisfaction is observed: its SHAP value rises from approximately -0.4 at lower health levels to ~ 0.0 at higher levels, suggesting that improving health rapidly shifts its impact from negative to positive. Landscape quality, in contrast, shows a consistently minimal direct contribution, with its SHAP value largely remaining near 0 across its perceived range. More complex, non-linear patterns are evident for other factors. For Educational facilities accessibility, its SHAP value demonstrates an undulating behavior, initially positive, dipping to ~ -0.002 around level 0.5, then sharply rising to ~ 0.004 at level 0.8, before declining again. Similarly, Commercial facilities convenience shows an initial slight positive contribution, followed by a sharp increase in its SHAP value peaking at approximately 0.004 around levels -0.5 to 0, and subsequently declining. Both Transport facilities and traffic conditions exhibit non-linear

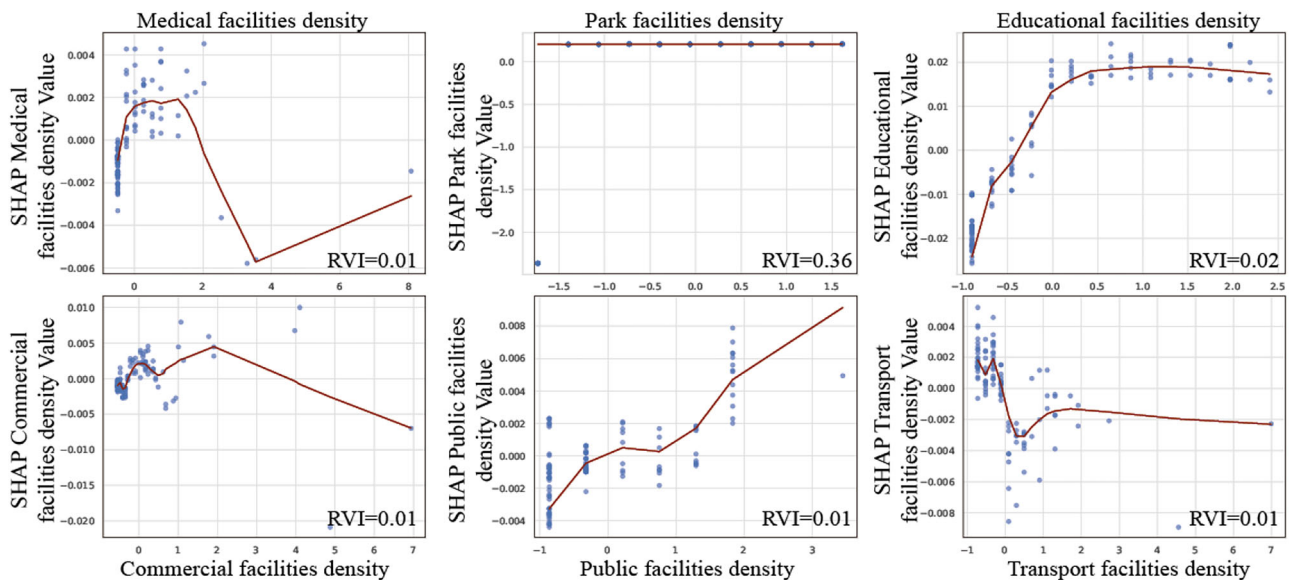


Fig. 10 Forecasting of objective factors and life satisfaction via XGBoost.

