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Unveiling the Geometric Elegance: A Comparative Analysis of Historical Garden Structures and Spatial Relations

Abstract

Historical gardens epitomize socio-cultural values intricately embedded within their geometric designs and spatial configurations, offering a window into collective and civic life through the lens of landscape architecture. This study explores the interplay between the geometric structures of historical gardens from the late 16th and early 17th centuries and their spatial dynamics, aiming to bridge historical design principles with contemporary landscape practices. Employing advanced software tools and inferential statistical methods, the research examines ten renowned historical gardens spanning Persian, Mughal, East Asian, European formal, and English landscape traditions. The analysis is based on satellite maps, field observations, and simulations conducted using Depthmap software. It identifies a universal set of geometric features, quantified through metrics such as Connectivity (C), Visual Integration (VI), Visual Entropy (VE), and Gate Counts (GC), alongside their contextual cultural interpretations. Persian and Mughal gardens, with high Visual Integration, symbolize unity and spirituality, while the fragmented layouts of East Asian gardens reflect meditative exploration. In contrast, European formal gardens emphasize dominance through high Connectivity and Line Length, whereas English landscape gardens promote emotional resonance and choice-driven exploration. Quantitative correlations highlight the interconnectedness of design elements, such as the positive relationships between Connectivity, Visual Integration, and Gate Counts, and the inverse relationship between Visual Entropy and Connectivity. These findings are contextualized within cultural frameworks, revealing how spatial characteristics align with philosophical traditions and shape user experiences. By integrating quantitative metrics with qualitative cultural narratives, this study provides a comprehensive framework for understanding historical garden design. The insights offer significant implications for modern landscape architecture, urban planning, and cultural heritage preservation, advocating for the integration of historical geometric principles to create green spaces that resonate with both environmental and cultural values.

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Abbreviations:

C - Connectivity

CH - Choice

GC - Gate Counts

LL - Line Length

VC - Visual Controllability

VCC - Visual Clustering Coefficient

VE - Visual Entropy

VI - Visual Integration

1 Introduction

This article aims to identify the spatial structure of historic gardens and answer the question of whether the spatial structure of gardens necessarily follows similar spatial structures for quality. Historical gardens throughout history have very different spatial structures with different qualities. At the same time, with different mental, behavioral, climatic, and historical characteristics, each country can be entirely unique. Analyzing spatial structure involves parameters such as Connectivity, Visual Integration, Visual Entropy, Gate Counts, Visual Controllability, Visual Clustering Coefficient, and Choice. These parameters quantify spatial relationships, enabling insights into visibility, accessibility, and movement patterns. For instance, Connectivity measures the direct links between spaces, while Visual Integration assesses how well a space connects to the overall configuration. Gate Counts track pedestrian flow at specific points, revealing areas of high activity and congestion, and Visual Controllability examines the potential of a space to visually dominate or offer access to expansive views.

Further, Visual Entropy evaluates the evenness of depth distribution around a space, and Clustering Coefficient measures how well-connected the surrounding spaces are relative to one another. Lastly, Choice represents the frequency a space appears on the shortest paths between other spaces, highlighting its importance in network connectivity. Together, these metrics offer a comprehensive, state-of-the-art framework for understanding spatial relationships in architectural and urban contexts.

Table 1. Background research (own research, 2025).

Authors	Discussion	Methodology	Results
(Peng et al., 2024)	The paper emphasizes the cultural importance of historic gardens and the challenges in preserving them. It shows how point-cloud technologies can analyze and apply spatial-visual design principles to aid in their protection and development.	A systemic framework to reveal spatial-visual characteristics using the voxelized model	Using Jichang Garden in Wuxi, China, as a case study, the research identifies design principles such as water body design, route arrangement, and planting strategies. It also develops conservation strategies based on these findings and discusses the methods' applicability and limitations.
(Wu et al., 2024)	The analysis revealed that the three gardens shared similar centralities in terms of accessibility distribution, indicating a consistent approach to spatial organization.	The study employed space syntax models, specifically visibility graph analysis and segment angular analysis, to analyze the spatial layout of three traditional gardens in Yangzhou City	The study analyzed the spatial layout characteristics of three traditional gardens in Yangzhou City—Heyuan Garden (1862), Geyuan Garden (1818), and the West Garden of the Daming Temple (1751)—using space syntax models. Specifically, visibility graph analysis and segment angular analysis were applied to understand the spatial configurations.
(Kiani et al., 2022)	Comparative Analysis of Persian Garden Values Based on Prospect-Refuge Theory Indicators	Comparative analysis and logical reasoning	Analysis of the findings of this study shows that the prospect & refuge theory focuses on material and environmental elements, the quality of space. In this theory, dealing with ambiguity, metaphor, allegory and symbolism, as well as the emotional dimension of human has been neglected.
(Sharghi et al., 2020)	Comparative Study of Fractal Geometry Patterns in Iranian Garden and Landscape Architecture (Case Study: Tabas Golshan Garden)	A descriptive-analytic	It is found from the study that if the Iranian garden has fractal features in structural, vegetative, irrigation and functional systems, it can be extended to the whole garden.
(Haghighatbin & Masouleh, 2019)	The Comparative Study of Ritual and Cultural Symbols in the Landscaping of Persian and Chinese Gardens	historical-interpretative	The Persian and Chinese gardens from the beginning of their formation have faced various methods according to the existing differences in the attitude to nature, ritual and cultural roots and climate factors and their effect on the appearance of general and specific symbols.

This article argues that while a study of spatial structure alone cannot fully encompass the essence of historic gardens, it nevertheless offers valuable insights. By examining and comparing the macro-level spatial organization of gardens across different countries and time periods, we can gain a deeper understanding of their underlying patterns.

Therefore, this article aims to identify spatial structure patterns in the plans of historic gardens to facilitate a comparative analysis of their spatial relationships. This analysis will enhance our understanding of these patterns and provide a clearer picture of the structure of historic gardens. Other qualities of these gardens, such as their aesthetic or symbolic aspects, can then be interpreted in relation to this spatial structure.

This comparative analysis focuses on common spaces like entrances, pre-entrances, paths, and collective spaces, revealing the relationship between the intended purpose and the spatial organization of the garden. Previous studies on spatial structure in parks and gardens are summarized in Table 1.

In previous research, only one or two gardens have been studied to study the beliefs, culture, and structural identity of the garden, and the relationship between the different components of the garden has not been considered. In this research, an attempt has been made to evaluate the form of garden design in different countries of the world from a new perspective to achieve similarities in the design of plans and the relationship between different spaces of gardens in the world. Gardening in each country and place has a unique identity and structural components, which has been expressed in various past studies. However, whether different gardens in the world in a particular period have similarities and differences in the design of paths and spaces. We are looking for a specific period or not in this research.

2 Literature review

Historical gardens, as manifestations of cultural identity, exhibit diverse structural and spatial characteristics that reflect the unique cultural and environmental contexts of their origin (Abbas et al., 2016; Lazzaro & Lieberman, 1990). These gardens, ranging from predictable geometric layouts to complex and naturalistic designs, represent an interplay between social, aesthetic, and environmental considerations. Despite their evident social and ecological value, their cultural, architectural, and perceptual significance often remains underexplored in the broader discourse.

Historic gardens, akin to architectural heritage or literary traditions, are intrinsic to the cultural identity of communities. Their designs evolve over time, influenced by natural processes, social needs, and cultural values (Hristov et al., 2018; Paiva et al., 2021). Defined by the Florence Charter of 1981 as a blend of architecture and horticulture of historical interest, these living entities are dynamic, perishable, and renewable (Bazarovna & Dzhakhongirovna, 2023; ICOMOS, 1981).

Globally, historical gardens showcase diverse design philosophies shaped by regional climates, communities, and cultures. For instance, Chinese and Japanese gardens feature intricate layouts rich in symbolic and philosophical meanings, while Persian and Mughal gardens emphasize geometric symmetry, evoking the imagery of paradise. European gardens, on the other hand, display a wide range of styles—from the grand formalism of French gardens to the naturalistic landscapes of English gardens. Despite their regional uniqueness, these gardens share commonalities in spatial design, reflecting universal themes of harmony, symbolism, and the human-nature relationship (Abbas et al., 2016; Akasaka, 2008; Baridon, 2008; Bassin, 1979; Lazzaro & Lieberman, 1990; VALE, 2013).

