

How Far Can Symmetry Create Coherence in Architecture? A Quantitative Analysis of the Impact of Sub-symmetries on Coherence in Architectural Façade

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Abstract

Despite recognizing coherence as a primary goal in architectural design, and the increasing acknowledgment that overall symmetry is not always the optimal solution for achieving it, the role of sub-symmetries and how they contribute to overall coherence remains underexplored, particularly from a quantitative and analytical perspective. Our research posits that the sub-symmetries across multi-levels of change in scale is related to coherence. Accordingly, we aim to quantitatively investigate the relationship between the number and distribution of sub-symmetries across the multi-scaling ratio (r) in architectural façades and the concept of coherence (C), considering the latter as an objective dependent, and measurable property. The study is based on the hypothesis that the distribution of sub-symmetries across different scales is not random, but rather follows a specific mathematical structure that can be measured and directly linked to the overall coherence of the façade. To achieve this, a quantitative methodology was applied to analyze several samples of architectural façades including calculating the total cumulative number of sub-symmetries in relevance to the scaling ratio. At first, the relationship between the scaling ratio and the number of cumulative sub-symmetries was examined. Then, the relationship between the total number of sub-symmetries and the level of coherence was measured using the proposed coherence index (CI). The results revealed a clear inverse relationship between the scaling ratio and the cumulative number of sub-symmetries, where the number increases as the scale decreases. More importantly, the study demonstrated a strong and direct relationship between the total number of sub-symmetries and the level of architectural coherence, suggesting that increasing the density of sub-symmetries significantly enhances coherence. The research concludes that architectural coherence is not merely an abstract concept, but a measurable property that depends heavily on the density and organization of sub-symmetries. These findings provide a quantitative basis to understand how precise structural organization, through sub-symmetries, contributes to achieving higher levels of coherence in architectural design and suggests the potential for developing analytical and design tools to enhance this property.

Keywords

Symmetry; Sub-Symmetries; Scaling Hierarchy; Coherence; Scaling ratio; Power law

1. Introduction

Architecture, at its core, is a continuous pursuit of creating environments that not only fulfill functional needs but also resonate with our aesthetic and psychological perception, achieving a sense of unity and harmony known as coherence. Coherence is not merely the regularity of structures, the coherent architecture creates a profound feeling that every part of the building is in its right place, fulfilling its purpose correctly and in perfect harmony. When all parts of a building harmonize and blend together, they create a complete visual experience. But how can coherence be achieved and what does it depend on?

Theories in environmental and cognitive psychology suggest that the human brain tends to seek unity and order within the visual field. The feeling of coherence in the surrounding environment is associated with psychological comfort and aesthetic preference. Historically, architects have relied on strong organizational principles, such as symmetry to impose order and achieve visual balance. Since symmetry provides a sense of harmony, order, and balance, it is viewed as a perfect form of equilibrium and a characteristic associated with stability (Azemati et al., 2020). Symmetry, with its elements distributed equally around an axis or point, is a fundamental mechanism for achieving visual harmony and structural order. This balanced distribution makes it the clearest and most complete form of equilibrium, leaving no doubt about the stability of the composition. Historically, whether in nature or in human creations like architecture, symmetry has been associated with concepts of stability, permanence, and strength, making it an intuitive choice for expressing these values. Symmetry in architecture is a multi-dimensional concept that connects geometric organization (at both surface and deeper levels), human perception, the fundamental need for order, aesthetic values (such as beauty and harmony), and can have a profound impact on human health and well-being (Zeki, 2019). So, symmetry transcends its traditional role as merely a mechanism for achieving visual harmony and structural order, or solely as a symbol of structural stability. Rather, it is a multi-faceted concept intricately linking precise geometric organization, at both superficial and profound levels, with innate human perception and the fundamental need for order. Its influence extends to aesthetic values, evoking feelings of beauty and satisfaction, and further to a profound impact on the psychological health and overall well-being of space users, reinforcing its role as a stabilizing element that transcends the physical dimension to encompass the psychological and experiential. Deep coherence of a structure relies on the dynamic interplay between order and complexity across all levels (Lewis, 2020). That means deep and vital coherence arises from more complex interactions, involving the organization of details and how they connect to the larger whole across multi-levels of changing scale. One might wonder, what is the relationship between coherence and symmetry? What role does symmetry play in achieving coherence? Can the degree of design coherence be determined based on local symmetries? To what extent does changing the scale affect the perception of local symmetries and what impact does that have on the design's coherence?

