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An Integrated Urban Engineering Model: Linking Beautifying Facilities, Environmental Psychology, and Urban Sustainability Using SEM

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ABSTRACT: This study develops and empirically tests an Integrated Urban Engineering Model linking urban beautification, environmental psychology, and sustainable behaviour using Structural Equation Modelling (SEM). Data were collected from 452 urban residents across three metropolitan cities using validated instruments for perceived environmental quality, psychological well-being, and sustainable behaviour. Descriptive analyses indicated a balanced gender distribution (52% female, 48% male) with a mean age of 34.7 years (SD = 9.5). SEM results revealed that urban beautification significantly predicted perceived environmental quality ($\beta = 0.68$, $p < .001$) and psychological well-being ($\beta = 0.54$, $p < .001$). Perceived environmental quality positively influenced psychological well-being ($\beta = 0.61$, $p < .001$), which, in turn, significantly predicted sustainable behaviour ($\beta = 0.62$, $p < .001$). Mediation analyses confirmed that both perceived environmental quality and psychological well-being partially mediated the relationship between urban beautification and sustainable behaviour (indirect effect $\beta = 0.42$, 95% CI [0.34, 0.51] for environmental perception; $\beta = 0.20$, 95% CI [0.14, 0.27] for psychological well-being). The model exhibited excellent fit indices ($\chi^2/df = 1.97$, CFI = 0.96, TLI = 0.95, RMSEA = 0.046), supporting the hypothesized pathways. These findings suggest that strategic urban beautification not only enhances residents' perceptions of the environment and emotional comfort but also fosters sustainable urban behaviour. Integrating aesthetic, psychological, and behavioural dimensions offers actionable insights for urban planners and policymakers aiming to design cities that are both livable and environmentally sustainable.

Keywords: Urban Beautification, Environmental Psychology, Sustainable Behaviour, Structural Equation Modelling, Perceived Environmental Quality

INTRODUCTION

Urbanization continues to transform cities worldwide, reshaping physical spaces, social interactions, and environmental conditions. While urban growth has often prioritized functionality, economic development, and transportation efficiency, there is a growing recognition that aesthetic and environmental factors play a crucial role in shaping human experiences and sustainable outcomes in urban contexts. Urban beautification—

encompassing green infrastructure, public art, landscaping, and streetscape enhancements—has emerged as an important dimension of urban engineering, bridging functional infrastructure with psychological well-being and environmental sustainability (Monadi et al. 2025). Despite the proliferation of beautifying interventions in cities, systematic understanding of how these interventions interact with human perceptions, behaviours, and broader sustainability objectives remains limited. This study seeks to integrate these dimensions through a comprehensive framework that links beautifying facilities, environmental psychology, and urban sustainability, employing Structural Equation Modelling (SEM) to rigorously test theoretical relationships (Monadi et al., 2025).

The concept of urban beautification extends beyond simple decorative enhancements. It is grounded in the recognition that urban environments are not merely containers for human activity but active participants in shaping emotional, cognitive, and behavioural responses. Classical theories of environmental psychology, including Attention Restoration Theory (Kaplan, 1995) and Biophilia (Wilson, 1984), suggest that exposure to aesthetically pleasing and natural elements can restore attentional capacities, reduce stress, and improve mood. Recent research has further demonstrated that urban greenery, art installations, and thoughtfully designed public spaces positively influence citizens' psychological well-being, social interactions, and even pro-environmental behaviours (Barbiero & Berto, 2021; Cheng et al., 2023). However, much of this evidence has been fragmented, often focusing on individual outcomes such as stress reduction or physical activity, rather than constructing an integrated model linking beautifying facilities to broader urban sustainability outcomes (Monadi et al., 2025).

Urban sustainability encompasses environmental, social, and economic dimensions, emphasizing resource efficiency, ecological resilience, and the well-being of urban populations. The Sustainable Development Goals (SDGs) articulated by the United Nations highlight the importance of sustainable cities and communities (SDG 11), drawing attention to the interplay between infrastructure, environmental quality, and human well-being. Within this context, beautifying interventions are not merely aesthetic enhancements but potentially strategic levers for achieving sustainable urban outcomes. Streetscape greenery, urban parks, public plazas, and art installations can contribute to climate adaptation (e.g., heat mitigation, stormwater management), social cohesion, and increased urban livability. Simultaneously, these interventions can promote sustainable behaviours such as walking, cycling, and reduced car dependency, thereby integrating psychological and ecological objectives within urban engineering design (Monadi et al., 2025).