The late 16th and early 17th centuries marked a transformative era for garden design, influenced by cultural philosophies, political aspirations, and global exchanges. The maritime trade revolution facilitated the transfer of exotic plants, gardening techniques, and design philosophies, fostering a synthesis of local and foreign traditions. Botanical gardens, established during this period, became centers of scientific study and acclimatization. Wealthy rulers invested in expansive gardens that served as both displays of power and expressions of aesthetic ideals (Biscione et al., 2023; Hunt, 1990; Smith, 2009; Thacker, 1985; Zhang et al., 2023).

Table 2. Analysis of Global Gardens (own research, 2025).

Region	Spatial Features	Design Philosophy	Influences
Iran	Axial planning, symmetry, charbagh layout, water channels	Paradise symbolism, climatic adaptation	Persian-Islamic ideals, trade with India, China & Europe
India	Terracing, cascading water, elevated pavilions	Cosmological order, integration of nature	Persian charbagh, European inputs
China	Organic forms, framed views, compact vastness	Daoism, harmony with nature	Silk Road, internal exchanges
Japan	Sequential views, asymmetry, Zen gardens	Meditative progression, simplicity	Chinese philosophical principles
France	Axial geometry, parterres, grand vistas	Absolutism, grandeur	Italian Renaissance designs
Italy	Terraces, axial layouts, water features	Humanism, blending of art and nature	Roman heritage, Renaissance trade
England	Early formal to naturalistic transitions	Pastoral idealism, natural mimicry	Italian and French influences
Germany	Formal symmetry, structured spaces	Baroque ideals, spatial grandeur	French inspiration
Russia	European-style formal layouts, native elements	Westernization, imperial symbolism	French and Italian designs

A comparative analysis reveals the intricate ways cultural philosophies shaped these gardens. Persian gardens symbolized paradise through their symmetrical charbagh layouts (Nottagh & Belali Oskuyi, 2023; Rahbar, 2024), while Mughal gardens integrated Persian geometries with Indian cosmological symbolism (Dickie & Zaki, 1985; Habibullah & Ruggles, 2024; Mubin, 2013). Chinese gardens emphasized naturalism and philosophical harmony, reflecting Daoist and Confucian ideals, while Japanese gardens, influenced by Zen Buddhism, focused on asymmetry and meditative spaces (Goto, 2003; Keane, 2012; Kiani & Khakzand, 2024; Rinaldi, 2012). European gardens, such as the formal French gardens and Renaissance Italian terraces, combined architectural control with social functions, serving as venues for rituals, intellectual gatherings, and festive events (Cullen et al., 2011; Steenbergen et al., 2003; Turner, 2011).

The spatial and ritualistic dimensions of these gardens underscore their cultural significance. For example, Persian gardens were spaces for royal and religious ceremonies, symbolizing order and divine harmony (Nottagh & Belali Oskuyi, 2023; Rahbar, 2024). Mughal gardens served as contemplative and ceremonial spaces, merging the spiritual with the functional (Dickie & Zaki, 1985; Habibullah & Ruggles, 2024; Mubin, 2013). Similarly, Chinese and Japanese gardens integrated features like tea houses and pathways for meditation and rituals (Goto, 2003; Keane, 2012; Kiani & Khakzand, 2024; Rinaldi, 2012). European gardens reflected the grandeur of their patrons, hosting events that blended nature, art, and social performance (Cullen et al., 2011; Steenbergen et al., 2003; Turner, 2011).

In summary, historical gardens are complex cultural landscapes shaped by the interplay of regional philosophies, environmental conditions, and social needs. By examining their spatial characteristics and cultural contexts, both regionally and cross-culturally, a deeper understanding of their enduring significance can be achieved (Table 2: The table has been developed based on the data discussed and the references cited in the Literature Review section) . This knowledge not only enriches the study of historical gardens but also informs contemporary landscape design and heritage conservation practices.

3 Materials and methods

This research represents a methodological development that seeks to expand the knowledge of the world's gardens. The research method in this research is quantitative-qualitative. The required data were collected using documentary methods and software analysis. Field visits and analyzes performed by depth map software have examined the spatial relationships between different gardens using logical reasoning and comparative analysis. The analysis unit is the garden as well as its components, elements, and values. In the research process, the subject of research and its importance and necessity are examined and presented in the form of questions and objectives of the general structure. The theoretical and experimental background, the theoretical literature of gardens has been examined. Then, the gardens were surveyed and compared by depth map software. Figure 1 shows the research process. For the selection of the investigated gardens, a list of gardens around the world with unique characteristics such as different hierarchies, direct and indirect movement paths, different views, and different cul-

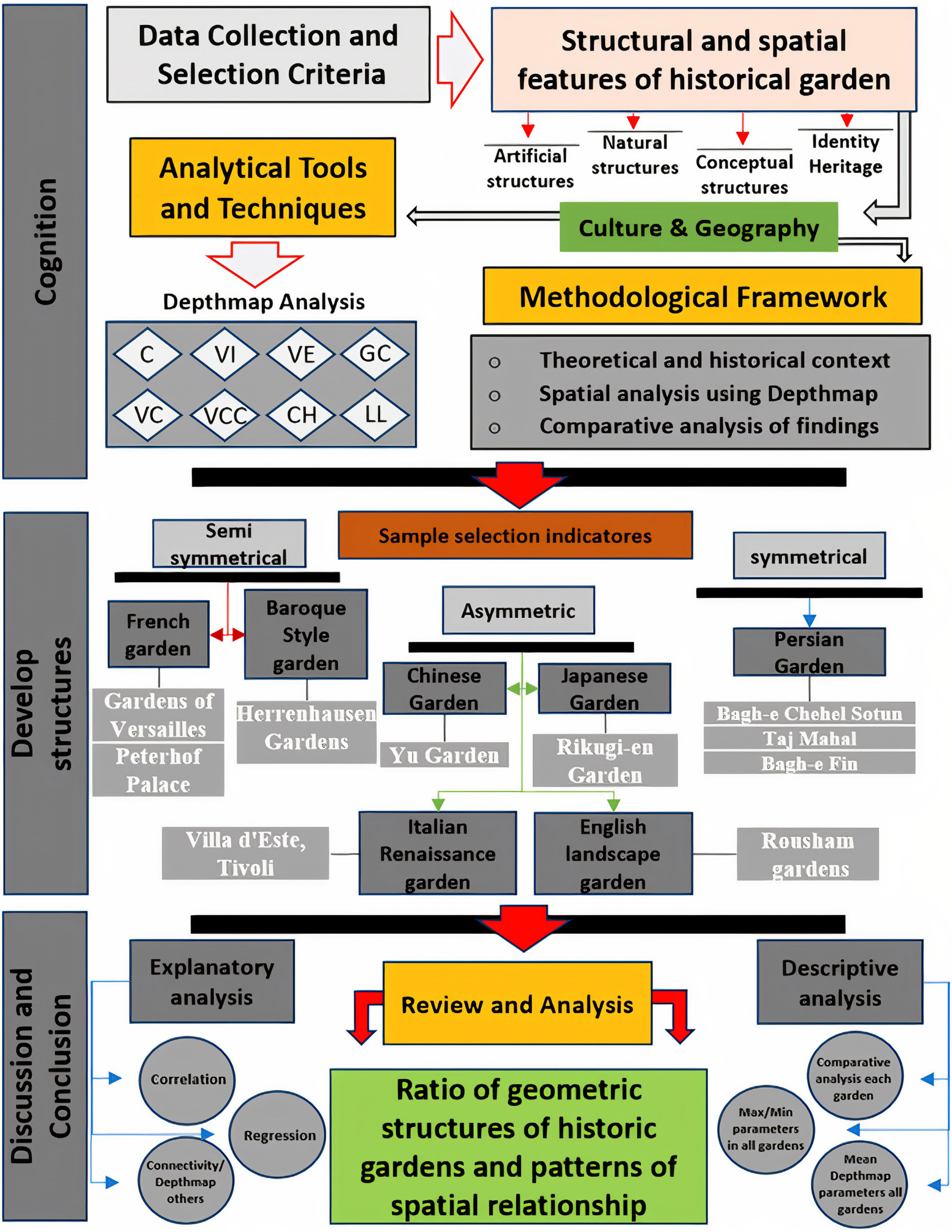


Figure 1. Research process (own research, 2025).

tural structures were selected for the structural and movement analysis of the garden space. To evaluate garden connectivity and safety, the analysis focused on key spatial parameters, including the accessibility of pathways, visibility within and across garden spaces, the ease of movement between key nodes, and the degree of enclosure provided by garden elements such as hedges, walls, or trees. These parameters were assessed using Depthmap's connectivity and visibility tools, complemented by expert opinions. 18 experts in the field of horticulture were contacted, and ten gardens were selected based on the hierarchical structure of the investigated

3.1 Data Collection and Selection Criteria

To gather primary data for the analysis of the selected gardens, a combination of remote spatial data extraction and field observations was employed. High-resolution satellite imagery and maps from Google Maps were retrieved between March and May 2024 to capture the layouts, precise dimensions, and structural elements of the gardens, such as pathways, fountains, and architectural features. These maps were processed using Geographic Information System (GIS) software to generate detailed base maps for spatial analysis. To validate and enrich the remotely collected data, field visits were conducted between June 2023 and April 2024. During these visits, the research team used precise measurement tools, including laser meters and GPS devices, to record spatial dimensions and document design elements. On-site observations and professional photography were also carried out to capture visual details, such as plant textures, visitor movement patterns, and cultural-historical features, enhancing the depth of the spatial analysis and providing a comprehensive understanding of each garden's cultural identity.