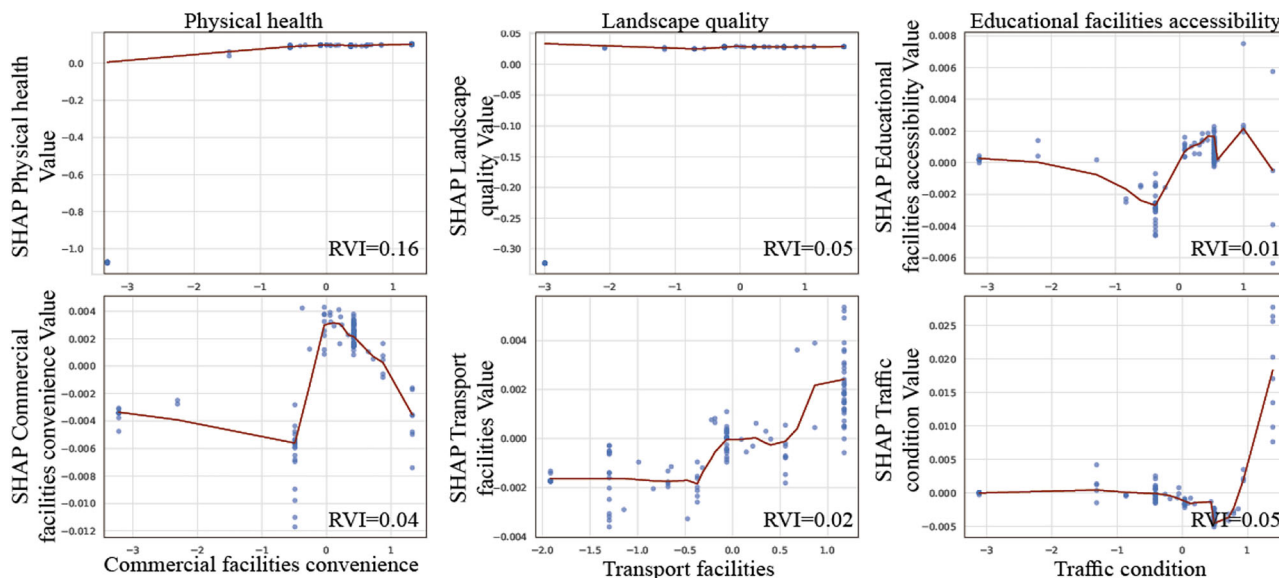


Fig. 11 Forecasting of subjective factors and life satisfaction via XGBoost.

patterns where their SHAP values generally remain low or slightly negative at lower levels, but show a notable surge at higher levels, with traffic condition’s SHAP value rising sharply from ~0 to ~0.015-0.02 at its highest perceived levels.

It is essential to note that Table 3 presents the relative importance of subjective questionnaire variables and, therefore, does not include the objective measure, medical facilities density, which conceptually corresponds to Physical health in the subjective questionnaire. Figures 10 and 11 show the XGBoost–SHAP results for objective and subjective factors, respectively. The negative marginal contribution of medical facilities density at higher density levels in Fig. 10 reflects the non-linear threshold effect and overcrowding externality: at lower densities, facility concentration improves accessibility and perceived safety; however, at higher densities, it may lead to negative outcomes such as congestion and environmental burden. In contrast, the positive impact of Physical health in Fig. 11 shows an overall improvement in life satisfaction, which is not directly correlated with the objective measure of medical facilities density. This coexistence of positive trends in subjective health and negative contributions of objective medical facilities density illustrates the asymmetry between perceived and objective accessibility and their non-linear effects.

Discussion and conclusion

Hypothesis testing. This study focuses on exploring the non-linear dynamics between socio-spatial integration and youth life satisfaction, particularly in community renewal in youth-oriented cities. Using GBDT to analyze the complex interactions between socio-spatial factors and youth life satisfaction, and XGBoost analysis was used to explore how urban environments can be optimized to enhance youth life satisfaction. Five hypotheses were tested, and the following main conclusions were obtained. Our findings partially support H1. Personal attributes indeed influence youth life satisfaction, as evidenced by their presence in the models. However, contrary to the hypothesis, GBDT analysis (Table 3) showed Household income (Weight: 1.20) was not the most critical determinant within this category; instead, Educational background (Weight: 1.80) and family structure (Weight: 1.70) held higher importance. Figure 5 further revealed a curvilinear relationship for income, where life satisfaction rises from

approximately 3.7 at the lowest level to 4.1–4.2 at the highest (5). Additionally, Age exhibited a clear threshold effect, with the older age group notably higher than the younger group (Sun et al., 2024).