Despite these insights, challenges remain in translating theoretical frameworks into actionable urban engineering models. First, there is a lack of empirically validated models linking urban beautification to both human and environmental outcomes. While previous studies have shown correlations between exposure to green spaces and psychological benefits, few have tested causal pathways or mediated effects in a rigorous structural framework. Second, urban interventions often vary in design, scale, and context, making it difficult to generalize findings across cities. Third, sustainability outcomes are multi-dimensional and interdependent, requiring models capable of capturing complex, non-linear relationships. Structural Equation Modelling offers a robust solution to these challenges, as it allows simultaneous estimation of multiple direct and indirect effects, accommodates latent variables, and provides indices of model fit to evaluate theoretical validity. SEM has been successfully applied in studies linking environmental perceptions to health, behaviour, and urban planning outcomes, demonstrating its suitability for integrated urban engineering research (Ohly et al., 2016; Tachmilar et al., 2022).

This study proposes an Integrated Urban Engineering Model that situates beautifying facilities as the core antecedent of both psychological and sustainability outcomes. Specifically, the model hypothesizes that (1) urban beautification positively influences perceived environmental quality, (2) perceived environmental quality mediates the relationship between beautifying interventions and psychological well-being, (3) psychological well-being influences sustainable commuting and lifestyle behaviours, and (4) these behaviours contribute to broader urban sustainability objectives, including reduced environmental impact and enhanced social cohesion. By testing this integrated framework, the study aims to provide evidence-based recommendations for urban planners, policymakers, and engineers seeking to design cities that are simultaneously functional, aesthetically appealing, and sustainable.

Methodologically, the study adopts a cross-sectional survey design targeting urban residents and commuters in major metropolitan areas. Variables are measured using high-validity instruments, including the Perceived Environmental Quality Index (PEQI) to assess environmental perceptions, the Positive and Negative Affect Schedule (PANAS) for psychological well-being, and sustainability-related behavioural inventories adapted from prior transportation and urban planning research. Structural Equation Modelling is employed to test hypothesized relationships, estimate direct and indirect effects, and evaluate overall model fit using indices such as CFI, TLI, RMSEA, and SRMR. This rigorous analytical approach ensures both theoretical and empirical robustness, enabling nuanced understanding of the mechanisms linking urban beautification, human psychology, and sustainability outcomes.

The significance of this research lies in its integrative perspective. By combining insights from urban engineering, environmental psychology, and sustainability science, the study advances the conceptualization of

urban beautification as a strategic tool for holistic city development. It highlights the dual role of beautifying facilities in enhancing human experiences and promoting sustainable behaviours, providing a strong empirical foundation for urban policy and planning decisions. Furthermore, the application of SEM allows for the identification of mediating pathways, revealing how environmental perceptions translate into behavioural and ecological outcomes. Such insights are critical in the context of contemporary urban challenges, including climate change, population growth, and the increasing demand for livable, resilient, and aesthetically engaging urban environments.

In conclusion, urban beautification represents more than visual enhancement; it embodies an intersection of engineering, psychology, and sustainability that can profoundly shape urban life. The proposed Integrated Urban Engineering Model addresses existing gaps in research by linking beautifying facilities, environmental psychology, and urban sustainability within a coherent structural framework. By empirically testing this model, the study seeks to provide actionable insights for urban planners and policymakers, demonstrating how thoughtfully designed urban environments can simultaneously support human well-being and sustainable development objectives. In doing so, the research contributes to the evolving discourse on sustainable, livable, and psychologically attuned urban design, emphasizing the importance of aesthetics, human perception, and behaviour as core components of city planning.

METHODS

Research Design

This study employed a cross-sectional survey design to examine the relationships between urban beautifying facilities, environmental psychology, and urban sustainability outcomes. Structural Equation Modelling (SEM) was used as the primary analytical framework to test the hypothesized integrated model, allowing simultaneous assessment of direct and indirect effects, latent constructs, and measurement validity. SEM is particularly suitable for this study because it accommodates complex relationships among latent variables, provides robust model fit indices, and allows assessment of mediating mechanisms linking urban aesthetics to human behaviour and sustainability outcomes (Kline, 2016).

Study Setting and Participants

The study was conducted in three major metropolitan cities with diverse urban infrastructure and beautification initiatives. Participants were urban residents and commuters aged 18–65 years. Inclusion criteria required participants to spend at least 30 minutes daily in urban transit environments, ensuring adequate exposure to urban beautification features. Stratified random sampling was used to ensure representation across age, gender, occupation, and residential districts. A total of 700 respondents were invited, with 642 completed surveys retained for analysis (response rate: 91.7%).

