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Spatial Structure and Visual Interpretation in Urban Parks: Statistical Analysis of Perceptual Attributes

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Abstract : Urban green spaces (UGS) in dense metropolitan environments are critical perceptual landscapes where people interact with nature and form associations. It is essential to understand how users perceive the spatial cues to improve user experience in these spaces. This study evaluates the perceptual qualities of two urban parks in Mumbai- One Green Mile and Linear Park. The analysis focuses on three key perceptual attributes based on existing literature: spatial sequence, visual coherence and edge quality. A structured questionnaire was developed and administered to 50 respondents, who rated their interpretation of each park using a 5-point Likert scale. The dataset was subjected to reliability analysis, normality testing, Mann-Whitney U comparisons and Spearman correlation to understand inter-relationships among the three spatial indicators and comparative analysis of the two parks. The findings highlight that spatial clarity in urban green spaces emerges from the interaction of sequential flow, coherence in spatial composition and smooth spatial transitions, rather than any single spatial attribute in isolation. Linear Park's stronger performance highlights the importance of consistent spatial rhythm and seamless transitions in enhancing user perception. The study contributes to evidence-based landscape evaluation by demonstrating how perceptual indicators can be quantitatively assessed and how spatial organisation influences user interpretation in urban parks. These insights support design strategies aimed at strengthening spatial clarity and improving user experience in high-density urban contexts.
Keywords: environmental interpretation, landscape experience, perceptual clarity, spatial organisation, user perception

I. INTRODUCTION

In dense metropolitan settings, urban green spaces (UGS) offer landscape experiences that combine ecological, perceptual, and psychological layers. Especially in Indian metropolitan settings, as cities densify, the quality of landscapes is dependent not merely on environmental indicators but also on perceptual and emotional attributes. These attributes become crucial indicators of the quality of life and well-being in dense urban fabric (Sangwan et al., 2023a; Yen et al., 2017). It has been consistently demonstrated by studies across environmental psychology, urban design, and landscape planning that UGS have a direct influence on mental restoration, emotional well-being, and guide social behaviour (Hoyle et al., 2017; Kaplan, 1995). Interpretations of landscapes guide these factors through spatial cues such as visual hierarchy, planting structure, openness, colour harmony, and spatial rhythm that shape how users perceive and interpret these spaces (Cai et al., 2022; Liu et al., 2023; B. Ma et al., 2020; X. Ma et al., 2021).

Existing literature in environmental psychology has demonstrated that users' interpretation of landscape is influenced by the perception of spatial attributes. The perception of landscape elements and their spatial organisation and coherence aid users in associating with the environment and forming meanings (B. Ma et al., 2020; Wan & Shen, 2015). The theoretical foundations laid by Kaplan (1995) demonstrated that natural settings help restore focus and mental fatigue, and Ulrich (1983) states that natural settings reduce stress both physiologically and psychologically. These theories have supported recent studies demonstrating that users' attention is guided by their perception of visual qualities such as visible depth, spatial definition, and structured planting (Hoyle et al., 2017). Similarly, studies identified landscape elements like focal nodes, water features, and edges as narrative cues that guide user experience through a sequential narration of the space (Cai et al., 2022; Millman, 2012; Sangwan et al., 2023a). Such studies on urban green spaces shift the perception of them from environmental systems towards complex psychological systems that shape how people view, interact, and develop deeper connections.

Within Indian metropolitan settings, where dwellers witness rapidly increasing urban density and evolving spatial conditions, urban green spaces are the primary settings of interaction with nature. This makes it highly relevant to systematically examine how users interact with these spaces.

Determinants of Landscape Perception

Users perceive the environment through sensory attributes that help them mentally organise these cues and conceive spatial organisation, and associate with the conceived spaces. Recent studies have identified spatial attributes such as vegetation structure, enclosure, visibility, planting richness, colour balance, textural variation, and visual coherence have strong influence on how users interpret and evaluate urban green spaces (Cai et al., 2022; Hoyle et al., 2017; Liu et al., 2023; B. Ma et al., 2020; Millman, 2012; Sangwan et al., 2023a). The spatial configuration of the landscape elements is a major attribute influencing experience by guiding user perception. The transition of spatial character forms the basis for sequential interpretation, which links different spaces of a green space into a coherent experience (X. Ma et al., 2021; Millman, 2012). Visual interpretation of urban green spaces is guided by focal

elements that hold users' attention. Studies show that focal elements such as water bodies, artworks or architectural markers serve as visual anchors, facilitating orientation and structuring attention (Cai et al., 2022). These focal elements aid visual hierarchy and guide users through spaces, reinforcing directional clarity. Collectively, these attributes form the foundations through which users read and experience the landscape. The collective interpretation of these key attributes determines visual coherence and directional clarity. While these attributes have been studied in existing literature, there remains a need for contextual evaluations of how they are perceived in Indian parks.