3.2 Analytical Tools and Techniques

Depthmap was initially developed in 1998 for the Silicon Graphics IRIX operating system as a simple program for processing isovists , which are visual fields or areas visible from a specific point in space (Turner, 2007). The software was designed to perform integration analysis of isovists, similar to the way axial line integration is calculated. Later, Depthmap evolved into a robust tool for spatial analysis, particularly in space syntax studies, which explore spatial configurations and their impact on human behavior and movement patterns (Turner, 2001, 2004; Turner et al., 2001).

Depthmap enables researchers to analyze and compare spatial structures with varying sizes and configurations by providing key metrics such as visibility, connectivity, and integration. In this research, Depthmap was used to evaluate and quantify various spatial characteristics, offering insights into the spatial dynamics of the studied environments. These metrics were instrumental in understanding the spatial structures and their impact on user interactions and movement patterns.

By leveraging Depthmap, the study could systematically analyze spatial relationships and draw comparisons across samples with different structural attributes (Turner, 2001, 2004, 2007; Turner et al., 2001). The software's ability to provide data-driven insights has made it an invaluable tool in fields such as urban design, architecture, and spatial planning.

The spatial analysis utilized Depthmap software, a tool originally developed for integration analysis of isovists and axial lines (Turner, 2001, 2004; Turner et al., 2001), this software was instrumental in quantifying key spatial metrics:

I. Connectivity

   It is defined as the number of points at which space is directly connected to other spaces. For instance, the connectivity of a room with two entrance doors to adjacent spaces is equal to two according to Eq. : Ci=K

   where k is the number of directly connected points to the intended point, and Ci refers to the connection at the i-th point (Alitajer & Nojoumi, 2016; Khalesian et al., 2009; Turner, 2001, 2004, 2007).

II. Visual Connectivity

   Visual Connectivity refers to the number of other spaces or points within a spatial layout that are directly visible from a given location. It quantifies the extent to which a point in space can "see" other areas, serving as a measure of immediate visual openness or accessibility. For instance, in a room with multiple open sightlines, the visual connectivity is higher than in a space with obstructed views. This metric is critical in understanding spatial dynamics such as visibility, navigation, and spatial perception, especially in the context of architectural design and urban planning (Alitajer & Nojoumi, 2016; Khalesian et al., 2009).

III. Line Length

Line Length in DepthmapX refers to the physical or visual extent of axial or segment lines used in spatial network analysis. Axial lines represent the longest straight lines of sight or movement through a layout, while segment lines are subdivisions of these lines at intersections (Alitajer & Nojoumi, 2016; Khalesian et al., 2009; McElhinney, 2018; Turner, 2001, 2004, 2007; Turner et al., 2001).

IV. Integration

Integration is a normalized version of Mean Visual Depth. It standardizes for plan size based on a user-set unit scale and results in values between the range 0-infinity, allowing for comparison between different plan configurations. A high value represents firmly integrated space, and a low value indicates segregated space (McElhinney, 2018).

$$dValue = \frac{2\left\{k\left[log2\left(\frac{K+2}{3}\right)-1\right]+1\right\}}{(k-1)(k-2)}$$

$$Integration\ (HH)_v = \frac{\text{dValue.}\ (k-2)}{2(MeanVisualdepth_v - 1)}$$

V. Visual Integration

Visual Integration is a spatial analysis metric derived from space syntax, used to measure the degree of connectivity and accessibility of a given point or area within a visual field. It reflects how visually accessible a location is relative to all other locations in the spatial layout. Higher visual integration values indicate spaces that are more visually connected and accessible, often functioning as central or prominent areas. In contrast, lower values correspond to more segregated or isolated spaces. This measure is particularly useful for understanding how spatial configurations influence human movement patterns, visibility, and wayfinding in architectural and urban environments (McElhinney, 2018; Turner, 2001, 2004, 2007; Turner et al., 2001).

VI. Entropy

Entropy measures the distribution of spaces in their Depth from space rather than the Depth itself. If many locations are close to space, the Depth from that space is asymmetric, and the entropy is low. If the Depth is more evenly distributed, the entropy is higher (Turner, 2004).

VII. Visual Entropy

Visual Entropy is a metric used in DepthmapX to measure the complexity and variability of the visual field from a specific point in a space. It analyzes how diverse and evenly distributed the visible elements are, with higher entropy indicating more visual complexity. This measure helps assess how spatial arrangements influence human perception and navigation in environments (Grajewski, 1992; Turner, 2004; Vaughan & Grajewski, 2001).

VIII. Gate count

Gate count refers to the process of measuring the flow of people moving through a particular location over a specified period. It is a method used to establish patterns of pedestrian movement and density at sampled locations, often within public spaces. In the context of Depthmap (a spatial analysis tool), gate count specifically tracks the accumulation of pedestrian agents as they pass through predefined “gates” in a simulated environment. This helps researchers analyze pedestrian flow, congestion points, and spatial accessibility within the studied area (Grajewski, 1992; Vaughan & Grajewski, 2001).

IX. Controllability

Controllability (Yv) expresses the potential for any location to be visually dominated in an ‘overlooking’ manner or where movement may provide access to an expanded visual field. In isovist terminology, controllability represents the average size of the isovist found from all points within said isovist’s perimeter. It increases as an isovist encompasses regions of space that generate larger isovists than itself, i.e., when a location can ‘see’ regions of space that in turn each 'see' relatively more space. A prime example of a location with controllability would be Bentham's panopticon structure cells, looking onto the open central void (McElhinney, 2018).

Isovist_2.2 generates isovists stochastically and summates their areas at any point 'V' that occurs within them to determine controllability. The total is divided by the number of isovists generated to give a mean value. The ratio of seen space to potentially see-able space is then found by dividing by the area at point 'V' (McElhinney, 2018).

In notation form, the calculation for controllability is expressed as:

$$C_i = \frac{1}{nA_v}\sum_{i=1}^{n} \mathrm{A_i}$$

X. Clustering coefficient

The clustering coefficient is defined as several edges between all vertices in the neighborhood of the generating vertex and divided by the total number of possible connections with that neighborhood size. In isovist terms, this is equivalent to finding the mean area of intersection between the generating isovist and all the isovists visible from it, as a proportion of the area of the generating isovist. Inset terms, the clustering coefficient Ci for the neighborhood Ni of location vi is where ki is the neighborhood size (Turner, 2001; Turner et al., 2001).

$$C_i = \frac{|\{e_{jk}: V_j, V_k \in N_i \wedge e_{jk} \in E\}|}{K_i(K_i - 1)}$$

XI. Visual Clustering Coefficient

The Visual Clustering Coefficient is a metric used in spatial analysis to measure the degree to which visually connected elements or spaces form clusters. It quantifies how visually grouped or clustered certain areas are within a given environment. A higher visual clustering coefficient indicates that the spaces are more visually interconnected, creating a sense of cohesion or grouping, while a lower value suggests a more dispersed or fragmented visual layout. This measure is useful for understanding how visual relationships between spaces affect human experience and movement within urban or architectural settings (Grajewski, 1992; Turner, 2001; Turner et al., 2001; Vaughan & Grajewski, 2001).

XII. Choice

It is a general measure that can be best understood as "water flow in space." Space offers a high degree of choice when many shortest connection paths intersect that space (Alitajer & Nojoumi, 2016; Dursun, 2007; Lima, 2001)

These metrics enabled a multi-dimensional understanding of garden layouts, their movement patterns, and their experiential and cultural characteristics.