H2 is generally supported, but H2a and H2b are partially nuanced by the results. The community environment is indeed a key determinant, with GBDT (Table 3) assigning it a substantial total weight of 13.0. OLS results (Table 4, M2) indicate that public facilities density ($\beta = 0.142$) is a significant linear predictor, supporting H2b. However, park facilities density ($\beta = 0.346$) and Educational facilities density ($\beta = 0.431$) emerged as more significant linear determinants than public facilities density. Figure 8 further revealed complex non-linear impacts, with community greenery showing an initial rise, then a significant dip to ~3.6 at level 3, before recovering, suggesting a complex dose-response rather than simple linearity. “Housing quality” as a direct variable was not the most significant factor in our models. H3 is largely supported. The commuting environment consistently emerged as a major factor, holding the highest total weight in GBDT analysis (30.5, Table 3). While OLS results for subjective factors (Table 4, M1) showed traffic condition ($\beta = 0.142$, $p < 0.05$) and transport facilities ($\beta = 0.091$) as significant, GBDT specifically highlighted motorized commuting time (Weight: 6.70) as a highly important factor within this category, supporting its significance. Figure 9 further illustrated non-linear dynamics, particularly for transportation mode, which exhibited a complex pattern with a significant dip in life satisfaction around an intermediate mode (~3.55–3.6 at level 3), reinforcing that the relationship with commuting is not simply linear (Zhang et al., 2021).

H4 is largely supported, social interaction is a significant influencing category (GBDT total weight 27.6, Table 3). However, physical health (Weight: 18.10) was overwhelmingly the most critical determinant within this category by GBDT, and also a highly significant linear predictor in OLS ($\beta = 0.609$). Work status (Weight: 4.00) had a lesser impact. Figure 6 also showed physical health as a strong positive non-linear predictor (Azizian and Polich, 2007). This discrepancy suggests that while employment status plays a role in social interaction, its influence is not as pronounced as other factors like physical health, which has a more substantial impact on youth life satisfaction. H5 is largely supported, specifically concerning the factors identified as Social Perception in our study. GBDT analysis (Table 3) assigned social

perception a substantial total weight of 21.3. Figure 7 consistently demonstrated strong positive non-linear correlations for all factors within this category: emotional stability, psychological well-being, and emotional state. Life satisfaction rapidly increased at lower-to-moderate levels of these factors before plateauing towards higher levels (~4.0–4.1), indicating diminishing returns. This confirms that these internal psychological perceptions positively correlate with and profoundly influence youth life satisfaction.

Theoretical contributions. The development of youth-oriented cities is still in its early stages, both in terms of policy and theoretical research. Our findings not only enrich the application of socio-spatial integration theory in community renewal and urban governance but also make three major theoretical contributions. First, existing literature on youth-oriented city development primarily focuses on surface-level aspects such as conceptual definitions (Bianchi et al., 2021; Korkmaz and Balaban, 2020), policy recommendations, or spatial development. These studies often overlook the complexity of the reciprocal relationship between youth development and urban growth. This study explores youth life satisfaction within the framework of socio-spatial integration theory, revealing the deep-seated mechanisms through which urban renewal influences youth-oriented city development. In doing so, it expands the theoretical boundaries of urban governance research (Chen et al., 2025b; Zhang et al., 2025). These findings help to equip urban renewal policymakers and planners, particularly on youth-related planning issues, with the tools to develop more targeted and actionable strategies.

Second, current research has not sufficiently considered the complexity and dynamism of socio-spatial integration, and lacks a comprehensive measurement framework that can capture holistic factors affecting youth perceptions of urban environments (Anrong and Jian, 2019; Huang et al., 2023). Moreover, the community level exploring the non-linear effects of socio-spatial factors on youth life satisfaction have received limited attention, despite their crucial role in developing effective governance mechanisms for youth-oriented city renewal (Xia et al., 2022; Ye et al., 2018). This study addresses the lack of a systematic measurement framework in youth-oriented urban research by proposing a comprehensive analytical framework that can simultaneously capture multidimensional and non-linear effects. The results reveal complex interactions and threshold effects between spatial accessibility, environmental quality, and social perceptions at the community level. These findings offer more targeted governance strategies for youth-oriented urban renewal (Przybyłowski et al., 2021; Taozhi Zhuang, 2020).