Need for Quantitative Evaluation of Perception in Indian Urban Park

There is an increasing need for statistical approaches to assess the perceptual qualities of urban green spaces, as these spaces are crucial natural environments in dense urban settings (Wang & Li, 2024; Zhang et al., 2025). A statistical analysis will provide a replicable method to evaluate spatial cues and understand how these cues interact with users. Such an approach will offer valuable insights for enhancing visual clarity and guiding evidence-based design strategies. This study examines user perceptions of two urban parks in India. These parks were selected for their distinct spatial arrangements and comparable scale. The study focuses on three crucial attributes, including spatial sequence, visual coherence and edge definition. By analysing the relationships among these perceptual cues, the study seeks to identify how spatial organisation shapes overall user interpretation in the selected urban parks. The findings from this study will support design strategies by identifying perceptual qualities that enhance spatial rhythm, visual clarity, and coherence for user-centred landscape planning and design in dense metropolitan settings.

II. MATERIALS AND METHODS

The study evaluates how users interpret the spatial qualities of two selected urban parks using a quantitative perception assessment framework. Based on existing literature, the study examines three attributes, namely, spatial sequence, visual coherence, and edge quality. A photo-based questionnaire was developed to evaluate these perceptual parameters. A focus group of 50 users were surveyed to analyse their landscape experience in these selected parks. The users were instructed to respond based on their immediate perception of the landscape visuals. The data thus collected were subject to rigorous tests and analysis to measure the predictive strength of the spatial cues on users' perception.

Study Area

Two urban parks in India were selected for this study based on their contrasting spatial structures and design strategies. Urban parks were selected because they are naturally rich settings where users engage in emotional associations within the dense urban fabric. These two sites offer distinct variations in spatial rhythm, visual order and boundary articulation, making them suitable for examining how users perceive differences in spatial qualities. One Green Mile, shown in Figure 1, represents the narrative of infrastructural adaptation by transforming an under-flyover space into a lively pedestrian zone by integrating human-scale interventions such as walking and cycling paths, seating pods, and tot lot areas. Whereas Linear Park, shown in Figure 2, is situated within a dense redeveloped corridor in the city of Mumbai, India. It is a reclaimed railway corridor transformed into a pedestrian greenway. Spreading over about 6000 sq m, the park uses sequencing and layering of landscape elements to tell the story of Mumbai.

Figure 1. Linear Park, Mumbai
Source: https://www.landscapeindia.net

Figure 2. One Green Mile, Mumbai
Source: https://studiopoddesign.com

The selected parks have comparable variables in terms of openness, enclosure, and edge transitions (Kaplan, 1995; Hoyle et al., 2017; Ma et al., 2020; Liu et al., 2023). Hence, this ensures the variable qualities for the required statistical analysis.

Methodological Framework

The study followed a methodological framework based on foundational theories, systematic data collection and a series of statistical data analyses. The study first examined existing literature and identified core perceptual quality principles relevant to user experience in urban green spaces. Then, several indicators for analysing perceptual responses were developed. An online questionnaire with representative images of each selected park was rated for the perceptual indicators. The results of this survey were subject to statistical analysis to develop a comprehensive understanding of the perceptual attributes of urban green spaces.