Our research explores a key aspect of this multi-scalar structure, seeking to understand the role of partial organization, specifically sub-symmetries, in achieving the overall coherence of architectural façades.

2. Coherence in Architectural Perception and Design

The concept of coherence is based on the phenomena observed in organic forms in nature, which exhibit a unity beyond the mere aggregation of elements and this ensures the actual functional efficiency of their systems. It is considered a feature of the external world that aims to achieve this kind of balance at all levels of structures (Al-Safty, 2021). Coherence is not merely a logical consistency which represents physical

organization, including the mechanism of connections between parts and the way elements hold together and resist separation. The presence of consistency is considered a necessary and essential condition for achieving coherence, but, the elements also must be connected according to a certain logic, to be used metaphorically in meaning-making (Koutsoumpou, 2013). Furthermore, consistency often refers to the continuity of a structure in time and space (Al-Safty, 2021). So, coherence can be defined as the interrelationship between the parts, components, or elements of a particular system, whether that system is physical, cognitive, linguistic, social, or architectural. This coherence should be consistent in terms of the type and number of elements, as well as the mechanisms of interconnection between them (the quantity and quality of the system's formation) in a balanced and logical manner, with a clear meaning and a specific goal, to ensure the achievement of an integrated and harmonious unity that can hold and be sustained. In architecture, coherence is a meaningful connection of different design elements in organized and logical ways, whether these elements are visual, functional, or structural, to achieve a specific purpose. This means that these elements should be harmonious and compatible to form an integrated whole that functions efficiently and has the ability to adapt to changes over time.

2.1 The Role of Scale and Hierarchy

Coherence is more than just an aesthetic attribute or a subjective impression. It represents a deep and objective structural property that can be mathematically analyzed and may vary in degrees across different parts of the space. It relies on concepts from complexity science, specifically the study of complex networks, which represent the regular arrangement of parts in naturally and efficiently coherent living (Jiang, 2020). The theory of *scaling hierarchy* is a distinctive characteristic of coherent systems (according to the complex networks concept), meaning there is a very large number of parts or details at small scales, fewer parts at intermediate scales, and very few parts at large scales that represent the whole. Both the strong interconnection among elements within the same scale (dependence) and their uneven distribution across scales (heterogeneity) are two fundamental features of complex networks (Chen & Jiang, 2018). And both *differentiation* and adaptation are fundamental processes for creating coherence. Coherence is global when smaller elements are more numerous than larger elements, and local when elements of the same size depend on each other (Jiang, 2020). This means that the coherence of the design as a whole depends on pattern repetition, hierarchy, and the integration of elements. Coherence is achieved through two processes: a suitable hierarchy of different levels and the interconnectedness of all elements within that hierarchy. This implies connecting elements on each scale individually and connecting them to elements at other scales with smooth and gradual transitions. When this happens, scaling coherence is achieved in the system as a whole, through strong local coherence (resulting from the differentiation and repetition of parts) which contributes to creating and enhancing global coherence (resulting from the adaptation of parts to the whole). When all levels are interconnected in this integrated way, comprehensive design coherence is achieved, leading to the structure appearing as a coherent, living, harmonious whole with deep meaning. In contrast, the absence of this scale hierarchy may lead some designs to fail in achieving vitality and coherence, as the details may appear missing or disconnected from the larger whole.

Architectural coherence emerges from the organization, repetition, and interrelation of diverse components across multi-scales. Our research claims that symmetry contributes significantly and directly to achieving coherence across multi-levels of changing scale.

3. Symmetry as a Fundamental Organizing Principle

Symmetry is a universal principle that provides a framework for understanding the fundamental laws of nature, the elegance of aesthetic forms, and the logic behind human perception. It offers a framework for the clarity and coherence of physical phenomena (Youvan, 2024). It represents stillness and stability (which stem from the need for balance), while at the same time allowing for transformation or motion. In other words, symmetry refers to the consistency of form under transformations such as reflecting, rotating, or translating the object, without changing its original shape (Kotoky, 2024). It refers to stability in shape or structure when applying certain transformations, occurring through the repetition of shapes or patterns according to a specific order, such as rotation, reflection, translation, or a combination of these. In architecture, it is a fundamental design principle based on geometric transformations used to create an organized repetition of shapes and spaces, aimed at achieving harmony, balance, and order. Through analyzing its role in organizing forms, it can be said that symmetry functions as a dual mechanism. On one hand, it is perceived as a sign of beauty and stability, and on the other hand, it acts as a fundamental structural feature that organizes the built environment, making it more understandable and interactive. This interconnectedness between aesthetics and cognitive organization is what explains the positive impact of symmetry on enhancing human well-being and health.

