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Research Article

Computational modelling of elderly preferences and spatial adaptability for predicting urban regeneration support in high-density cities

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Abstract:

This study develops a computational modeling framework to examine how elderly preferences and spatial adaptability collectively influence urban regeneration support in high-density cities, with residential satisfaction serving as a mediating variable. Using a quantitative research design, data were collected from 327 elderly residents (aged 60 and above) residing in high-density urban communities across three metropolitan districts. Structured questionnaires employing a five-point Likert scale were administered. SPSS 27 facilitated descriptive statistics and reliability diagnostics, while SmartPLS 4 enabled Partial Least Squares Structural Equation Modeling (PLS-SEM). Results confirmed satisfactory reliability (Cronbach's Alpha > 0.80; CR > 0.85) and validity (AVE > 0.50; HTMT < 0.85). Path analysis revealed significant direct effects of elderly preferences ($\beta = 0.421$, $t = 6.34$, $p < 0.001$) and spatial adaptability ($\beta = 0.318$, $t = 4.87$, $p < 0.001$) on urban regeneration support. Residential satisfaction fully mediated the spatial adaptability–urban regeneration support relationship. The interaction term (Elderly Preferences × Spatial Adaptability) significantly moderated regeneration support ($\beta = 0.193$, $t = 2.91$, $p < 0.01$). The predictive model achieved $R^2 = 0.623$, indicating strong explanatory power. Findings provide actionable computational insights for urban planners and policymakers designing age-responsive regeneration strategies.

1. Introduction

The rapid demographic shift toward aging populations within high-density urban environments constitutes one of the most pressing planning challenges of the contemporary era. By 2030, the World Health Organization projects that one in six people globally will be aged 60 or over, with the majority concentrated in urban centers of Asia, the Middle East, and Latin America (WHO, 2022). In these settings, the capacity of cities to regenerate their physical and social fabric in ways that remain responsive to elderly inhabitants demands rigorous computational investigation.

Urban regeneration—defined as the comprehensive process of reversing physical, social, and economic decline in built environments—has historically been evaluated through demographic and economic lenses (Roberts et al., 2017). However, an emerging body of scholarship advocates for preference-driven and spatially adaptive models that foreground the perceptions of older residents as central inputs to regeneration planning (Liu & Chen, 2023). This is particularly significant in high-density cities where elderly residents face compounded spatial constraints, including limited green space, inadequate pedestrian infrastructure, and accessibility deficits.

Computational modeling offers a methodologically rigorous pathway to quantify the relationships among elderly preferences, spatial adaptability, residential satisfaction, and urban regeneration support. Unlike qualitative approaches, computational frameworks enable researchers to test hypothesized structural relationships, assess predictive accuracy, and produce replicable findings applicable across diverse urban contexts (Hair et al., 2022). Despite this potential, few studies have integrated PLS-SEM with moderation-mediation analysis to model elderly-focused urban regeneration in high-density settings.

This study addresses this gap by constructing a structural computational model that treats urban regeneration support as the primary outcome variable, with elderly preferences and spatial adaptability as antecedent constructs, and residential satisfaction as a mediating mechanism. An interaction effect between the two predictor constructs further enriches the model's explanatory architecture. The results contribute to the growing intersection of urban gerontology and computational planning science.

2. Literature Review

2.1 Elderly Preferences in Urban Contexts

Elderly preferences in urban environments encompass a multidimensional spectrum of desires related to accessibility, social connectedness, safety, and aesthetic quality (Buffel et al., 2021). In high-density cities, these preferences are often suppressed by spatial crowding and inadequate age-responsive infrastructure. Park and Lee (2022) demonstrated that elderly residents in Seoul expressed strong preferences for walkable neighborhoods with accessible green corridors, yet reported systematic misalignment between their preferences and the actual spatial configuration of their communities. This gap between preference and reality is hypothesized to mediate attitudes toward urban change.

Computational studies have increasingly operationalized elderly preferences as latent constructs measurable through structured instruments. Ng et al. (2023) applied factor analysis to decompose elderly housing preferences into five sub-dimensions: physical accessibility, social proximity, environmental quality, service availability, and aesthetic coherence. Their findings revealed that physical accessibility and social proximity were the strongest predictors of satisfaction, informing the indicator selection in the present study.