3.3 Methodological Framework

Theoretical and Historical Context: The literature review examined the cultural, structural, and experiential dimensions of gardens, with a focus on their spatial structures.

Spatial Analysis: Depthmap simulations evaluated structural attributes and movement dynamics within the gardens.

Comparative Analysis: Findings were synthesized to identify universal design principles and culturally specific adaptations.

Figure 1 provides a visual representation of the research process.

3.4 Limitations

While the field observations enriched the dataset, a key limitation stems from the subjective nature of these visits. Each garden was observed by different members of the research team, with each author bringing their unique perspective to the analysis. This approach, while beneficial in capturing diverse viewpoints, also introduces the possibility of inconsistent interpretations or overlooking key details.

To address this limitation, findings from individual observations were cross-validated through group discussions and comparisons with remote spatial data. Despite these efforts, the potential for bias in personal interpretations remains a limitation. This underscores the importance of integrating multiple perspectives and iterative analysis to minimize errors.

Additionally, differences in cultural and professional backgrounds among the team members could influence their focus during observations, resulting in variations in how certain spatial or experiential attributes are evaluated. Future studies could mitigate this by employing a standardized observational framework and involving third-party reviewers to ensure more uniform assessments.

This integrated methodological framework not only addresses spatial configurations but also elucidates the cultural narratives embedded within garden designs, offering a comprehensive perspective on the interplay between structure, culture, and user experience.

4 Case descriptions

The research examines various gardening styles, comparing them to draw broad conclusions. Examples include Persian, Chinese, Japanese, Baroque, English landscape, French, and Italian Renaissance gardens. Each style represents distinct cultural and design traditions and reflects unique approaches to spatial organization (Figure 2 – Table 3).

Historical garden styles often reflect a dichotomy between geometric designs, which emphasize symmetry, order, and control over nature, and irregular or naturalistic designs, which prioritize harmony with the natural environment and asymmetry.

Geometric Gardens

- Persian gardens, exemplified by Bagh-e Chehel Sotun and Bagh-e Fin, showcase a highly organized, four-part structure (chaharbagh) symbolizing paradise and luxury. Their symmetrical layouts prioritize visual integration, water management, and a sense of grandeur (Abbas et al., 2016; Wilber, 1957).
- French gardens, such as the Garden of Versailles, feature rigid geometric patterns with carefully shaped hedges, fountains, and pathways. These designs reflect authority, order, and the cultural ideal of human dominance over nature (Baridon, 2008; Eriksson, 2012; Mukerji, 1997, 2012; Thompson, 2006).
- Baroque gardens, like Herrenhausen Garden, balance semi-symmetry with elaborate sculptures and water features, symbolizing opulence and

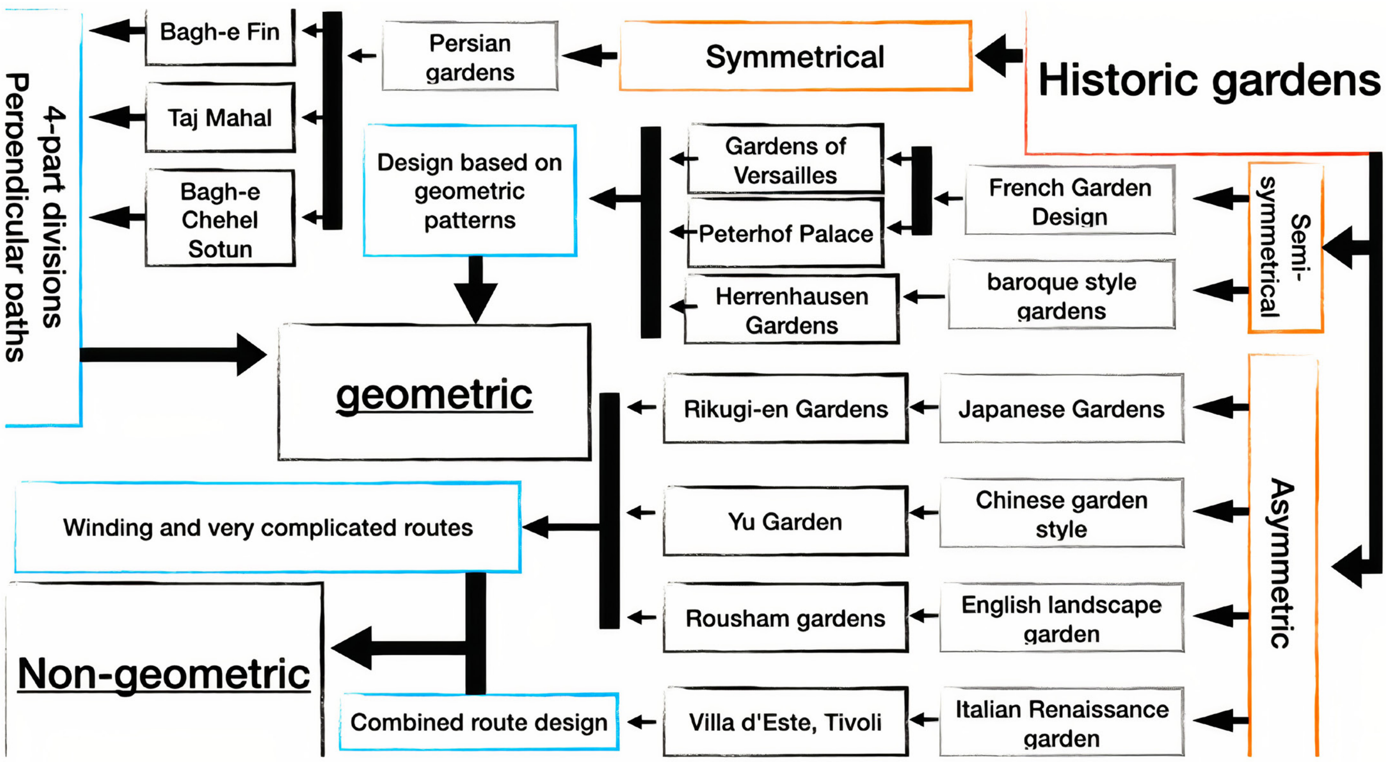
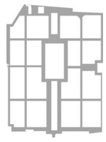
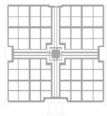
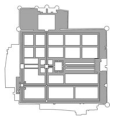
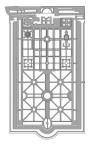
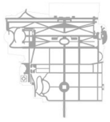
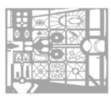
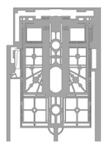
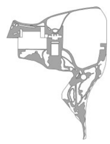


Figure 2. Research methods (own research, 2025).

Table 3. Sample introduction (own research, 2025).

Case	Garden name	Country	Construction starting	Design style	The geometry	Area (ha)	Position	Dominant vegetation	Main elements	Map
1	Bagh-e Chehel Sotun	Iran	1646	Persian garden	Regular symmetric geometry	5.8	Inside the city	Trees, Flowers & Plants	Pond, sculpture & water fountain	
2	Taj Mahal	India	1632	Persian garden	Symmetrical checkered geometry	17	Inside the city	Trees, Flowers, Graas & Plants	Pond & water fountain	
3	Bagh-e Fin	Iran	1571	Persian garden	Symmetric geometry	7.6	suburb	Trees, Flowers, Graas & Plants	Ponds, water fountains & waterways	
4	Yu Garden	China	1559	Chinese garden	Eclectic Geometry - A winding grid	2	Inside the city	Trees, Aquatic plants & Plants	Fountain, water pond, waterway, bridge, stone elements, Mythical sculptures & porch	
5	Rikugi-en Garden	Japan	1695	Japanese Garden	Natural geometry of the site	9	Inside the city	Trees, Graas & Plants	Pond, bridge, fishing pavilions, wooden porch, well, stone lanterns & moon observation deck	
6	Herrenhausen Gardens	Germany	1640	baroque style garden	Symmetric geometry	135	Inside the city	Trees, Flowers, Graas & Plants	Mythical sculptures, water fountain, pool & topiary	
7	Rousham garden	United Kingdom	1685	English landscape garden	Eclectic geometry	-	suburb	Trees, Flowers, Graas & Plants	Pond, water fountain, waterway, sculpture & topiary	
8	Garden of Versailles	France	1661	French Garden Design	Eclectic geometry	800	suburb	Trees, Graas & Plants	Pond, water fountain, waterway, sculpture & topiary	
9	Peterhof Palace	Russia	1714	French Garden Design	Symmetric geometry	3,934.1	suburb	Trees, Graas & Plants	Pond, water fountain, waterway, Mythical sculptures & topiary	
10	Villa d'Este, Tivoli	Italy	1563	Italian Renaissance garden	Natural geometry	4.5	suburb	Trees, Graas & Plants	Pond, water fountain & historical elements	

power among European royalty (Martin, 1934; VALE, 2013).