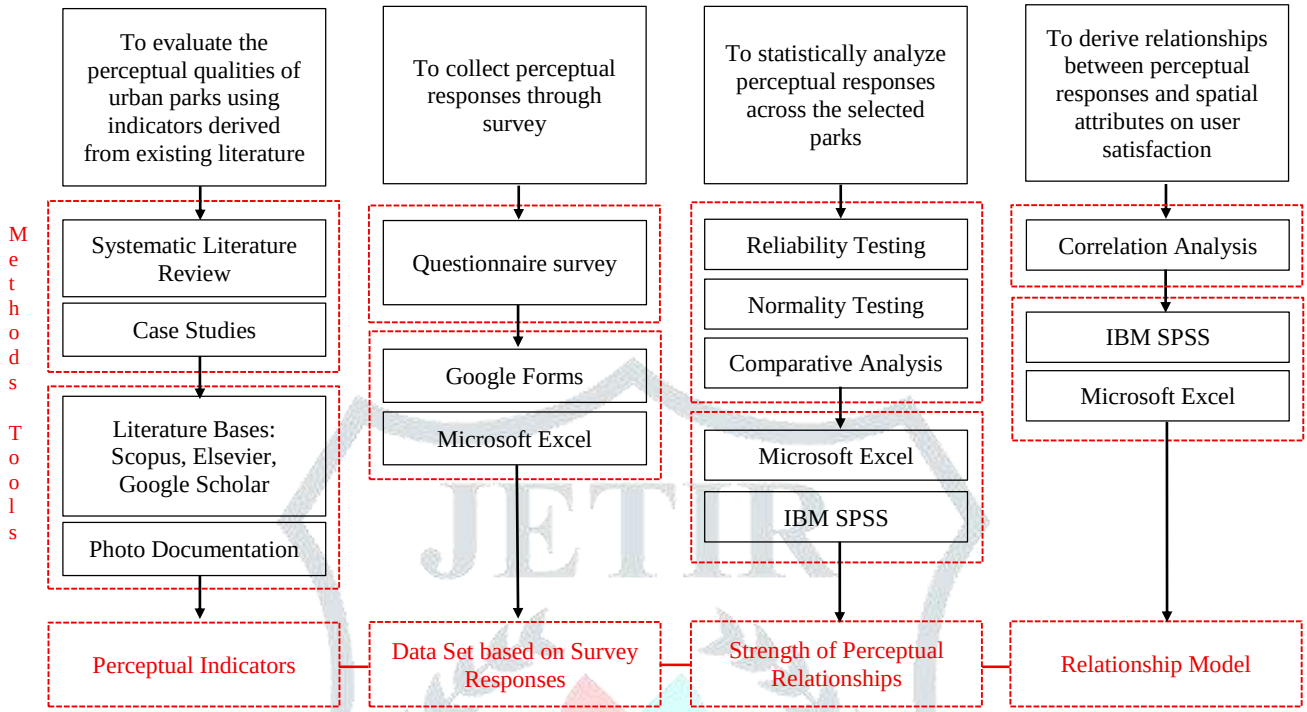

Figure 3. Methodological Framework

Questionnaire Design

The questionnaire was developed online through a literature-informed process. Each park was represented through selected photographs that capture the spatial composition, focal elements and spatial transitions in them. To evaluate the perceptual qualities of these parks, direct statements for each park were rated by a select group of respondents. The respondents were instructed to rate their immediate responses on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The questionnaire consisted of three parts: the first part collected basic demographic data of the respondents, the second part recorded the perceptual responses of each park, and the third part recorded comparative responses of all the selected parks. The perceptual responses were based on foundational principles from environmental psychology (Kaplan, 1995), spatial perception (Cai et al., 2022; B. Ma et al., 2020), and aesthetic coherence (Hoyle et al., 2017). Based on the existing foundational theories, the study identifies indicators that measure the perceptual-emotional attributes of UGS.

III. Results and Discussions

Data Collection

A semi-structured interview was conducted to obtain the response dataset for this study. A total of 50 responses were collected from users, each of whom evaluated visual representations of the two selected parks. The participants rated three perceptual indicators (spatial sequence, visual coherence, and edge quality) on a 5-point Likert scale for the two selected parks. The dataset thus obtained consists of fifty responses for three variables of each park. The responses were compiled, screened and checked for consistency. No missing values or invalid entries were reported. The final dataset consisted of 300 valid observations (50 respondents × 3 indicators × 2 parks). These were organised in Microsoft Excel as shown in Table 1, for statistical processing in IBM SPSS.

Table 1. Template for Dataset in Excel

respid	parkid	seq	coh	edge

Data Analysis

The obtained responses compiled in Microsoft Excel were exported to IBM SPSS for statistical analysis. The analytical procedure involved four stages. Initially, Cronbach's alpha test was used to evaluate the reliability of the three indicators. This was performed to ensure that the indicators formed a cohesive framework for assessment. Then, the obtained data were subjected to the Shapiro-Wilk test to assess their normality. The results from this test guided the subsequent statistical choices. A comparative analysis of the selected parks was done using the Mann-Whitney test to determine whether perceptual evaluations varied significantly between them. This was followed by a correlation analysis among the three indicators. Spearman's rank correlation coefficients were calculated to assess the relationship between the three indicators.