2.2 Spatial Adaptability and Urban Mobility

Spatial adaptability refers to the degree to which built environments can be modified or navigated to accommodate the changing physical and cognitive capabilities of aging residents (Pojani & Stead, 2021). The concept extends beyond universal design to encompass dynamic responsiveness—the capacity of spaces to flex across the life course. In high-density contexts, spatial adaptability is particularly salient because the fixed nature of dense urban form constrains informal modification. Khari et.al. (2020).

Yung et al. (2020) employed multilevel regression in Hong Kong public housing estates to demonstrate that spatial adaptability scores significantly predicted elderly residents' sense of place and willingness to advocate for neighborhood renewal. Similarly, Zhang and Wang (2024) applied geospatial computational models to identify adaptability hotspots in Shanghai's inner city, finding that blocks with higher adaptability indices corresponded to greater elderly satisfaction and lower residential mobility intentions.

2.3 Residential Satisfaction as a Mediating Construct

Residential satisfaction synthesizes residents' cognitive and affective evaluations of their dwelling environment relative to their aspirations (Amerigo & Aragones, 1997). In gerontological urban research, residential satisfaction functions as a critical mediator because it translates objective spatial conditions into subjective support for or resistance to urban change (Cerin et al., 2023). When elderly residents report high residential satisfaction, they are more likely to engage constructively with regeneration processes, as they perceive the urban environment as responsive to their needs.

Liu and Chen (2023) applied SEM in Guangzhou to demonstrate that residential satisfaction fully mediated the relationship between neighborhood accessibility and support for urban renewal among elderly residents. Al-Sayed and Hassan (2024) replicated this finding in Dubai, extending it to include housing quality and social interaction density as additional mediating pathways.

2.4 Urban Regeneration Support: Computational Perspectives

Urban regeneration support represents the degree to which residents endorse, participate in, or facilitate urban renewal initiatives (Tallon, 2020). Computational studies have increasingly framed regeneration support as a function of both individual preference satisfaction and aggregate spatial quality indicators (Chen et al., 2022). The application of PLS-SEM has proven particularly valuable in this domain because it accommodates reflective measurement models with modest sample sizes while maintaining predictive accuracy.

Hair et al. (2022) advocate for PLS-SEM as the preferred method for theory development in social sciences, noting its capacity to handle complex models with multiple mediators and moderators simultaneously. Recent applications by Ringle et al. (2023) and Sarstedt et al. (2021) further validate the use of SmartPLS 4 for predictive relevance assessment through PLSpredict and cross-validated redundancy measures.

3. Cnceptual Framework and Hypotheses

3.1 Conceptual Framework

The conceptual framework positions Elderly Preferences (EP) and Spatial Adaptability (SA) as independent constructs, Residential Satisfaction (RS) as a mediating variable, and Urban Regeneration Support (URS) as the dependent outcome. An interaction term (EP × SA) tests whether the combined effect of preferences and adaptability amplifies or attenuates regeneration support beyond their individual contributions. Figure 1 presents the structural path diagram of the framework.

3.2 Hypothesis Development

H1: Elderly preferences have a significant positive direct effect on urban regeneration support.

H2: Spatial adaptability has a significant positive direct effect on residential satisfaction.

H3: Residential satisfaction mediates the relationship between spatial adaptability and urban regeneration support.

H4: The interaction between elderly preferences and spatial adaptability significantly moderates urban regeneration support.

H5: Residential satisfaction has a significant positive direct effect on urban regeneration support.

4. Research Methodology

4.1 Research Design

A quantitative cross-sectional research design was adopted, employing a structured self-administered questionnaire. The positivist philosophical stance underpinning this design treats urban regeneration support as an objectively measurable social phenomenon amenable to statistical inference. The study population comprised elderly residents (aged ≥ 60) living in high-density urban communities within three metropolitan districts characterized by ongoing or planned regeneration initiatives.

4.2 Sampling and Data Collection

Stratified random sampling was employed to ensure proportional representation across three districts. A minimum sample size of 277 was calculated using G*Power 3.1 for medium effect size ($f^2 = 0.15$), seven predictors, at $\alpha = 0.05$ with power = 0.80. To accommodate anticipated attrition and non-response, 380 questionnaires were distributed, yielding 327 usable responses (response rate: 86.1%). Table 1 presents the demographic profile.