Irregular/Naturalistic Gardens

- Chinese gardens, like Yu Garden, emphasize asymmetrical designs and winding paths, reflecting ancient philosophical and artistic traditions. They aim to provide a serene escape from urban life (Kiani & Khakzand, 2024).
- Japanese gardens, such as Rikugi-en Gardens, blend asymmetry, symbolism, and nature to create serene landscapes. They often feature winding paths around central elements. They often feature winding paths around central elements

(Akasaka, 2008; Chen et al., 2020; Ono, 2005; Pearson, 2023).

- English landscape gardens, represented by Rousham Gardens, adopt a naturalistic approach, with open lawns, irregular water features, and scattered trees to create a picturesque harmony between design and nature (Bassin, 1979; Hunt & Willis, 1988; Kroll; Willis, 1977).
- Italian Renaissance gardens, like Villa d'Este, combine Islamic and Christian influences to create elaborate, asymmetrical designs. They often feature mythological and botanical elements (Hunt, 2016; Lazzaro & Lieberman, 1990; Leslie, 1992; Morgan, 2015).

Geometric gardens often convey power, order, and cultural sophistication, reflecting societal values that prioritize control and organization. These designs create immersive experiences through their precise layouts, emphasizing visual dominance and symbolic representation. For example, the strict symmetry of Persian and French gardens illustrates cultural ideals of order and paradise, often tied to religious or royal influences.

In contrast, irregular or naturalistic gardens emphasize individual reflection, harmony with nature, and philosophical depth. The asymmetry and fluidity seen in Chinese and Japanese gardens foster a sense of peace, inviting visitors to engage with their surroundings meditatively. Similarly, English landscape gardens prioritize emotional engagement with nature, promoting a more relaxed and introspective experience.

While geometric gardens are often linked to formalism and the demonstration of authority, irregular designs offer a counterbalance by celebrating organic beauty and human-nature connections. Despite these differences, both styles share a common goal: creating immersive environments that resonate with cultural ideals and aesthetic values.

The proximity of these historical styles in time and space underscores a dynamic exchange of ideas, with elements of symmetry, ornamentation, and naturalism influencing one another across regions. This synthesis has left a lasting legacy, shaping the evolution of garden design worldwide.

5 Depthmap Analysis

Analysis of 10 proposed samples based on the analytical components of Depthmap software shown in Table 4:

Table 5 shows the gardens with the highest and lowest values in different spatial relationship items.

Analyzing the data from Table 5 reveals intriguing insights into the characteristics of various gardens, each offering a unique blend of connectivity, visual coherence, and visitor experience. Rikugi-en Gardens stands out for its exceptional connectivity, boasting the highest level among the examples provided. This suggests a well-integrated layout that facilitates movement and exploration throughout the garden.

Conversely, Herrenhausen Gardens presents the lowest level of connectivity, accompanied by a high visual entropy value. This indicates a design perhaps characterized by isolated features or a lack of cohesive pathways, potentially fostering a more unpredictable visitor experience. Bagh-e Fin excels in visual integration, indicating a harmonious layout where elements seamlessly blend to create a cohesive visual experience.

Regarding visual controllability, Yu Garden takes the lead, suggesting a design that allows for precise control over the visual experience, potentially guiding visitors along predetermined paths or toward focal points. Rousham Gardens impresses with its high gate count, indicative of a grand entrance experience, while also boasting the lowest line length, suggesting a compact layout that maximizes space and minimizes travel distance between points of interest. The Gardens of Versailles, known for its grandeur, offers visitors an abundance of choices with a staggering choice value, while maintaining low visual entropy, hinting at a carefully curated and structured design that minimizes visual clutter.

In contrast, Peterhof Palace features the highest line length, indicating extensive pathways or sprawling grounds, yet its low visual controllability suggests a design that may offer visitors a more organic and less directed experience. In essence, each garden exemplifies a distinct approach to design and visitor

Table 4. Depthmap analysis (own research, 2025).

Garden name		Bagh-e Chehel Sotun	Taj Mahal	Bagh-e Fin	Yu Garden	Rikugi-en Gardens	Herrenhausen Gardens	Rousham gardens	Gardens of Versailles	Peterhof Palace	Villa d'Este, Tivoli
Case		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Connectivity	min	120	28	15	19	23	1	10	3	3	9
	mid	1447	331.35	1158.82	499.37	1660.98	310.67	1221.84	1007.04	1007.04	752.88
	max	3808	1043	4120	1641	5864	1141	4193	3376	3376	2258
Visual Integration	min	3.40	2.50	2.80	2.30	2.55	0.98	2.13	2.64	2.64	1.99
	mid	5.99	3.25	5.50	4.02	4.66	2.87	4.75	5.78	5.78	4.34
	max	10.34	5.45	15.42	8.82	6.94	4.60	6.99	9.84	9.84	7.03
Visual Entropy	min	1.41	1.72	1.00	1.41	1.31	2.23	0.99	1.04	1.04	0.69
	mid	1.85	2.46	1.91	2.07	2.06	2.62	2.03	1.81	1.81	2.06
	max	2.15	2.84	2.28	2.31	2.32	2.97	2.29	2.12	2.12	2.30
Gate Counts	min	1	1	1	1	1	1	1	1	1	1
	mid	18.42	32.77	19.53	12.84	10.12	46.00	14.26	27.01	27.01	26.41
	max	112	202	155	1641	118	1014	4193	246	246	622
Visual Controllability	min	0.04	0.02	0.02	0.04	0.04	0.01	0.03	0.007	0.007	0.008
	mid	0.22	0.19	0.34	0.40	0.33	0.31	0.24	0.21	0.21	0.35
	max	0.41	0.44	0.80	0.95	0.84	0.93	0.79	0.83	0.83	0.84
Visual Clustering Coefficient	min	0.39	0.33	0.34	0.39	0.31	0	0.35	0.30	0.30	0.32
	mid	0.84	0.90	0.87	0.84	0.75	0.84	0.84	0.76	0.76	0.78
	max	1	1	1	1	1	1	1	1	1	1
Choice	min	0	0	0	0	0	0	0	0	0	0
	mid	434.89	3015.97	3257.18	13263.5	37375.3	14696.4	18897.8	35254.4	35254.4	124941.1
	max	3512	48259	73091	429663	1.27	445879	705857	3.28	3.28	597969
Line Length	min	7.39	8.62	6.64	3.30	2.10	1.12	0.60	5.12	5.12	1.66
	mid	79.57	60.08	75.45	28.90	33.01	54.12	37.15	101.06	101.06	40.41
	max	235.65	245.90	281.50	252.31	181.76	337.35	251.84	434.3	453.32	186.59

Table 5. Depthmap Analysis – min/max (own research, 2025).

The least and the most	C		VI		VE		GC	VC		VCC	CH	LL	
	min.	**max.**	**min.**	**max.**	**min.**	**max.**	**max.**	**min.**	**max.**	**min.**	**max.**	**min.**	**max.**
Case	6	5	6	3	8	6	7	9	4	6	8	7	9
Value	1	5864	0.98	15.42	0.54	2.97	4193	0.007	0.95	0	999442	0.60	453.32

experience, from the meticulously curated grandeur of the Gardens of Versailles to the more organic and sprawling landscapes of Peterhof Palace, offering visitors a diverse array of experiences to explore and enjoy.

Examining the data from Table 3, we can discern intriguing patterns and distinctions among the various gardens, shedding light on their design characteristics and visitor experiences. Bagh-e Chehel Sotun emerges as a standout in terms of visual integration, boasting the highest average value among the examples provided. This suggests a layout where elements seamlessly blend, creating a cohesive and visually engaging environment. However, it also exhibits the lowest average choice value, implying a potentially more structured or guided visitor experience compared to other gardens.

On the other hand, the Taj Mahal showcases the highest average visual clustering coefficient, indicating a design that promotes clustering or grouping of visual elements, potentially creating focal points or areas of interest within the garden. Rikugi-en Gardens shines in terms of average connectivity, boasting the highest value among the examples provided. This suggests a well-connected layout that facilitates movement and exploration, allowing visitors to navigate the garden with ease and discover its various features and vistas.