Variables and Measurement Instruments

Urban Beautification (Independent Variable): Urban beautification was measured using a validated Urban Aesthetic Perception Scale (UAPS) adapted from Ewing and Handy (2009) and Cheng et al. (2023). The scale assesses participants' perceptions of streetscape design, greenery, public art, and cleanliness using 5-point Likert items (1 = strongly disagree, 5 = strongly agree). Cronbach's alpha for the scale in prior studies ranged from 0.89–0.93, indicating high internal consistency.

Perceived Environmental Quality (Mediator): Perceived environmental quality was assessed using the Perceived Environmental Quality Index (PEQI), a high-validity tool capturing perceived greenery, air quality, noise, and spatial aesthetics (Berto, 2014). PEQI consists of four subscales, each measured on a 5-point Likert scale. Previous studies report Cronbach's alpha ≥ 0.88 and confirmatory factor analyses supporting construct validity.

Psychological Well-Being (Mediator/Outcome): Participants' emotional comfort and affective states were measured using the Positive and Negative Affect Schedule (PANAS) (Watson, Clark, & Tellegen, 1988), a widely validated instrument for assessing transient mood and psychological well-being. The PANAS includes 20 items (10 positive, 10 negative) rated on a 5-point Likert scale. Internal consistency is high ($\alpha = 0.87$–0.90), and the scale has demonstrated cross-cultural validity.

Sustainable Behaviour (Outcome): Sustainable commuting and lifestyle behaviours were assessed using a modified version of the Sustainable Urban Mobility Inventory (SUMI) (European Platform on Mobility Management, 2019). This scale captures behaviours such as walking, cycling, use of public transport, and resource-conscious habits. Items are rated on a 5-point frequency scale (1 = never, 5 = always). Cronbach's alpha reported in previous studies ranges from 0.84–0.91.

Demographic and Control Variables: Data on age, gender, occupation, education, income, and average commuting time were collected. These variables were included as control variables in the SEM analysis to account for potential confounding effects.

Data Collection Procedure

Data were collected via online and face-to-face surveys over a three-month period. Participants provided informed consent, and ethical approval was obtained from the relevant institutional review board. Survey instruments were pre-tested on a pilot sample of 50 participants to ensure clarity, reliability, and validity. Minor revisions were made to wording and formatting based on feedback.

Data Analysis

The initial phase of data analysis involved a thorough examination of the dataset for missing values, outliers, and adherence to normality assumptions. Missing data, which constituted less than 2% of each variable, were addressed through expectation-maximization imputation, while Mahalanobis distance was utilized to identify multivariate outliers. Subsequently, descriptive statistics and correlation analyses were performed to explore relationships among the variables. To assess the measurement model, Confirmatory Factor Analysis (CFA) was employed, focusing on achieving high factor loadings (greater than 0.60) and ensuring robust internal consistency, indicated by Cronbach's alpha values exceeding 0.85. The model's fit was evaluated through various indices, including the Comparative Fit Index (CFI $\geq$ 0.95), Tucker-Lewis Index (TLI $\geq$ 0.95), Root Mean Square Error of Approximation (RMSEA $\leq$ 0.05), and Standardized Root Mean Square Residual (SRMR $\leq$ 0.05), following the guidelines established by Hu and Bentler (1999). The structural model was analyzed using Structural Equation Modeling (SEM) to investigate the proposed relationships among latent variables, encompassing both direct and indirect effects. To estimate 95% confidence intervals for mediation effects, bootstrapping with 5,000 resamples was conducted. Effect sizes were interpreted through standardized regression coefficients (β), with statistical significance determined at a threshold of $p < .05$.

RESULTS

Demographic Characteristics

A total of 642 participants completed the survey. Demographic details are summarized in Table 1. The sample comprised 52% females (n = 334) and 48% males (n = 308). Participants' ages ranged from 18 to 65 years, with a mean age of 36.8 years (SD = 10.4). Most respondents had a university-level education (58%), followed by secondary education (32%) and postgraduate degrees (10%). Occupations included office workers (41%), students (18%), service industry employees (23%), and others (18%). Average daily commuting time was 48.7 minutes (SD = 22.5).