Third, to effectively assess the outcomes of youth-oriented urban renewal, we advance the robustness of the findings by employing GBDT and the additional layer of predictive refinement offered by XGBoost. Traditional linear models, while valuable in certain contexts, struggle to capture the complexity of social phenomena, especially when it comes to non-linear interactions between various factors affecting youth well-being. Therefore, this study applies a combination of GBDT and XGBoost models to the non-linear analysis of youth-oriented urban renewal. This approach breaks through the limitations of traditional linear models in revealing the complex socio-spatial interaction mechanisms. It also provides an actionable technical path for subsequent urban planning evaluations (Zhang et al., 2025; Zhao et al., 2025).

Youth-oriented urban renewal practical implications and governance mechanisms. Beyond a singular focus on green spaces, this study's comprehensive non-linear analysis of diverse

socio-spatial factors and youth life satisfaction yields crucial practical implications for youth-oriented urban renewal and governance, advocating for a data-driven and balanced approach (Chen et al., 2024a; Hu et al., 2024). The findings underscore that an effective governance framework must balance short-term interventions, medium-term optimization, and long-term sustainability, relying on the active involvement of multiple stakeholders, including government, residents, market actors, and social organizations (Chen et al., 2025a). Policy choices should adhere to the non-linear thresholds identified in this paper, setting supply caps for high-density situations to avoid additional investment leading to negative marginal utility (Chen et al., 2026). The governance process should be guided by quarterly tracking of metrics (e.g., satisfaction, repair-request closure, commuting time, and facility gaps) to form an evidence-driven optimization path.

In the short term, immediate efforts should prioritize enhancing the most significant determinants of life satisfaction within the community and commuting environments (Yu et al., 2024). This involves upgrading property services, enhancing landscape quality (beyond mere quantity), and optimizing access to commercial and educational facilities. Given the observed non-linear diminishing returns for many of these factors (e.g., Property services, Educational facilities density in Figs. 8 and 10), policies should focus on maximizing marginal returns by targeting underserved areas rather than simply increasing overall provision (Fan et al., 2022). For commuting, reducing commuting times, improving public transportation, optimizing traffic flow, and promoting sustainable mobility options are essential. The complex non-linear relationship with transportation mode (Fig. 9), which can show dips in satisfaction at certain modes, further suggests the need for nuanced transport solutions that offer diverse and well-integrated networks to avoid creating disutility (Chen et al., 2024b). Short-term strategies should focus on low-cost, high-impact measures. This means establishing a closed-loop system for property management services, including response, case closure, and follow-up. Priority should be given to filling gaps in basic services and educational facilities within a 10–15 min walking radius. For high-density areas that are at or nearing their thresholds, implementing a moratorium on new additions and optimizing existing structures is crucial. This will prevent the cumulative effects of congestion, noise, and competition. On the commuting front, the focus should be on the “first/last mile” of a journey. Setting actionable time thresholds and running small-scale pilot programs can help verify how well these improvements adapt to specific local contexts.

For the medium term, strategies should focus on fostering the psychological and social well-being of young residents (Kim et al., 2020; Liu et al., 2020; Mayer et al., 2019). This includes promoting a healthy work-life balance through flexible work policies and family-friendly initiatives, acknowledging that while work status is important, its impact can be complex and non-linear. Fostering social interaction and community cohesion is vital, achievable by encouraging community-based activities and creating spaces that facilitate positive social encounters, aligning with the importance of neighborhood relations and communication frequency (Fig. 6). Increases in emotional stability, psychological well-being, and emotional state (Fig. 7), alongside physical health being a strong positive predictor, mental health support services must be integrated into urban renewal strategies (Rosenthal et al., 2022). Furthermore, the complex non-linear effect of community greenery (Fig. 8), which showed a dip in satisfaction, suggests that innovative landscape design focusing on quality and specific types of green spaces, beyond just quantity, is crucial for shaping positive spatial interactions and enhancing well-being (Middel et al., 2019). Mid-term strategies emphasize the institutionalized

provision of social and psychological well-being. This means regular community activities and accessible, usable public spaces should work together to promote positive interaction and encourage people to stay. Incorporating a system for light counseling, referrals, and follow-ups into the community service framework can directly address the significant link between physical/mental health and satisfaction found in this study. Additionally, spatial renewal should be usage-oriented, with clear divisions between active and quiet zones, well-designed paths, and seating. The effectiveness of these changes should be measured using process-based metrics like participation rates, dwell time, and complaint rates.