In contrast, Herrenhausen Gardens presents the lowest average connectivity, accompanied by the lowest average visual integration. This suggests a design characterized by isolated features or pathways, potentially fostering a more disjointed or unpredictable visitor experience. Moreover, it features the highest average gate count and visual entropy, indicating a potentially more complex or maze-like layout. Yu Garden stands out for its high average visual controllability, suggesting a design that allows for precise control over the visual experience, potentially guiding visitors along predetermined paths or toward focal points. Additionally, it boasts the lowest average line length, indicating a compact layout that maximizes space efficiency.

The Gardens of Versailles, known for its grandeur, presents the lowest average gate count and visual controllability, suggesting a design that prioritizes expansive vistas and open spaces over intricate pathways or controlled visual experiences. It also exhibits the lowest visual clustering coefficient, indicating a more evenly distributed layout without prominent clusters or focal points.

Villa d'Este, Tivoli, impresses with the highest average choice value, suggesting a garden design that offers visitors a wealth of options and paths to explore, fostering a sense of freedom and discovery. Lastly, Peterhof Palace stands out for its high average line length, indicating extensive pathways or sprawling grounds, yet it also boasts the lowest average visual entropy, suggesting a design that balances complexity with coherence, guiding visitors through the landscape with clarity and purpose.

It is important to acknowledge that these analyses are based on the current form of these historic gardens. However, gardens are dynamic entities that evolve over time. Changes in planting schemes, the addition or removal of structures, and even shifts in maintenance practices can significantly impact spatial configuration and visual coherence.

5.1 Analysis of different parts of gardens

The investigation involves a comprehensive evaluation of the Depthmap software's constituent components. This analysis extends across various sectors of garden layouts, encompassing the Entrance and Exit areas, central core regions, and the primary and secondary routes. Figure 3 and 4 provide detailed insights into these divisions for meticulous examination and comparison.

Analyzing the characteristics of various garden designs based on their connectivity, visual integration, visual entropy, gate counts, visual controllability, visual clustering coefficient, and choice reveals distinct patterns across different cases.

First, let's examine the entrance and exit areas. Bagh-e Chehel Sotun, Herrenhausen Gardens, and Rousham Gardens stand out with high gate counts (GC), indicating potentially larger entrances or exits, suggesting a grand entrance experience. Conversely, the Gardens of Versailles and Peterhof Palace exhibit high visual controllability (VC) but low visual entropy (VE), suggesting a more controlled and structured entrance and exit experience.

Moving to the central areas, Bagh-e Fin and Herrenhausen Gardens demonstrate high visual integration (VI) and visual clustering coefficient (VCC), indicating a harmonious layout with interconnected pathways and features. Conversely, the Taj Mahal and Yu Garden have lower VI and VCC but higher choice (CH), suggesting a more varied and potentially labyrinthine central design.

Regarding main versus secondary routes, Bagh-e Chehel Sotun and Bagh-e Fin showcase higher VI and lower VE on main routes, indicating a focus on visual coherence and guiding visitors along prominent pathways. Conversely, the Taj Mahal and Rousham Gardens exhibit higher VI and lower VE on secondary routes, potentially offering more secluded or exploratory experiences away from the main thoroughfares.

Finally, considering the overall design, Rikugi-en Gardens and Villa d'Este, Tivoli, emerge with unique characteristics. Rikugi-en Gardens features high choice (CH) and a low visual clustering coefficient (VCC), suggesting a design that prioritizes variety and individual exploration over cohesive clustering. On the other hand, Villa d'Este, Tivoli, presents high visual entropy (VE) and low visual integration (VI), implying a more organic and potentially less structured layout compared to other cases.

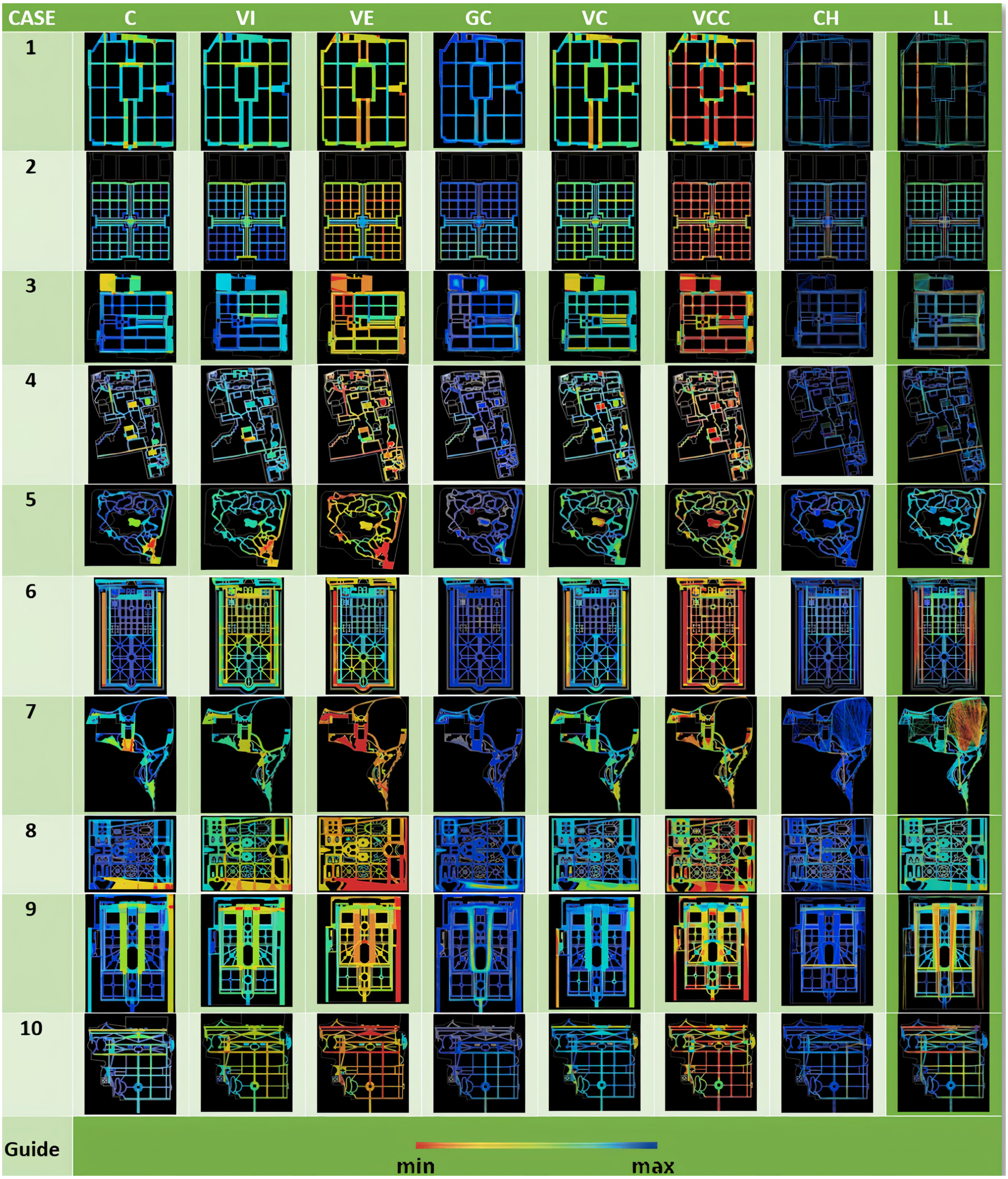


Figure 3. Analysis of garden structures (own research, 2025).

In summary, each garden design showcases a unique blend of connectivity, visual coherence, and visitor experience, with distinct approaches to entrances, central layouts, route design, and overall aesthetic. These variations offer visitors diverse experiences, from structured and guided pathways to more organic and exploratory journeys through the landscapes.

Figure 4. Analysis of the structure of different parts of gardens (own research, 2025).

5.2 Relationships of Connectivity with other elements

Analysis of the relationship between spatial Connectivity and other analytical elements of DepsMap in gardens are shown in Figure 5.

Analyzing the relationship between connectivity and various components across different garden case studies reveals intriguing patterns and distinctions. In all cases except for VCC, a positive correlation exists between connectivity and the other components. However, the strength of this relationship varies among the case studies. Consistently, the most significant relationship is observed between connectivity and VC, indicating that visual controllability plays a crucial role in determining a garden's overall connectivity. This suggests that gardens with well-defined visual pathways and focal points tend to exhibit higher connectivity.