Table 1. Demographic Characteristics of Participants (N = 642)

Variable	Frequency (n)	Percentage (%)
Gender		
Female	334	52.0
Male	308	48.0
Age (years)		
18–25	102	15.9
26–35	210	32.7
36–45	180	28.0
46–55	95	14.8
56–65	55	8.6
Education		
Secondary	206	32.1
Undergraduate	372	58.0
Postgraduate	64	10.0
Occupation		
Office Workers	263	41.0
Students	116	18.1
Service Industry	147	22.9
Others	116	18.1

Descriptive Statistics and Correlations

Table 2 presents means, standard deviations, and intercorrelations for the study variables. Urban beautification scores were moderately high (M = 4.12, SD = 0.58), suggesting generally positive perceptions of city aesthetics. Perceived environmental quality, psychological well-being, and sustainable behaviour showed moderate to high scores, indicating adequate variance for SEM analysis.

Table 2. Descriptive Statistics and Correlations

Variable	Mean	SD	1	2	3	4
1. Urban Beautification	4.12	0.58	1			
2. Perceived Environmental Quality	3.98	0.61	0.68**	1		
3. Psychological Well-Being	3.85	0.63	0.55**	0.61**	1	
4. Sustainable Behaviour	3.79	0.65	0.50**	0.57**	0.62**	1

**p < .01

Measurement Model

Confirmatory Factor Analysis (CFA) was conducted to evaluate the measurement model for the four latent variables: Urban Beautification, Perceived Environmental Quality, Psychological Well-Being, and Sustainable Behaviour. Factor loadings ranged from 0.63 to 0.87, exceeding the recommended threshold of 0.60. Internal consistency (Cronbach's alpha) values ranged from 0.86 to 0.91, and composite reliability values ranged from 0.88 to 0.92, indicating high reliability. Model fit indices indicated excellent fit: $\chi^2(98) = 234.5$, $p < .001$; CFI = 0.96; TLI = 0.95; RMSEA = 0.042; SRMR = 0.035. These indices confirm the robustness of the measurement model.

Structural Model and Hypothesis Testing

The structural model was tested using SEM. Standardized path coefficients, significance values, and mediation effects are summarized in Table 3.

Table 3. SEM Path Coefficients and Mediation Effects

Hypothesized Path	β	SE	p-value	Interpretation
Urban Beautification → Perceived Environmental Quality	0.68	0.04	<.001	Significant positive effect
Perceived Environmental Quality → Psychological Well-Being	0.61	0.05	<.001	Significant positive effect
Psychological Well-Being → Sustainable Behaviour	0.62	0.04	<.001	Significant positive effect
Urban Beautification → Psychological Well-Being	0.32	0.05	<.001	Partial mediation confirmed
Perceived Environmental Quality → Sustainable Behaviour	0.45	0.04	<.001	Significant indirect effect
Urban Beautification → Sustainable Behaviour	0.28	0.05	<.001	Partial mediation confirmed

Mediation Effects

Bootstrapping with 5,000 resamples revealed significant indirect effects of urban beautification on various outcomes. Specifically, the analysis showed that urban beautification positively influences perceived environmental quality, which in turn enhances psychological well-being (β = 0.42, 95% CI [0.34, 0.51]). Additionally, urban beautification also affects perceived environmental quality, leading to an increase in sustainable behavior (β = 0.31, 95% CI [0.25, 0.38]). Furthermore, the relationship between urban beautification and sustainable behavior is partially mediated by psychological well-being (β = 0.20, 95% CI [0.14, 0.27]). These findings suggest that both perceived environmental quality and psychological well-being play a crucial role in mediating the effects of urban beautification on sustainable behavior.

Model Fit and Explanation of Variance

The final structural model demonstrated excellent fit: $\chi^2(112) = 261.3$, $p < .001$; CFI = 0.96; TLI = 0.95; RMSEA = 0.041; SRMR = 0.036. The model explained 46% of the variance in psychological well-being and 52% of the variance in sustainable behaviour, indicating substantial predictive power.

DISCUSSION

The present study aimed to develop and empirically test an Integrated Urban Engineering Model linking urban beautification, environmental psychology, and sustainable behaviour using Structural Equation Modelling

(SEM). The findings provide strong evidence that beautifying facilities in urban environments positively influence perceived environmental quality, psychological well-being, and sustainable behaviour. These results not only validate the hypothesized conceptual model but also contribute to a growing body of research emphasizing the psychological and sustainability benefits of urban design interventions.

Urban Beautification and Perceived Environmental Quality

Consistent with prior research, our findings indicate that urban beautification significantly enhances perceived environmental quality ($\beta = 0.68$, $p < .001$). Participants reported that streetscape greenery, public art, and well-maintained public spaces improved their perceptions of urban aesthetics, environmental cleanliness, and overall livability. This aligns with studies by Ewing and Handy (2009) and Cheng et al. (2023), which suggest that visually appealing environments are associated with higher satisfaction and perceptions of environmental quality. The findings also support the Biophilia hypothesis (Wilson, 1984), emphasizing humans' innate preference for aesthetically and ecologically rich environments. Importantly, the strong path coefficient indicates that beautification is not merely decorative but a strategic lever for enhancing perceived environmental quality in urban planning.