For many people, the understanding of symmetry often is limited to the most familiar example of two mirrored halves of an image, as seen in a reflection. However, the concept is much broader, including many different types of symmetry. Reflectional symmetry, the focus of our research, is of particular importance in human perception due to its association with the structure of living beings, such as the human face, as shown in Figure 1. Studies indicate that reflectional symmetry is efficiently processed by the visual system and therefore is aesthetically preferred (Kotoky, 2024). There is rotational symmetry, translational symmetry, scaling symmetry, (Figure 2), and various composite forms that combine these types. Moreover, there also are symmetry-breaking processes, which are important for understanding many biological and physical phenomena (Mehaffy & Salingaros, 2021). Deep symmetry, however, describes a specific kind of hierarchical structure organization that is multi-layered, intricate, and embedded across different scales of measurement within the system. This results in highly complex forms composed of several different types of symmetries at varying scales, meaning it is a symmetry within a symmetry within a symmetry, each at a different scale (Qureshi et al., 2021). Each type of symmetry offers a distinct method for connecting and organizing elements, contributing to coherence in its own way. Simple symmetries (reflective, translational, rotational) provide fundamental tools for order, unity, and balance. Symmetry breaking and composite symmetry offer the flexibility and complexity necessary to make a design dynamic and adaptable while maintaining order. Scale symmetry and deep symmetry, on the other hand, aim to achieve a more comprehensive, profound, and organic coherence.

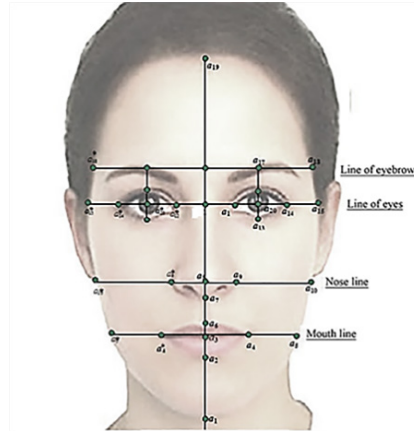


Figure 1. Reflectional symmetry in a human face.

Source: (Kazimov, 2014).

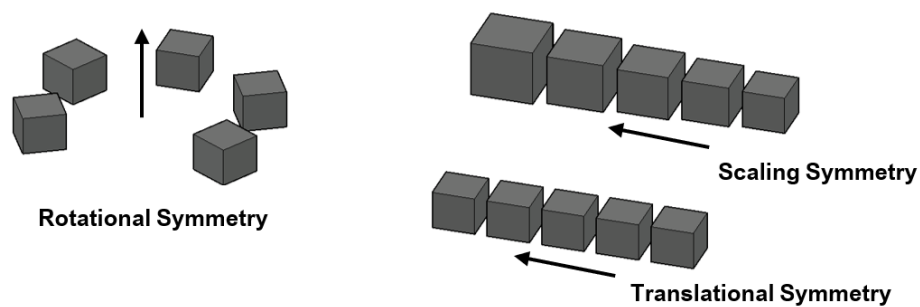


Figure 2. Translational, scaling, and rotational symmetry of a cube.

Source: The researchers.

4. Wholeness and Achieving Coherence through Centers

Christopher Alexander linked the concept of coherence to a deeper concept of wholeness or life in the built environment. He believed that coherence is more than just shallow harmony, it represents a deep structural property of a wholeness or living environment. This coherence, and thus wholeness, is achieved through interconnected and coherent centers. A center is an organized entity or a focal point in space, and it can exist at any scale, from a small pattern in a decoration to an entire building or neighborhood (Alexander, 2002). The interconnectedness of these centers, and the coherence of their relationships across various scales, is what weaves the fabric of a “living” and integrated environment, one that transcends outward appearance to touch the essence of human experience. The fundamental characteristic of these centers is their hierarchical and multi-scalar structure. Each center is made up of smaller centers, is part of larger centers and also is connected to other centers at the same scale (Dawson, 2023). When all these centers overlap and interconnect deeply, they reinforce each other and create a coherent overall structure that inherently reflects wholeness.