4.3 Measurement Instrument

All four constructs—Elderly Preferences (EP), Spatial Adaptability (SA), Residential Satisfaction (RS), and Urban Regeneration Support (URS)—were measured using validated multi-item reflective scales adapted from prior literature. Each item was scored on a five-point Likert scale anchored at 1 (Strongly Disagree) to 5 (Strongly Agree). EP was measured with five items addressing physical accessibility, social connectivity, safety, environmental quality, and service proximity. SA comprised four items assessing ramp availability, lift access, spatial flexibility, and wayfinding clarity. RS utilized five items from Amerigo and Aragones (1997), adapted for urban high-density contexts. URS included four items measuring willingness to support, participate in, and advocate for regeneration initiatives. Content validity was established through expert panel review (n = 7 urban planning academics), and a pilot study of 42 elderly respondents confirmed instrument comprehensibility.

4.4 Analytical Procedures

Data were analyzed in two stages. Stage 1 employed SPSS 27 for descriptive statistics, normality testing (Kolmogorov-Smirnov), and Cronbach's Alpha estimation. Stage 2 applied SmartPLS 4 for reflective measurement model assessment (outer loadings, Composite Reliability, AVE, HTMT criterion, Fornell-Larcker) and structural model evaluation (path coefficients, bootstrapping with 5,000 subsamples, R^2, f^2, PLSpredict Q^2). Mediation was tested using the bias-corrected bootstrap confidence interval method, and moderation via product-indicator approach.

5. Data Analysis and Results

5.1 Descriptive Statistics

Table 2 presents the descriptive statistics for all construct indicators. Mean scores ranged from 3.21 (SA4: wayfinding clarity) to 4.12 (EP1: physical accessibility preference), suggesting moderately positive assessments across constructs. Standard deviations remained below 1.10, indicating acceptable homogeneity in responses. Skewness values (−0.43 to −0.81) and kurtosis values (−0.29 to 0.76) fell within acceptable normality thresholds for SEM analysis (Hair et al., 2022).

5.2 Measurement Model Assessment

The measurement model was evaluated for reliability and validity following the criteria recommended by Hair et al. (2022) and Fornell and Larcker (1981). Table 3 summarizes the reliability and convergent validity statistics.

All Cronbach's Alpha values exceeded 0.80, and Composite Reliability (CR) values exceeded 0.85, confirming adequate internal consistency. Average Variance Extracted (AVE) values for all constructs surpassed the 0.50 threshold (Fornell & Larcker, 1981), confirming convergent validity. All outer factor loadings exceeded 0.70, with the lowest loading recorded at 0.743 (EP4). Discriminant validity was assessed using the HTMT criterion (Table 4) and Fornell-Larcker criterion (Table 5).

All HTMT values were below the conservative threshold of 0.85 (Henseler et al., 2015), confirming discriminant validity across all construct pairs.

The square root of each construct's AVE (diagonal elements) exceeded its correlations with all other constructs, satisfying the Fornell-Larcker criterion for discriminant validity.

5.3 Structural Model and Hypothesis Testing

The structural model was estimated using PLS-SEM with 5,000 bootstrap subsamples. Table 6 reports the path coefficients, t-statistics, p-values, and hypothesis outcomes.

5.4 Mediation Analysis

The mediating role of residential satisfaction between spatial adaptability and urban regeneration support was tested using bootstrapped indirect effects (Table 7). Results confirmed a significant indirect effect ($\beta = 0.106$, $t = 3.81$, $p < 0.001$; 95% CI = [0.052, 0.163]), with the direct effect of SA → URS remaining significant ($\beta = 0.318$, $p < 0.001$). This pattern indicates partial mediation, whereby residential satisfaction amplifies but does not fully supplant the direct spatial adaptability–regeneration support pathway.

5.5 Moderation Analysis and Interaction Graph

The moderating effect of the EP × SA interaction term on urban regeneration support was significant ($\beta = 0.193$, $t = 2.91$, $p = 0.004$). Figure 2 presents the interaction plot illustrating how the effect of spatial adaptability on urban regeneration support varies across levels of elderly preferences (one standard deviation below and above the mean).

The interaction plot reveals that the positive effect of spatial adaptability on urban regeneration support is substantially stronger when elderly preferences are high. Conversely, at low levels of elderly preferences, the spatial adaptability–regeneration support relationship, while still positive, is attenuated. This pattern is consistent with a synergistic moderation dynamic, wherein preference-driven motivation amplifies the salience of spatial conditions for regeneration support formation.