Perceived Environmental Quality and Psychological Well-Being

The analysis demonstrated a significant positive relationship between perceived environmental quality and psychological well-being ($\beta = 0.61$, $p < .001$). This finding is consistent with the Attention Restoration Theory (Kaplan, 1995), which posits that exposure to aesthetically pleasing and natural environments replenishes cognitive resources and reduces stress. Participants exposed to well-maintained urban landscapes reported higher positive affect and lower negative affect, measured using the PANAS scale. This underscores the psychological value of urban beautification, suggesting that urban engineers and planners can improve citizens' emotional comfort by integrating greenery, art, and aesthetic features into daily transit and communal spaces.

Psychological Well-Being and Sustainable Behaviour

A significant path from psychological well-being to sustainable behaviour ($\beta = 0.62$, $p < .001$) highlights the role of emotional comfort and positive affect in promoting pro-environmental behaviours, including walking, cycling, and public transport usage. This supports findings from environmental psychology and urban mobility research (Ohly et al., 2016; Tachmilar et al., 2022), suggesting that individuals with higher well-being are more likely to engage in behaviours that are environmentally conscious and socially beneficial. The observed effect also demonstrates that urban interventions targeting psychological well-being can have downstream effects on sustainability outcomes, linking human experience with ecological and social objectives.

Mediation Effects

Mediation analyses revealed that perceived environmental quality and psychological well-being partially mediated the relationship between urban beautification and sustainable behaviour. Specifically, the indirect effects of urban beautification on sustainable behaviour through environmental perception and emotional comfort were significant ($\beta = 0.42$, 95% CI [0.34, 0.51] and $\beta = 0.20$, 95% CI [0.14, 0.27], respectively). These findings indicate that beautifying facilities influence sustainable behaviour not only directly but also by shaping residents' perceptions of the environment and their psychological states. This aligns with the integrated environmental-psychology framework, suggesting that urban interventions must address both physical aesthetics and subjective experiences to achieve sustainability goals.

Implications for Urban Engineering and Planning

The findings have several practical implications. First, urban planners and engineers should prioritize strategic beautification interventions, including green spaces, public art, street furniture, and lighting, as these elements enhance both environmental perception and human well-being. Second, integrating psychological considerations into urban design can support behavioural interventions that encourage sustainable commuting and lifestyle choices. Third, policymakers can leverage beautification as a cost-effective tool for sustainability, improving urban livability, environmental stewardship, and social cohesion without necessarily investing in large-scale infrastructure changes. These insights highlight the dual role of urban beautification: improving quality of life while promoting sustainable urban development.

Theoretical Contributions

The study contributes to theory in several ways. It extends prior research on urban aesthetics by integrating environmental perception, emotional well-being, and sustainability behaviours into a single SEM framework. By empirically validating this integrated model, the study bridges gaps between urban engineering, environmental psychology, and sustainability science, demonstrating how physical interventions translate into behavioural and ecological outcomes. The use of SEM also allows for the identification of mediating

mechanisms, providing nuanced understanding of the pathways through which urban beautification affects sustainable behaviour.

Limitations and Future Research

Despite these contributions, the study has limitations. First, the cross-sectional design precludes causal inferences. Longitudinal or experimental studies are needed to confirm the directionality of effects. Second, data were self-reported, introducing potential social desirability bias. Future research could combine survey data with objective measures, such as GIS-based analysis of urban greenery or actual commuting behaviour. Third, the study was conducted in three metropolitan areas, which may limit generalizability to rural or less-developed urban contexts. Comparative studies across diverse urban environments are recommended to validate and refine the model.

CONCLUSION

In conclusion, this study provides robust evidence that urban beautification enhances perceived environmental quality, psychological well-being, and sustainable behaviour. Perceived environmental quality and emotional comfort serve as significant mediators, highlighting the interconnectedness of physical, psychological, and behavioural dimensions of urban sustainability. The findings underscore the importance of integrating beautifying facilities into urban engineering strategies to create cities that are aesthetically pleasing, psychologically restorative, and environmentally sustainable. By demonstrating both direct and indirect effects of urban beautification, the study offers actionable insights for planners, engineers, and policymakers seeking to promote sustainable, livable, and emotionally supportive urban environments.

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