Alexander (2002) also identified fifteen fundamental structural properties necessary for achieving this living and coherent structure of centers (Figure 3). These properties serve as guiding principles for creating environments that resonate with the human sense of comfort and well-being. Therefore, he presents coherence as an emergent property of a hierarchical structure rich in interconnected centers across all scales (Gorichanaz, 2023). These properties serve as practical guidelines. Their goal is to empower designers to create environments characterized by a living, coherent structure of centers. Crucially, these environments are not merely aesthetic compositions, but rather those that resonate deeply with the human sense of comfort and well-being. Therefore,

coherence in this context is presented not as a specific design goal, but as an emergent property. In other words, true coherence is not achieved by forcibly imposing it, but rather it arises naturally when a hierarchical structure rich in closely interconnected centers across all scales is formed, following these fifteen properties. They are, in effect, the tools that help in building a network of coherent centers and this coherence is what generates life and the wholeness of the built environment.

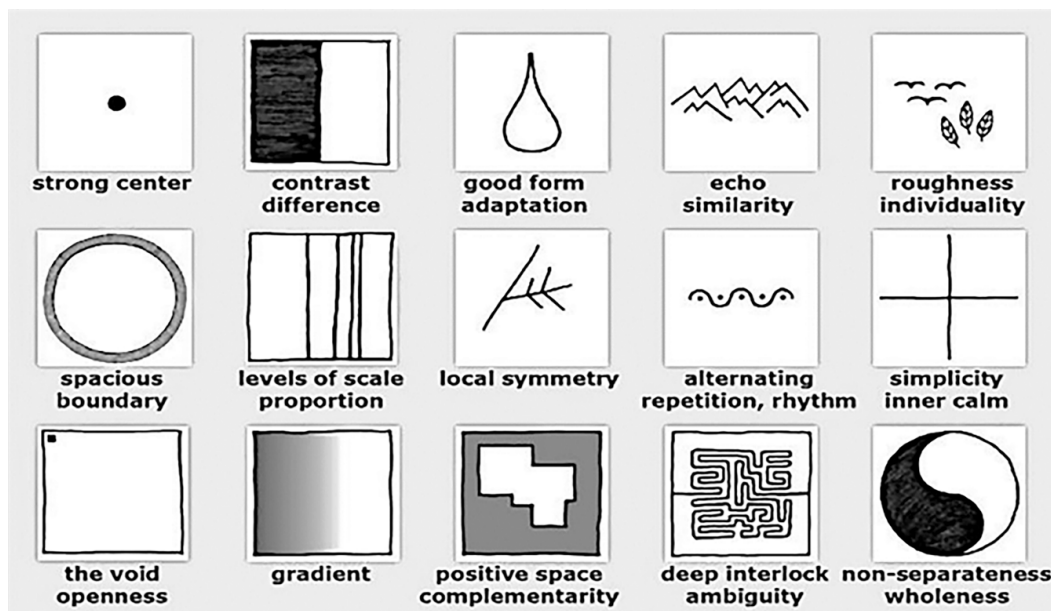


Figure 3. The fifteen properties of the living structure of Christopher Alexander.

Source: (Alexander, 2002)

5. Sub-Symmetries and Architectural Coherence

Symmetry at many different scales and in many different forms is inherent in the structure of our world and it significantly influences the shape and appearance of many natural and anthropogenic scenes (Lopes & Machado, 2020). In context of the importance of multiple scales, the concept of *sub-symmetries* emerges as a complement to global symmetry, referring to the presence of symmetrical organization within specific parts or elements of the overall structure (such as windows, doors, entrances, etc.) (Malewcz et al., 2024). Sub-symmetry therefore refers to the symmetry found within the components of a structure and is related to the organization of individual elements. It appears in specific parts of the structure through the repetition of elements across different levels within the hierarchical scale of the structure. It does not require the overall external form (global) of the structure to be symmetrical; in fact, the overall plan may appear asymmetrical (Figure 4) and its details may be replete with multiple symmetries at various levels, including courtyards, rooms, and columns. This interaction between sub-symmetries creates balance and harmony without leading to rigidity in design. It provides a sense of order and organized complexity at the (local) level and plays an active role in achieving coherence and visual complexity in living environments.