Conversely, the relationship between connectivity and VCC tends to be weaker and often exhibits a negative correlation. This implies that as connectivity increases, the visual clustering coefficient decreases, suggesting a trade-off between overall connectivity and the localized clustering of visual elements within the garden. The distribution of points on the diagrams further illuminates these relationships. In some instances, such as Bagh-e Chehel Sotun and Villa d'Este, Tivoli, the equilibrium line between connectivity and VC closely aligns with the distribution of points, indicating a strong and consistent relationship. Conversely, in cases like the Taj Mahal and Herrenhausen Gardens, the alignment is less pronounced, suggesting a weaker association between connectivity and VC.

Furthermore, the weakest relationship between connectivity and other components varies across cases. For example, in the Taj Mahal and Yu Garden, the weakest association is with GC, indicating that gate counts have less influence on overall connectivity. In other cases, such as Rikugi-en Gardens and Peterhof Palace, VE exhibits the weakest relationship, suggesting that visual entropy plays a less critical role in determining connectivity in these gardens. While a positive correlation between connectivity and other components is a common thread across the cases, the strength of this relationship and the influence of individual components vary, highlighting the nuanced nature of garden design and spatial relationships.

6 Discussion

6.1 Correlation

There is a strong correlation between Connectivity with Visual Integration and Gate Counts. Therefore, with increasing Connectivity, Visual Integration and Gate Counts also increase sharply.

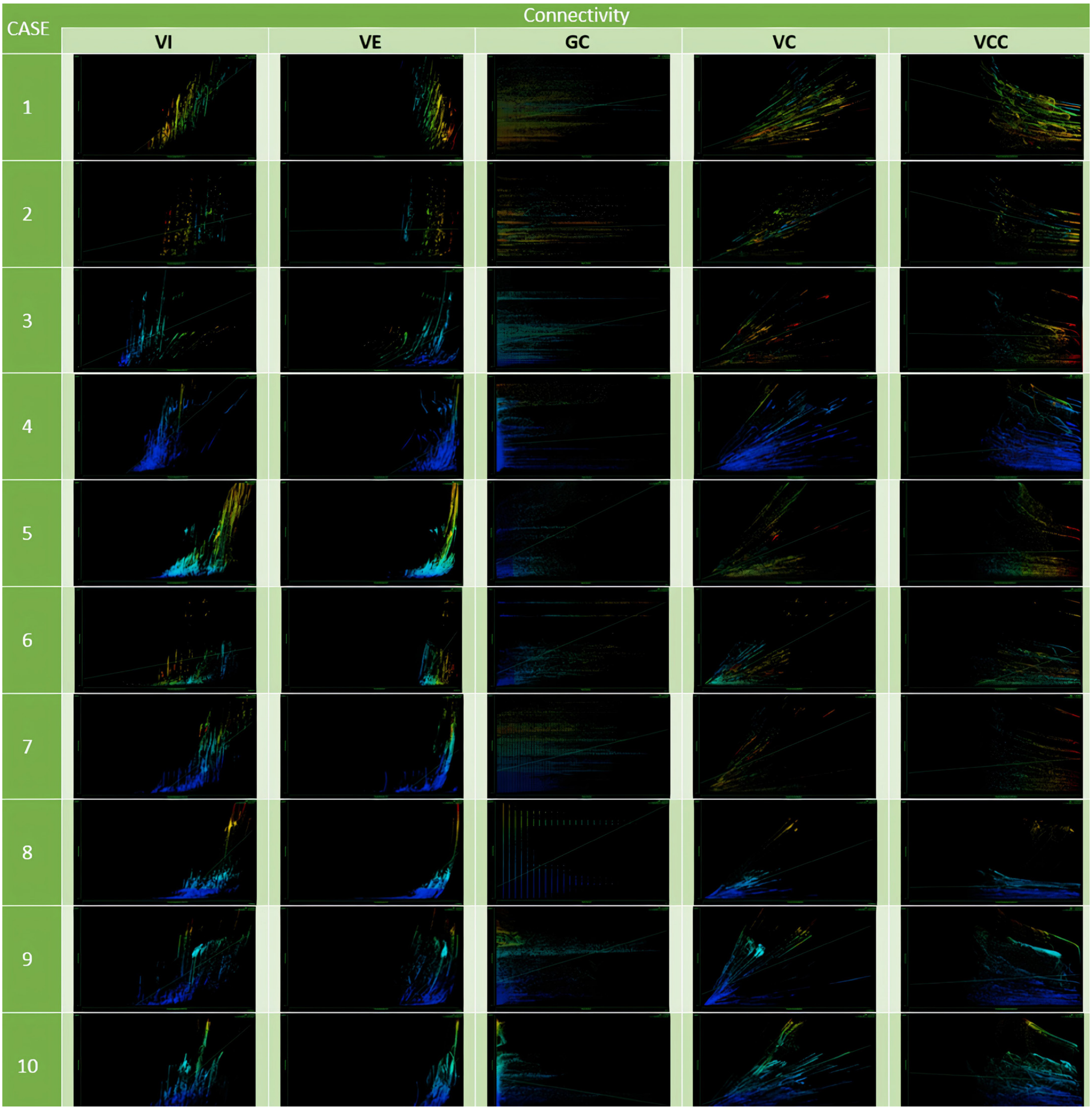


Figure 5. Spatial connectivity (own research, 2025).

However, with increasing Line Length, connectivity increases slightly and has a limited correlation with connectivity. Also, with the increase of Visual Controllability, due to its strong correlation with Visual Clustering Coefficient, it increases with great intensity. There is a relative correlation between Choice and Visual Controllability that with increasing Choice, Visual Controllability increases slightly less intensely. There is a good correlation between Visual Entropy and connectivity and Visual Integration. With increasing the amount of Visual Entropy, Visual Entropy and Visual Integration components decrease with less intensity. There is also a relationship between Line Length and Visual Integration, Visual Entropy, Gate Counts, Visual Controllability, and Choice, which increases the expression of Line Length components. They are reduced depending on their correlation with Line Length. All of these

Table 6. Correlations (own research, 2025).

		Correlations							
		C	VI	VE	GC	VC	VCC	CH	LL
C	Pearson Correlation	1	.760*	-.726*	.505	-.221	-.329	-.030	.113
VI	Pearson Correlation	.760*	1	-.939**	.017	-.156	-.096	-.039	.549
VE	Pearson Correlation	-.726*	-.939**	1	-.016	.116	.251	-.104	-.342
GC	Pearson Correlation	.505	.017	-.016	1	.236	-.018	.099	-.355
VC	Pearson Correlation	-.221	-.156	.116	.236	1	.645*	.266	-.427
VCC	Pearson Correlation	-.329	-.096	.251	-.018	.645*	1	-.101	-.001
C	Pearson Correlation	-.030	-.039	-.104	.099	.266	-.101	1	-.267
LL	Pearson Correlation	.113	.549	-.342	-.355	-.427	-.001	-.267	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

relationships are two-way and work the other way around, and It is shown in Table 6.

6.2 Specialized Discussion and Review Improvement: Cross-Cultural Garden Analysis

The spatial characteristics of historic gardens reflect deep cultural and philosophical underpinnings, which are illuminated through metrics such as Connectivity (C), Visual Integration (VI), Visual Entropy (VE), Gate Counts (GC), Visual Controllability (VC), Visual Clustering Coefficient (VCC), Choice (CH), and Line Length (LL). To enhance the current quantitative findings, it is essential to contextualize these metrics within the cultural frameworks and user experiences they represent.

Comparative Spatial Dynamics Across Cultures

- Persian and Mughal Gardens

  Persian and Mughal gardens, exemplified by Bagh-e Fin, Bagh-e Chehel Sotoun, and the Taj Mahal, are characterized by high Visual Integration (VI) and moderate Visual Controllability (VC). These spatial attributes signify the ordered geometries and axial symmetry that embody concepts of paradise and spirituality. Gardens of this tradition often served as metaphors for cosmic harmony, creating a sense of unity and contemplation for users.
- East Asian Gardens

  Japanese and Chinese gardens, such as Rikugien and Yu Garden, display low Line Length (LL) and Connectivity (C), reflecting intricate paths and fragmented layouts designed to mimic natural landscapes. These configurations align with philosophical traditions like Taoism and Zen Buddhism, emphasizing impermanence and a meditative journey. The low Visual Entropy (VE) and controlled Visual Clustering Coefficient (VCC) foster secluded and tranquil environments, enriching the user's sensory engagement.
- European Formal Gardens

  The grandeur of European gardens, including Versailles, Villa d'Este, and Peterhof Palace, is evident in their high Connectivity (C), Line Length (LL), and Gate Counts (GC). These metrics illustrate expansive axial pathways and open vistas that prioritize visibility and control, often serving as symbols of royal dominance and societal hierarchy. Their low Visual Entropy (VE) underscores a predictable and highly controlled landscape aesthetic, enhancing their ceremonial and display-oriented functions.
- English Landscape Gardens

  Gardens such as Rousham Gardens introduce a contrast with their moderate Gate Counts (GC) and high Choice (CH). These designs reflect a more naturalistic approach, promoting exploration and individual interpretation, inspired by Romantic ideals of freedom and emotional resonance.