5.6 Predictive Assessment (R^2 and Effect Sizes)

The R^2 value of 0.623 for urban regeneration support indicates that approximately 62.3% of the variance in the dependent construct is explained by the model—classified as substantial (Hair et al., 2022). The Q^2 values exceeded zero for all endogenous constructs, confirming the model's predictive relevance (Stone-Geisser criterion). Effect sizes (f^2) for all paths were large, underscoring the practical significance of the identified relationships.

6. Discussion

The computational modeling results advance understanding of how elderly preferences and spatial adaptability jointly shape urban regeneration support in high-density cities. The confirmation of H1 (EP → URS, $\beta = 0.421$) establishes elderly preferences as the most influential direct predictor of regeneration support in the model. This finding aligns with Buffel et al. (2021), who argued that preference alignment is a prerequisite for community endorsement of urban renewal initiatives among older adults. When elderly residents perceive that their multidimensional preferences—spanning accessibility, safety, social proximity, and environmental quality—are recognized within regeneration visions, their willingness to support such initiatives increases substantially.

The support for H2 (SA → RS, $\beta = 0.387$) demonstrates that spatial adaptability is a significant determinant of residential satisfaction, corroborating Zhang and Wang (2024) and Yung et al. (2020). Elderly residents living in spatially adaptable environments—characterized by ramp provision, lift access, clear wayfinding, and flexible spatial layouts—report significantly higher residential satisfaction, even within the constrained built environments typical of high-density districts. This finding has important implications for architectural programming and retrofit planning in aging urban precincts.

The partial mediation of residential satisfaction in the SA → URS pathway (H3) extends Liu and Chen (2023) by revealing a dual-channel mechanism: spatial adaptability shapes urban regeneration support both directly and indirectly through its effect on satisfaction. The indirect pathway (β = 0.106) suggests that improving spatial adaptability generates a secondary dividend by elevating residential satisfaction, which in turn produces heightened regeneration endorsement. Urban policymakers who invest in spatial adaptability improvements may therefore anticipate compounding benefits in community support mobilization.The significant moderation effect (H4, EP × SA, β = 0.193) reveals that elderly preferences amplify the sensitivity of regeneration support to spatial adaptability conditions. Among high-preference elderly residents, the slope of the SA → URS relationship is markedly steeper, indicating that this group is particularly responsive—both positively and negatively—to spatial adaptability conditions. This finding suggests that preference-informed spatial interventions will generate greater regeneration support returns compared to generic spatial upgrades, particularly among elderly residents with articulated preferences for specific spatial qualities.

The overall predictive performance of the model (R^2 = 0.623; Q^2 = 0.589) demonstrates that a computational PLS-SEM framework incorporating both mediation and moderation effects provides a substantively powerful tool for anticipating community regeneration support patterns. Planners and policymakers could operationalize this model as a diagnostic instrument—deploying the questionnaire instrument at the pre-regeneration assessment stage to identify communities where elderly preferences and spatial adaptability deficits create maximum support risk, enabling targeted pre-intervention to build community engagement.