In the long term, governance strategies should address deeper, structural factors influencing life satisfaction and promote sustainable urban development that balances economic growth with social equity (Nakano and Washizu, 2018). Recognizing the varied impacts of personal attributes like Income (curvilinear rise in Fig. 5) and the higher satisfaction among older age groups, policymakers should prioritize improving living conditions for low- and middle-income households through targeted vocational training, housing improvements, and social services. Enhancing and strategically distributing green spaces and leisure facilities remain essential to providing young people with places for relaxation and socialization (Tian et al., 2024). By adopting a multi-stakeholder governance framework, future urban renewal initiatives can ensure that spaces are not only economically vibrant but also environmentally sustainable, socially inclusive, and truly conducive to promoting long-lasting well-being and engagement for all young residents (Heyes and Zhu, 2019). Long-term strategies require institutionalizing a framework for multi-stakeholder collaboration and budgeting, and solidifying a closed-loop governance system with annual re-evaluation. For low-to-middle-income and new workforce populations, this means combining housing improvements, subsidized rentals, and vocational training to stabilize their foundational living conditions. Public recreational spaces and green areas should be prioritized based on accessibility and operational maintenance. For over-saturated areas, strong constraints should be implemented to prevent rising negative externalities from eroding subjective well-being.

Limitations and future research

This study acknowledges several limitations that warrant further exploration. First, while GBDT excels at uncovering non-linear relationships within large datasets, future studies should validate whether these findings align with results from other quantitative approaches. Second, the factors explored here—such as personal attributes, social interaction, community environment, and commuting—are not exhaustive. Future research could explore additional variables, such as the motivations driving youth decisions to settle in urban environments, which may provide deeper insights into the factors influencing life satisfaction. Furthermore, using an 18–50 band broadens coverage but may mask heterogeneity across life-course stages (e.g., 18–35 vs. 36–50) in housing choice, travel behavior, and social networks. Accordingly, our conclusions generalize primarily to early–mid career youth and young adults in urban China. Future research should conduct age-stratified analyses and test age-by-factor interactions to probe heterogeneity and assess robustness. Finally, the urban renewal process is constantly advancing and changing, and the social space is also developing dynamically, while our study only focuses on the developmental stages of urban renewal in Suzhou city, and lacks comparative studies between regions with different urban renewal processes or spatial dynamics. Given the single-city, single-wave cross-sectional design, the results may be affected by selection, spatial sorting, and unobserved confounding; they

therefore warrant correlational—rather than causal—interpretation. Future work should employ multi-wave/multi-city data and quasi-experimental strategies to examine whether the thresholds and non-linearities identified here are causally robust. In the future, we can pay attention to the different stages of urban renewal and the dynamization of the social space, to enhance the robustness and universality of the social-spatial integration-life satisfaction relationship.

Data availability

The geospatial data analyzed during the current study are available from the corresponding author upon reasonable request. Due to privacy and confidentiality considerations, social media and questionnaire survey data cannot be made publicly accessible. To uphold the robustness of the analytical models and ensure transparency in data use, anonymized data were provided to reviewers during the peer-review process.

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Author contributions

J.C., H.N. and H.S. wrote the main manuscript text; J.C., P.L. and H.N. prepared all data and revision writing; and P.L. prepared all figures and tables. All authors reviewed the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

The questionnaire survey was approved by the Ethics Committee of Xi'an Jiaotong-Liverpool University (Approval No: ER-LRR-1088523720240325103538) on March 26th, 2024. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent

Before the study commenced, all participants—who were non-vulnerable individuals—received an online information sheet and consent form embedded within the survey, distributed between May 1st, 2024, and July 31, 2025. They were clearly informed about the study's aims, data usage, confidentiality measures, and the absence of any foreseeable risks. Participants confirmed that they had read and understood the study's objectives, the intended use of their data, and their right to withdraw at any time. All participants were aged 18 years or above. No personally identifiable information was collected at any stage of the research. Only those who provided informed consent proceeded to take part. The consent form also included contact details for further inquiries or withdrawal. Written consent was obtained electronically, and ethical approval for the study was granted by the institution's ethics committee.

Additional information

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