The analysis examined how users interpreted three core perceptual attributes (spatial sequence, visual coherence, and edge quality) across the two selected urban parks. The analysis collectively provided an understanding of how users interpret the spatial attributes of the two parks and how the three perceptual indicators relate to one another.

Reliability and Distribution of the Indicators

The Cronbach's alpha test produced a reliability coefficient of $\alpha = 0.760$ as shown in Table 2. This indicated a satisfactory level of consistency among the three indicators. Thus, the test validated the suitability of the indicators for further statistical analysis.

Table 2. Reliability Statistics

Reliability Statistics	
Cronbach's Alpha	**N of Items**
.760	3

The Shapiro-Wilk test of all three indicators yielded values less than .001 ($p < .001$) as shown in Table 3. This revealed that all three indicators had a non-normal distribution. The subsequent non-parametric tests were based on this result.

Table 3. Normality Tests

Variables	parkid	Shapiro-Wilk		
		Statistic	df	Sig.
seq	1	.890	50	.000
	2	.795	50	.000
coh	1	.827	50	.000
	2	.814	50	.000
edge	1	.897	50	.000
	2	.854	50	.000

Descriptive Statistics

A significant difference was observed in the way respondents interpreted the two selected parks. Linear Park consistently received higher mean scores than One Green Mile across all three indicators. Linear Park scored a higher average of 4.04 in spatial sequence compared to One Green Mile's average of 3.62. This reveals a clear spatial organisation in Linear Park. A similar difference was observed in terms of edge transitions between Linear Park (Mean - 3.92) and One Green Mile (Mean - 3.38). This shows that edge quality and transitions were seamless in Linear Park. There was a very small difference observed in the mean scores of visual coherence in the two parks. This revealed that parks maintain a relatively unified visual composition, but Linear Park achieves slightly higher perceptual clarity. The comparative means of the two parks are shown in Figure 1.

Table 4. Descriptive Statistics

Indicator	Park	Mean	Median	Std. Deviation	Variance	Skewness
Spatial Sequence	One Green Mile	3.62	4	0.907	0.822	-0.505
Spatial Sequence	Linear Park	4.04	4	0.814	0.663	-0.726
Visual Coherence	One Green Mile	3.76	4	0.779	0.607	-0.435
Visual Coherence	Linear Park	4	4	0.689	0.475	-0.745
Edge Quality	One Green Mile	3.38	3	1.116	1.246	-0.097
Edge Quality	Linear Park	3.92	4	0.963	0.928	-0.601

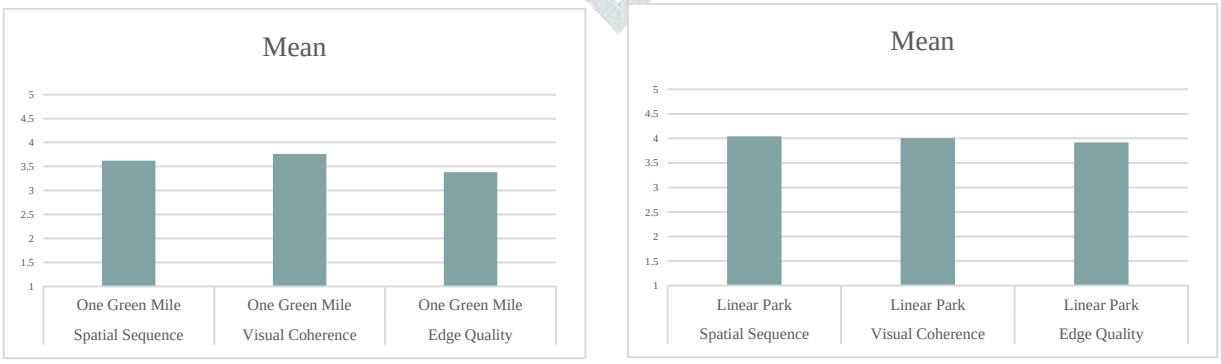

Figure 3. Comparative Means of the Selected Two Parks
Source: Author

Comparative Analysis

The Mann-Whitney U test was conducted to evaluate the perceptual differences between the two parks, due to the non-normal distribution of variables. Significant differences were observed in spatial sequence ($p = .034$) and edge quality ($p = .034$) as shown in Table 5. This validates the higher mean values of Linear Park, highlighting that it has a more continuous spatial flow and seamless edge transitions than One Green Mile. Meanwhile, visual coherence did not differ significantly between the two parks ($p = .529$). This shows that despite their structural differences, both parks appear to maintain comparable levels of coherence in visual and spatial composition.