Impact on User Experience

The spatial configurations of gardens strongly influence user experiences, aligning with cultural values and intended functions:

- Persian and Mughal gardens evoke unity, order, and contemplation through their symmetrical layouts.
- East Asian gardens foster introspection and discovery, reflecting their fragmented and organic

designs.

- European gardens emphasize dominance, control, and public display, appealing to a collective sense of awe.
- English gardens celebrate individuality and emotional engagement, blending natural landscapes with cultural symbolism.

6.3 Integration of Quantitative and Qualitative Insights

The integration of quantitative metrics such as Connectivity (C), Visual Integration (VI), and Visual Entropy (VE) with qualitative cultural and historical narratives provides a deeper understanding of the spatial and experiential dynamics of historic gardens. These metrics are not just numerical representations of design features but are intrinsically linked to the cultural philosophies, rituals, and social functions embedded within each garden's layout. For instance, the high Visual Integration (VI) in Persian and Mughal gardens reflects their emphasis on axial symmetry and spiritual symbolism, aligned with Islamic cosmology's representation of paradise. Conversely, the low Line Length (LL) and Connectivity (C) in East Asian gardens mirror Taoist and Zen principles, fostering an organic, fragmented layout that emphasizes meditative exploration. Similarly, the high Connectivity (C) and Line Length (LL) in European formal gardens underline their role as expressions of royal authority and control, creating grand, highly visible spaces for public and ceremonial purposes. By juxtaposing these metrics with cultural interpretations, the analysis reveals how spatial configurations influence user experiences, shaping emotions, behaviors, and interactions within the garden. This synthesis of quantitative and qualitative insights bridges the gap between numerical analysis and cultural significance, enabling a holistic evaluation of historical garden design that transcends purely technical perspectives.

7 Conclusion

Historic gardens exhibit a diverse range of structures and components, each possessing unique characteristics. While these characteristics vary significantly in terms of layout and spatial relationships, similarities can be observed in their integration of natural and artificial elements, their underlying conceptual frameworks, and the cultural heritage they embody. For instance, Indian gardens often feature irreg-

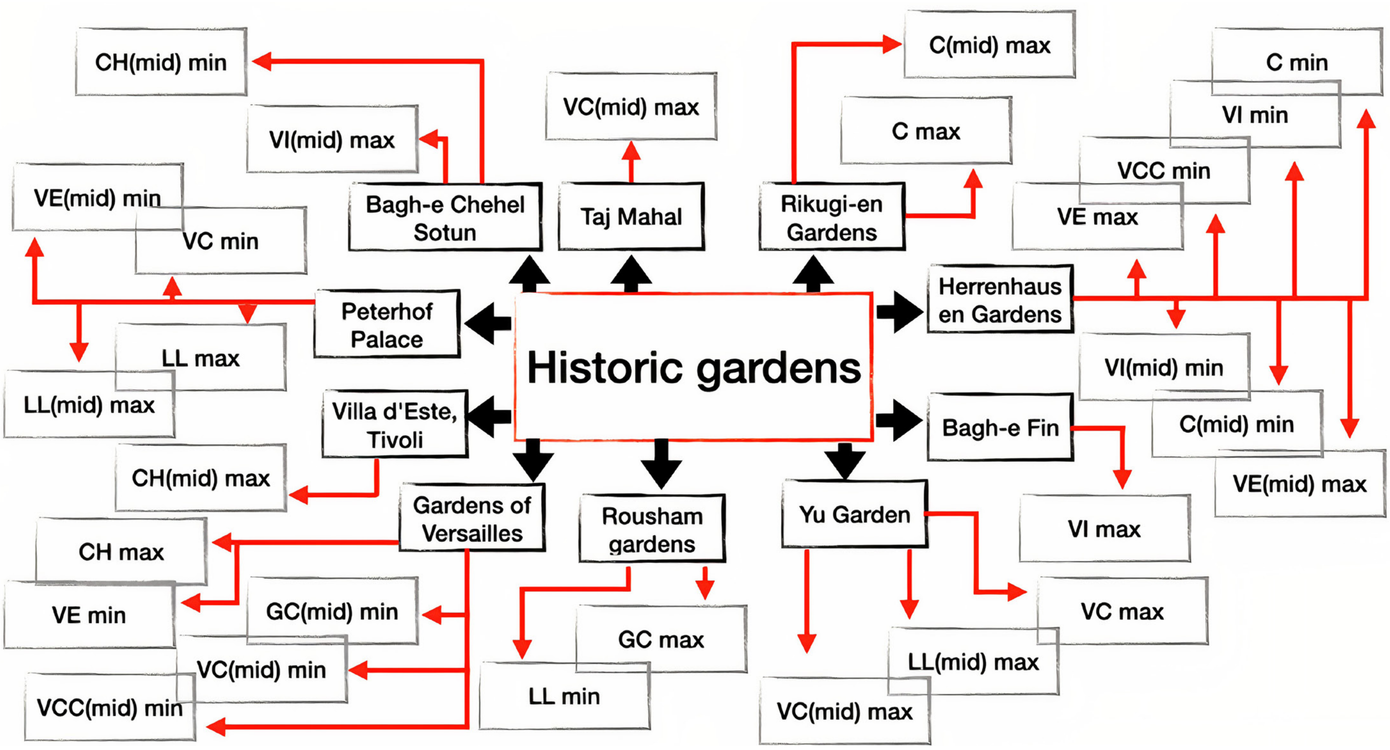


Figure 6. Features of gardens (own research, 2025).

ular layouts that connect the garden with the surrounding landscape geometry. In contrast, gardens characterized by strong geometry, asymmetry, and a defined order may exhibit reduced connectivity between different sections. Regardless of the specific layout, whether ordered or irregular, the spatial relationships within a garden are fundamental to its structure and can be enhanced by increasing connectivity between different areas. The unique characteristics of each garden are visually represented in Figure 6.

Historic gardens exhibit diverse structural characteristics, broadly categorized into two types: geometric and irregular. Geometric gardens typically feature a more ordered and integrated spatial layout, with open, interconnected spaces that promote visual connectivity and a sense of expansive depth. However, this structured approach may result in a more limited range of distinct landscape experiences. In contrast, irregular gardens prioritize a more varied and compartmentalized spatial organization, offering a greater diversity of views and experiences within the garden. This often leads to fluctuations in connectivity, with some areas highly interconnected and others more secluded, depending on the specific design. While visual depth may be more limited in certain areas, these gardens often emphasize a strong central element or focal point that anchors the overall composition.

8 Outlook

The findings of this research offer promising avenues for future exploration and application in multiple domains of urban planning, landscape architecture, and cultural heritage preservation. One immediate implication lies in the integration of geometric principles observed in historical gardens into modern landscape design. This approach could inform the development of green spaces that not only contribute to environmental sustainability but also reflect cultural values, enhancing the identity of public spaces in urban settings.

In cultural heritage preservation, these insights could guide the restoration and adaptive reuse of historical gardens, ensuring that the core geometric values of these spaces are retained while making them relevant for contemporary use. The study's emphasis on the relationship between geometry and spatial experience provides a framework for designers to consider both aesthetic and functional aspects in the preservation of historical garden spaces.

Moreover, the comparative nature of this research, examining gardens across various cultural contexts, opens new directions for cross-cultural studies. Future work could explore how diverse societies have used geometric principles to shape their public and private spaces, facilitating an exchange of knowledge and best practices in landscape design. This research could also inspire hybrid design approaches that blend traditional and modern elements to create more inclusive, culturally resonant urban environments.

The analytical tools and methods applied in this study hold significant potential for future applications in contemporary urban green space design. By incorporating the geometric patterns and spatial relationships identified in historical gardens, urban planners can develop green spaces that not only address ecological concerns but also promote a deeper sense of place, heritage, and community engagement. This research ultimately provides a valuable foundation for advancing the integration of cultural identity and user experience in modern urban landscapes.

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Declaration of Competing 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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