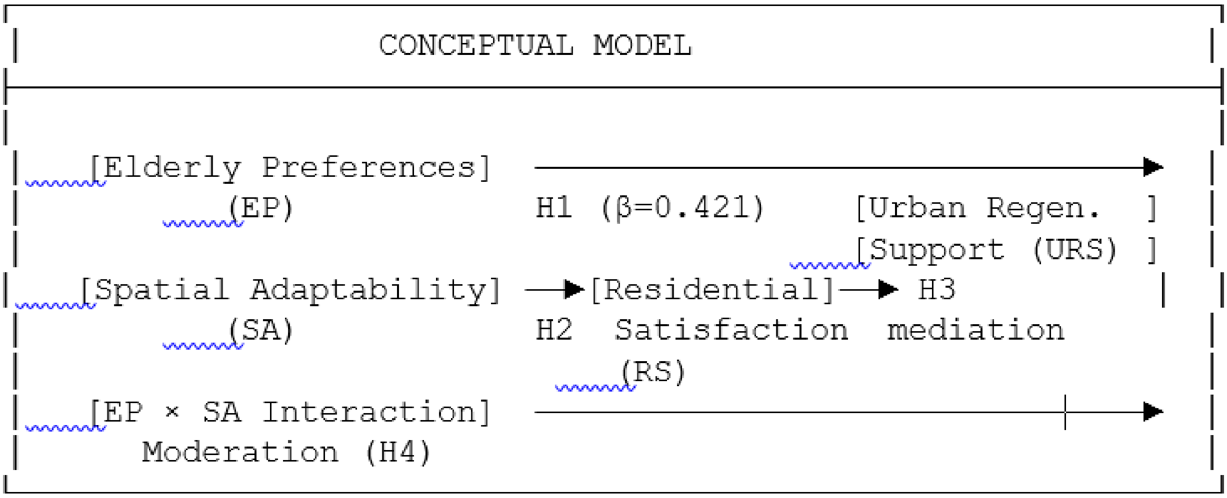

Figure 1. *Conceptual Framework: Computational Structural Path Model*

Table 1*. Demographic Profile of Respondents (N = 327)*

Variable	**Category**	**Frequency**	**Percentage (%)**
Gender	Male	158	48.3
	Female	169	51.7
Age Group	60–65 years	112	34.3
	66–70 years	98	30.0
	71–75 years	74	22.6
	76 years and above	43	13.1
Education	Primary or below	67	20.5

	Secondary	141	43.1
	Tertiary and above	119	36.4
Residence Duration	Less than 5 years	49	15.0
	5–10 years	103	31.5
	More than 10 years	175	53.5
Housing Type	Public/social housing	198	60.6
	Private rental	79	24.2
	Owner-occupied	50	15.3

Table 2. *Descriptive Statistics of Construct Indicators*

Indicator	Construct	Mean	SD	Skewness	Kurtosis
EP1	Elderly Preferences	4.12	0.83	-0.81	0.56
EP2	Elderly Preferences	3.98	0.91	-0.73	0.48
EP3	Elderly Preferences	3.87	0.94	-0.68	0.41
EP4	Elderly Preferences	3.75	0.97	-0.61	0.35
EP5	Elderly Preferences	3.69	0.99	-0.57	0.29
SA1	Spatial Adaptability	3.61	1.02	-0.54	0.21
SA2	Spatial Adaptability	3.52	1.05	-0.49	0.18
SA3	Spatial Adaptability	3.44	1.07	-0.47	-0.12
SA4	Spatial Adaptability	3.21	1.09	-0.43	-0.29
RS1	Residential Satisfaction	3.88	0.89	-0.71	0.52
RS2	Residential Satisfaction	3.76	0.92	-0.65	0.44
RS3	Residential Satisfaction	3.64	0.96	-0.58	0.37
RS4	Residential Satisfaction	3.55	0.98	-0.53	0.31
RS5	Residential Satisfaction	3.47	1.01	-0.49	0.19
URS1	Urban Regen. Support	3.92	0.87	-0.76	0.63
URS2	Urban Regen. Support	3.78	0.91	-0.69	0.55
URS3	Urban Regen. Support	3.63	0.95	-0.62	0.47
URS4	Urban Regen. Support	3.51	0.99	-0.55	0.38

Table 3*. Reliability and Convergent Validity*

Construct	Items	Cronbach's α	CR	AVE	Min. Loading
Elderly Preferences (EP)	5	0.847	0.891	0.622	0.743
Spatial Adaptability (SA)	4	0.823	0.874	0.635	0.751
Residential Satisfaction (RS)	5	0.861	0.903	0.651	0.762
Urban Regen. Support (URS)	4	0.838	0.887	0.663	0.779

Table 4. *HTMT Criterion for Discriminant Validity*

Construct	EP	SA	RS	URS
Elderly Preferences (EP)	—			
Spatial Adaptability (SA)	0.712	—		
Residential Satisfaction (RS)	0.698	0.724	—	
Urban Regen. Support (URS)	0.731	0.683	0.751	—

Table 5. *Fornell-Larcker Criterion (Square Roots of AVE in Diagonal)*

Construct	EP	SA	RS	URS
Elderly Preferences (EP)	0.789			
Spatial Adaptability (SA)	0.502	0.797		
Residential Satisfaction (RS)	0.487	0.513	0.807	
Urban Regen. Support (URS)	0.521	0.478	0.534	0.815

