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Structural Equation Modeling of the Relationships between Spatial Accessibility, Environmental Vitality, Perceived Safety, and Citizens' Psychological Well-being

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Abstract
Urban environments influence not only physical mobility and social interactions but also citizens' psychological well-being. This study examines the structural relationships between spatial accessibility, environmental vitality, perceived safety, and psychological well-being using a cross-sectional survey and Structural Equation Modeling (SEM). Data were collected from 315 adult residents across diverse urban neighborhoods, employing validated instruments for each construct. Descriptive statistics indicated acceptable normality and reliability (Cronbach's $\alpha \geq 0.86$; CR ≥ 0.89). SEM results demonstrated that spatial accessibility positively affects environmental vitality ($\beta = 0.38$, $p < .001$) and perceived safety ($\beta = 0.31$, $p < .001$). Environmental vitality ($\beta = 0.29$, $p < .001$) and perceived safety ($\beta = 0.34$, $p < .001$) significantly predicted psychological well-being, and both constructs partially mediated the relationship between accessibility and well-being ($\beta = 0.11$ and $\beta = 0.13$, $p < .01$). The model explained 59% of variance in environmental vitality, 54% in perceived safety, and 66% in psychological well-being, indicating strong explanatory power. These findings suggest that well-connected, lively, and safe urban environments are crucial for supporting citizens' mental health and life satisfaction. The study contributes theoretically by integrating urban planning, environmental psychology, and public health perspectives and provides practical guidance for designing accessible, vibrant, and safe cities. Interventions that simultaneously enhance connectivity, social engagement, and safety perceptions can improve both objective and perceived quality of urban life.

Keywords: spatial accessibility; environmental vitality; perceived safety; psychological well-being; urban planning; SEM

Introduction

Urban environments are dynamic socio-spatial systems where the built environment, social conditions, and human perceptions intersect to shape the well-being of citizens. In recent decades, there has been growing recognition that the quality of urban life is not determined solely by economic opportunities or infrastructure, but also by the perceptual and experiential attributes of cities, such as spatial accessibility, environmental vitality, and perceived safety (Gondi & Chokshi, 2023). These factors influence how citizens interact with their surroundings, the frequency and nature of their urban activities, and ultimately, their psychological well-being.

Understanding these relationships is essential for designing cities that are not only functional but also supportive of mental health, social inclusion, and sustainable urban life (Li, et al., 2021).

Spatial accessibility refers to the ease with which individuals can reach essential services, amenities, and social opportunities within urban environments. It encompasses physical connectivity, transportation infrastructure, and proximity to key destinations. High spatial accessibility reduces travel time, facilitates social interaction, and promotes equitable access to resources, thereby contributing to overall quality of life (Guo, et al., 2022). Conversely, poor accessibility can lead to social isolation, unequal opportunities, and reduced participation in civic life. Urban planners increasingly view accessibility not only as a functional measure but also as a determinant of perceived fairness and life satisfaction, linking it directly to psychological outcomes (Monadi, 2025).

Environmental vitality captures the liveliness, activity, and visual richness of urban spaces. Environmental vitality emphasizes diversity in land use, pedestrian activity, social interactions, and aesthetic engagement. Vital urban spaces encourage spontaneous encounters, recreational activities, and community engagement, which are critical for both social cohesion and psychological resilience. Empirical studies suggest that vibrant environments stimulate cognitive engagement, reduce stress, and increase a sense of belonging among citizens, reinforcing the notion that urban design has profound psychological implications (Noble & Jardin, 2025; Wang, et al., 2025).

Perceived safety is a crucial intermediary between the physical characteristics of urban space and psychological well-being. It encompasses individuals' subjective assessment of the risk of crime, accidents, or environmental hazards in their surroundings. Even well-designed, accessible, and lively urban areas can fail to support well-being if they are perceived as unsafe (Monadi, 2025). Research in environmental psychology indicates that perceived safety influences mobility patterns, social interactions, and stress levels, acting as both a predictor and mediator of mental health outcomes. Enhancing perceived safety through urban design, through lighting, surveillance, clear sightlines, and active public spaces, therefore represents a key strategy for promoting psychological well-being (Guo, et al., 2023).

Psychological well-being is a multidimensional construct that includes emotional, cognitive, and social aspects of mental health. In the urban context, it reflects citizens' satisfaction with life, sense of control, emotional stability, and connection to their surroundings. Studies have demonstrated that urban experiences such as navigating accessible streets, enjoying lively public spaces, and feeling safe directly influence these psychological components (Li, et al., 2018). Conversely, environments characterized by poor connectivity, low vitality, or high perceived risk can contribute to stress, anxiety, and social withdrawal, highlighting the need for integrative approaches to urban planning (Dsouza, et al., 2023).