Table 5. Mann-Whitney U Test

Indicator	Mean Rank (One Green Mile)	Mean Rank: (Linear Park)	U	Z	p-value (Sig.)
Spatial Sequence	43.12	57.88	917.0	-2.120	0.034
Visual Coherence	48.55	52.45	1197.5	-0.628	0.529
Edge Quality	42.66	58.34	894.0	-2.127	0.034

Correlation among the Indicators

Table 6 shows the Spearman correlation analysis, which demonstrates that the three perceptual indicators are strongly interrelated. Each of the variables was tested for correlation with the others. Spatial sequence showed a moderate positive correlation with visual coherence (ρ = .337) and a strong positive correlation with edge quality (ρ = .532). This indicated that a clearer spatial rhythm is associated with better-defined edges and greater perceptual order. Similarly, visual coherence also correlated positively with edge quality (ρ = .436). This shows that smooth transitions give an overall sense of visual organisation within parks. These relationships reflect that sequence, structure and boundaries are interconnected spatial attributes that influence how users interpret landscapes (Liu et al., 2023; Sangwan et al., 2023b).

Table 6. Correlation Analysis

Correlations					
			seq	coh	edge
Spearman's rho	seq	Correlation Coefficient	1.000	.337**	.532**
		Sig.	.	.001	.000
	coh	Correlation Coefficient	.337**	1.000	.436**
		Sig.	.001	.	.000
	edge	Correlation Coefficient	.532**	.436**	1.000
		Sig.	.000	.000	.

Integrated Interpretation

Collectively, the findings highlight that clearer sequencing of spaces and smooth transitions in Linear Park resulted in stronger perceptual scoring. The park's linear geometry and visual alignment likely enhance its spatial sequence, which improves legibility in the landscape (Kaplan, 1995; X. Ma et al., 2021). Meanwhile, lower ratings were recorded for One Green Mile in terms of sequence and edge transitions, owing to the park's under-flyover setting. This resulted in the fragmented edges and discontinuous sequences, and alternating spaces. However, a higher visual coherence score suggests that design strategies have created a visually unified space. The strong correlations among spatial sequence, coherence and edges highlight that these three perceptual cues are not individual attributes but function collectively as layers of spatial interpretation. This finding reinforces the growing understanding that perceptual clarity emerges from the interaction of multiple spatial attributes rather than any single design element.

IV. Conclusions

This study examined how users interpret spatial qualities in two urban parks in Mumbai (One Green Mile and Linear Park), using three key perceptual indicators: spatial sequence, visual coherence and edge quality. Through a structured survey and quantitative analysis, the findings reveal distinct differences in how these spatial cues are perceived across the two parks, offering insights into the spatial design clarity within each landscape. The results indicate that Linear Park demonstrated stronger perceptual performance in spatial sequence and edge quality in comparison to One Green Mile. However, both parks performed similarly in visual coherence, suggesting that visual organisation remain relatively consistent across the sites, although they differ significantly in spatial structure. The correlations among the three perceptual indicators emphasise that spatial sequence, coherence and edge quality operate as an integrated perceptual system. This finding supports existing landscape perception literature, which argues that perceptual clarity emerges from the interaction of multiple layers of spatial attributes rather than from isolated design elements.

The findings highlight the importance of designing parks with well-articulated spatial qualities to enhance spatial interpretation. As cities densify and the role of UGS becomes increasingly critical, such perceptual insights can inform design strategies that promote clarity, usability and experiential richness. Future research may extend these insights by examining additional park typologies, integrating on-site behavioural observations, and comparing perceptual responses across broader user groups. The present study demonstrates the value of quantitative perceptual assessment in evaluating spatial qualities of urban parks and provides an analytical foundation for improving user-centred design.

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