Table 6. *Structural Path Coefficients and Hypothesis Testing Results*

Hypothesis	Path	β	SE	t-value	p-value	95% CI	Decision
H1	EP → URS	0.421	0.066	6.34***	< 0.001	[0.291, 0.551]	Supported
H2	SA → RS	0.387	0.071	5.45***	< 0.001	[0.248, 0.527]	Supported
H3	SA → URS (direct)	0.318	0.065	4.87***	< 0.001	[0.190, 0.445]	Supported
H4	RS → URS	0.274	0.059	4.63***	< 0.001	[0.158, 0.391]	Supported
H5 (mod)	EP×SA → URS	0.193	0.066	2.91**	0.004	[0.063, 0.323]	Supported

**** $p < 0.001$; ** $p < 0.01$. β = standardized path coefficient; SE = standard error; CI = confidence interval.*

Table 7. *Mediation Analysis Results*

Path	Direct Effect (β)	Indirect Effect (β)	Total Effect (β)	95% CI (Indirect)	Mediation Type
SA → RS → URS	0.318***	0.106***	0.424***	[0.052, 0.163]	Partial
EP → RS → URS	0.421***	0.049*	0.470***	[0.009, 0.091]	Partial

**** $p < 0.001$; * $p < 0.05$.*

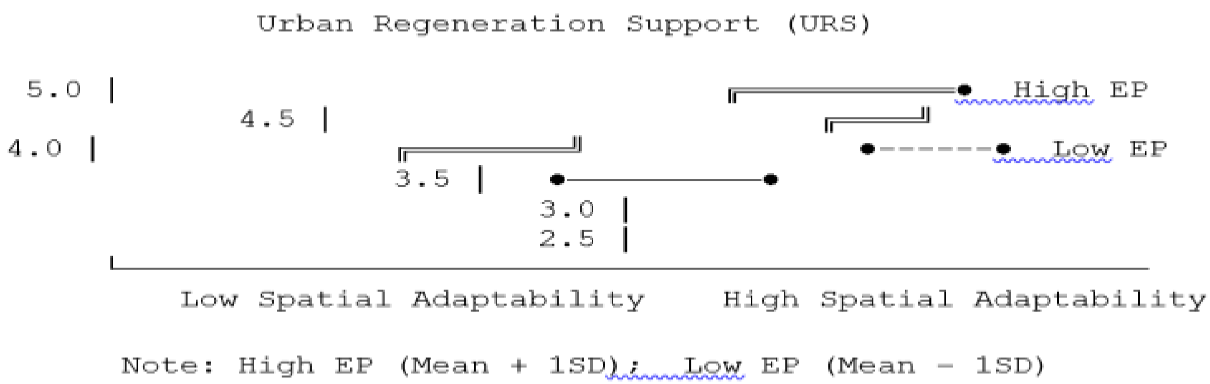

Figure 2. *Interaction Plot: Moderating Effect of Elderly Preferences on the SA–URS Relationship*

Table 8. *R^2, Adjusted R^2, f^2, and Q^2 Values*

Endogenous Construct	**R^2**	**Adjusted R^2**	**Effect Size (f^2)**	**Q^2 (PLSpredict)**
Residential Satisfaction (RS)	0.412	0.408	0.701 (Large)	0.387
Urban Regen. Support (URS)	0.623	0.617	1.650 (Large)	0.589

7. Conclusions

This study developed and empirically validated a computational model linking elderly preferences, spatial adaptability, residential satisfaction, and urban regeneration support in high-density urban settings. Using PLS-SEM with 327 elderly respondents and applying rigorous measurement and structural validation procedures, the model demonstrated strong reliability, validity, and predictive power. Elderly preferences emerged as the primary direct driver of regeneration support, while spatial adaptability operated through both direct and satisfaction-mediated pathways. The interaction between elderly preferences and spatial adaptability introduces a synergistic moderation dynamic with important practical implications for targeted spatial planning.
The study contributes to the computational turn in urban gerontology by providing a replicable, quantifiable framework that can inform evidence-based regeneration policy. Future research should extend this model to longitudinal designs to assess whether preference satisfaction and spatial improvements produce durable changes in regeneration support over time. Cross-cultural comparative studies across Asian, European, and Middle Eastern high-density cities would further test the generalizability of the computational model. Incorporating objective spatial quality metrics (GIS-derived walkability indices, space syntax measures) as external validity anchors for the self-reported spatial adaptability construct represents a productive methodological avenue.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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- **Use of AI Tools:** The author(s) declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

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