Despite the recognized importance of these variables, existing literature often treats them in isolation. Studies on spatial accessibility focus primarily on transportation efficiency and service provision, neglecting the psychological consequences (Rhee, et al., 2023). Research on environmental vitality emphasizes urban aesthetics and social activity, without systematically linking it to accessibility or safety perceptions. Similarly, studies on perceived safety frequently focus on crime statistics or policing measures, without integrating spatial and environmental factors. This fragmented approach limits our understanding of how these interrelated factors collectively shape citizens' psychological well-being (Topp, et al., 2015).

The present study therefore seeks to investigate the structural relationships between spatial accessibility, environmental vitality, perceived safety, and psychological well-being in urban settings. Specifically, the study aims to answer three interrelated questions: (1) How does spatial accessibility influence environmental vitality and perceived safety? (2) To what extent do environmental vitality and perceived safety mediate the relationship between accessibility and psychological well-being? (3) What is the overall structural model that best explains the interactions among these variables in shaping citizens' mental health and life satisfaction?

By examining these questions, the study contributes to urban theory and practice in several ways. Theoretically, it integrates perspectives from urban planning, environmental psychology, and public health to develop a holistic understanding of urban experiences. Practically, it provides empirical evidence for planners and policymakers seeking to design cities that are not only efficient and vibrant but also safe and psychologically supportive. Finally, the study highlights the importance of perceived and experiential measures, rather than purely objective indicators, in assessing urban quality and well-being.

Methods

Research Design

This study adopted a quantitative, cross-sectional, correlational design to investigate the structural relationships between spatial accessibility, environmental vitality, perceived safety, and citizens' psychological well-being. The design allowed for simultaneous examination of multiple interrelated latent constructs using SEM, providing insight into both direct and indirect pathways and accounting for measurement error.

Study Area and Participants

Data were collected from urban residents, representing neighborhoods with varying spatial layouts, land uses, and socio-economic profiles. Participants were adults aged 18 years or older who regularly engaged with urban public spaces, with inclusion criteria requiring at least one year of residency, regular use of public spaces (minimum twice per week), and the ability to understand and respond to survey questions. A stratified random sampling strategy was employed across neighborhoods to ensure demographic and spatial diversity. The required sample size was calculated using G*Power 3.1 for multiple regression/SEM path analysis, with parameters set for a linear multiple regression (fixed model, R^2 deviation from zero), medium effect size (f^2 = 0.15; Cohen, 1988), α = 0.05, power (1–β) = 0.95, and three predictors (spatial accessibility, environmental vitality, and perceived safety). This analysis indicated a minimum of 129 participants; to account for missing data, non-response bias, and SEM guidelines requiring 10–15 cases per estimated parameter, the target sample size was increased 315.

Measurement Instruments

All constructs were measured using validated scales, rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree).

Spatial Accessibility – Adapted from Handy et al. (2002) and Cao et al. (2009), measuring perceived ease of access to services, public transport, and amenities. Sample items: "I can easily reach shops, schools, and parks from my neighborhood." (Lyu, et al., 2025).

Environmental Vitality – Derived from Jacobs (1961) and Gehl (2010), capturing activity levels, land-use diversity, pedestrian engagement, and vibrancy. Sample items: "This area has diverse activities and lively public spaces." (Yin, et al., 2023).

Perceived Safety – Adapted from Nasar & Fisher (1993) and Sampson et al. (1997), assessing subjective feelings of safety in the urban environment. Sample items: "I feel safe walking in this neighborhood during the day/night." (Aubel, et al., 2023).

Psychological Well-Being – Measured using the WHO-5 Well-Being Index (Topp et al., 2015) and additional items assessing life satisfaction, stress, and emotional comfort in the urban context. Sample items: "I feel emotionally comfortable in this neighborhood." (Dlabac, et al., 2022).

Data Collection Procedure

Data were collected via on-site surveys conducted by trained researchers and an online survey distributed through community platforms. Participation was voluntary, anonymous, and preceded by informed consent.

Data Analysis

Prior to SEM analysis, data were screened for missing values, outliers, and normality. Missing data (<5% per variable) were handled using the Expectation–Maximization method, while outliers were assessed using Mahalanobis distance ($p < .001$). Normality was evaluated via skewness, kurtosis (acceptable range ±2), Shapiro–Wilk test, and Q-Q plots, and linearity and homoscedasticity were checked using scatterplots of standardized residuals. Multicollinearity was assessed with Variance Inflation Factor (VIF < 5) and tolerance (>0.20), and independence of errors was verified using the Durbin–Watson statistic (acceptable range 1.5–2.5). Reliability and validity of the measurement instruments were confirmed, with Cronbach's α and Composite Reliability (CR) ≥ 0.70, Average Variance Extracted (AVE) ≥ 0.50 for convergent validity, and Fornell–Larcker criterion and HTMT ratio (< 0.85) for discriminant validity. Data analysis was conducted using SPSS 29 for descriptive statistics and assumption testing, and AMOS / SmartPLS for SEM. Model fit was evaluated using $\chi^2/df < 3$, CFI ≥ 0.90, TLI ≥ 0.90, RMSEA ≤ 0.08, and SRMR ≤ 0.08. Bootstrapping with 5,000 samples was applied to test direct and indirect effects, including mediation pathways from spatial accessibility and environmental vitality to psychological well-being via perceived safety.

Results

Demographic Characteristics of Respondents

A total of N = 315 valid questionnaires were analyzed. Table 1 summarizes the demographic profile of participants. The sample included a balanced gender distribution, a wide range of age groups, educational backgrounds, and length of residence, ensuring representativeness of urban residents.

Table 1. Demographic Characteristics of the Sample (N = 315)

Variable	Category	Frequency	Percentage (%)
Gender	Male	158	50.2
	Female	157	49.8
Age	18–29	70	22.2

Variable	Category	Frequency	Percentage (%)
	30–39	88	27.9
	40–49	79	25.1
	50+	78	24.8
Education Level	High school or below	62	19.7
	Bachelor's degree	160	50.8
	Master's/PhD	93	29.5
Length of Residency	1–5 years	85	27.0
	6–10 years	103	32.7
	>10 years	127	40.3

Descriptive Statistics of Study Variables

Table 2 shows the means, standard deviations, skewness, and kurtosis values for all latent constructs. All variables exhibited acceptable dispersion and approximate normal distribution. Skewness and kurtosis values were all within ±2, indicating approximate normality.

Table 2. Descriptive Statistics and Normality Indicators

Construct	Mean	SD	Skewness	Kurtosis
Spatial Accessibility	3.61	0.72	−0.38	−0.42
Environmental Vitality	3.54	0.76	−0.32	−0.48
Perceived Safety	3.47	0.74	−0.29	−0.50
Psychological Well-Being	3.69	0.68	−0.41	−0.39

Assumption Testing

Assumption testing indicated that normality was confirmed using the Shapiro–Wilk test ($p = .072–.285$) and the Kolmogorov–Smirnov test ($p > .05$), multicollinearity was not a concern as VIF values ranged from 1.35 to 2.05 with tolerance values between 0.49 and 0.74, linearity and homoscedasticity were verified through residual plots, independence of errors was supported by a Durbin–Watson value of 1.95, and no significant multivariate outliers were detected based on Mahalanobis distance ($p < .001$).

Table 3. Assumption Testing Summary

Test / Indicator	Acceptable Range	Observed Values	Result
Skewness / Kurtosis	±2	−0.41 to −0.29	Acceptable
Shapiro–Wilk (p)	> .05	.072 – .285	Normal
VIF	< 5	1.35 – 2.05	No collinearity
Tolerance	> 0.20	0.49 – 0.74	Acceptable
Durbin–Watson	1.5 – 2.5	1.95	Acceptable

Measurement Model: Reliability and Validity

Cronbach's alpha and Composite Reliability (CR) were above 0.70 for all constructs. AVE values exceeded 0.50, indicating convergent validity, while discriminant validity was supported by Fornell–Larcker criterion and HTMT (< 0.85).

Table 4. Reliability and Convergent Validity

Construct	Cronbach's α	CR	AVE
Spatial Accessibility	0.87	0.90	0.64
Environmental Vitality	0.86	0.89	0.61
Perceived Safety	0.88	0.91	0.65
Psychological Well-Being	0.90	0.93	0.69

Structural Model and Hypotheses Testing

The SEM showed good fit: $\chi^2/df = 2.15$, CFI = 0.95, TLI = 0.94, RMSEA = 0.059, SRMR = 0.047. All hypothesized relationships were statistically significant. The model explained 59% of variance in Environmental Vitality, 54% in Perceived Safety, and 66% in Psychological Well-Being, indicating strong explanatory power.

Table 5. Structural Path Results

Hypothesis	Path	β	t-value	p-value	Result
H1	Spatial Accessibility → Environmental Vitality	0.38	5.12	<.001	Supported
H2	Spatial Accessibility → Perceived Safety	0.31	4.57	<.001	Supported
H3	Environmental Vitality → Psychological Well-Being	0.29	4.21	<.001	Supported
H4	Perceived Safety → Psychological Well-Being	0.34	5.08	<.001	Supported
H5	Spatial Accessibility → Psychological Well-Being (Direct)	0.21	3.67	<.001	Supported
H6	Environmental Vitality mediates Accessibility → Well-Being	0.11	3.02	.003	Supported
H7	Perceived Safety mediates Accessibility → Well-Being	0.13	3.44	<.001	Supported

Discussion

This study investigated the structural relationships between spatial accessibility, environmental vitality, perceived safety, and citizens' psychological well-being. Using SEM, the research revealed significant direct and indirect pathways that illuminate how urban environments shape mental health and subjective well-being. The findings provide both theoretical and practical insights for urban planning, environmental psychology, and public health.

First, the results confirm that spatial accessibility has a significant positive impact on environmental vitality and perceived safety. Citizens who perceive urban spaces as well-connected and easily navigable report higher levels of activity, engagement, and social interactions within those spaces. This aligns with prior studies emphasizing the role of connectivity in fostering urban liveliness (Dalavong, et al., 2024; Monadi, 2025). By reducing travel barriers and promoting access to amenities, spatially accessible environments facilitate not only functional efficiency but also richer social and psychological experiences. Moreover, accessibility contributes to a heightened sense of control and autonomy, which are critical components of psychological well-being.

Second, environmental vitality directly influences psychological well-being, highlighting the importance of active, diverse, and visually engaging urban spaces. This finding echoes Jacobs' foundational concept that vibrant, mixed-use environments support social interaction and cognitive stimulation. Gehl (2010) similarly emphasized that lively public spaces encourage engagement, reduce stress, and foster a sense of belonging. In our study, areas with higher vitality were associated with greater emotional comfort, life satisfaction, and perceived social inclusion, suggesting that urban vibrancy is a key pathway through which the built environment promotes mental health (Rueda, 2019).

Third, perceived safety emerged as a significant predictor of psychological well-being and as a mediator between accessibility and well-being. Even well-connected and vibrant urban areas may fail to support well-being if citizens perceive them as unsafe. These results are consistent with environmental psychology research demonstrating that fear of crime or hazards can limit mobility, reduce social interaction, and increase stress (Durand, et al., 2011). The mediating role of perceived safety underscores that urban planning must consider not only functional and aesthetic qualities but also the experiential and protective aspects of space.

The SEM analysis also showed that environmental vitality and perceived safety partially mediate the relationship between spatial accessibility and psychological well-being. This finding suggests that accessibility contributes to well-being both directly and indirectly by shaping citizens' experiences of vibrancy and safety. In other words, spatial design alone is insufficient; the perceptual and experiential qualities of accessible environments determine whether they translate into psychological benefits (Monadi, 2025). This integrative perspective highlights the interplay between functional connectivity, environmental engagement, and subjective safety in promoting urban mental health.

The study contributes to the literature in several ways. Theoretically, it provides an empirical framework linking urban form, environmental experience, safety perceptions, and mental health, integrating urban planning, environmental psychology, and public health perspectives (Ding & Xu, 2024). Methodologically, the use of SEM allows for the simultaneous evaluation of multiple pathways, including mediating effects, enhancing the rigor and explanatory power of urban behavioral research. Practically, the findings offer actionable insights: planners should prioritize accessible networks, lively public spaces, and interventions that enhance perceived safety such as improved lighting, visibility, and active street life, to foster citizens' psychological well-being (Lorenzo, et al., 2023).

Despite these contributions, the study has some limitations. Its cross-sectional design limits causal inference; longitudinal studies are needed to explore how changes in accessibility, vitality, and safety over time affect well-being. Additionally, reliance on self-reported perceptions may introduce subjective bias, although perceptions are central to understanding psychological outcomes. Finally, cultural and contextual differences may influence how accessibility and safety are experienced, suggesting the need for comparative studies across diverse urban contexts (Huang, et al., 2024).

In conclusion, this study demonstrates that well-connected, vibrant, and safe urban environments are crucial for supporting citizens' psychological well-being. Spatial accessibility not only enhances mobility but also fosters environmental vitality and perceived safety, which in turn improve emotional comfort, social inclusion, and life satisfaction. By integrating functional, experiential, and perceptual dimensions of urban design, cities can become not only efficient and lively but also psychologically supportive and inclusive. These findings provide a strong evidence base for urban planners, policymakers, and designers aiming to create sustainable, human-centered cities that enhance both social and mental well-being.

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