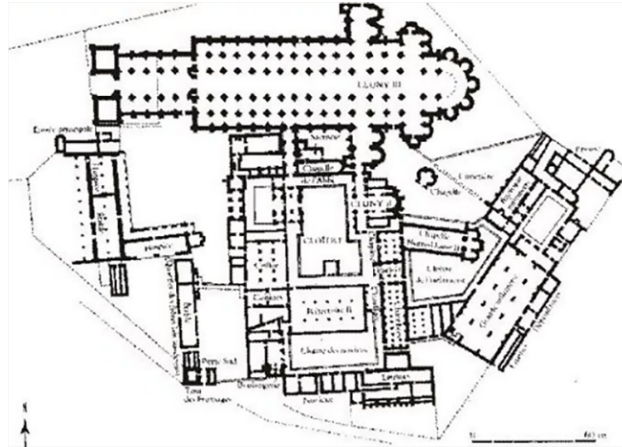


Figure 4. Sub-symmetries in the plan of Cluny Abbey, France.

Source: (Microsoft Bing, 2017).

While overall general symmetries do not contribute to the formation of strong centers, local symmetries play a crucial role in achieving coherence within a design. Also, Alexander (2002) explains that local symmetries act as a glue that binds spaces together, making them appear more coherent and solid. For this glue to be effective, local symmetries must overlap and interact with each other (Alexander, 2002). Global symmetry is more than just strict geometric correspondence when it results from multiple local symmetries on different scales, compatible with and operating within the overall symmetry. When parts appear to naturally belong to the overall structure, they generate a sense of unity, balance, and stability, which form the foundation upon which harmony is built. This harmony is the overall impression left by the coherent structure as a whole. Conversely, perfect symmetry indicates the death of a structure when it lacks sufficient local symmetries to bring life to the overall structure. It is considered less interesting and less appealing, containing coldness, rigidity, immobility, and a sense of stagnation, and is therefore less beautiful and lacking in life. That means *the more sub-symmetries present in a structure, the more coherence and harmony it has and increasing the number of sub-symmetries across multiple levels of scale change leads to an increase in coherence.*

6. Scaling Law and Power Law

The concept of a scaling law (one of the concepts from complexity science and statistical physics that may be applied to analyze architectural and urban structures) provides a general framework for describing any regular relationship or pattern that explains how a particular property of a system (such as the number of elements or the density of details) changes with scales or levels of observation (Jiang & Rijke, 2021B). Scaling law is a fundamental concept that enables us to provide a quantitative and systematic description of scale-dependent relationships within systems. In architecture, it can help us to understand structures that maintain coherence through the transition from small detail to the larger whole.

Within this broader framework, the power law emerges as a specific and highly significant type of scaling law, which is a mathematical relationship that describes how a given quantity is distributed across a wide range of scales and often is associated with phenomena that exhibit self-similarity or fractal structure (Molinero & Thurne, 2021). This law is characterized by the appearance of a straight line reflecting the linear representation of the relationship after logarithmic transformation, where the slope of the line represents the exponent (k) that describes how the quantity changes with scale (Lopes & Machado, 2018).

$$Y = a r^k \quad (\text{Equation of power law (Jiang \& Rijke, 2021B)})$$

$$\log(Y) = \log(a) + k \log(X) \quad (\text{The linear representation or transformation of a power law})$$

Where:

Y: SS (The cumulative number of sub-symmetries)

a: Constant

r: (Scaling ratio, the levels of changing the scale)

k: CI (The architectural coherence index)

Understanding this principle provides a powerful tool for analyzing and designing complex systems, including built environments, where it can help achieve coherent and vibrant structural organization across various scales. Some researchers argue that the distribution of elements or details in cities and architectural designs perceived as good or living often follows certain power laws and that deviations from these distributions may be linked to a loss of coherence or liveness (Jiang & Rijke, 2021A). Therefore, testing whether the distribution of sub-symmetries across different levels of scale change in architectural façades follows a power law and identifying the meaning of the resulting exponent may offer new insights into the deep coherence of architectural structures.

We assume that architectural coherence is related to or arises when the cumulative number distribution of sub-symmetries across multi-levels of scale change, follows a power-law relationship where the exponent describes the nature of this distribution. The value of the exponent itself is not coherence, but rather a parameter that describes the mathematical relationship that may be fundamental to coherence. Coherence will depend on the cumulative number of sub-symmetries, which in turn depends inversely on the scaling ratio. The smaller the scale, the greater the cumulative number of sub-symmetries, and consequently, the greater the architectural coherence.

7. Estimating Architectural Coherence by Sub-Symmetries

The research followed a multi-stage quantitative methodology to experience, analyze, and estimate the number of sub-symmetries in five architectural façades representing masterpieces of classical architecture registered on the UNESCO World Heritage List, giving them a high reference value for comparative analysis. The five façades include the Taj Mahal, Parthenon, St. Peter's Basilica, Palatine Chapel (Aachen), and Dome of the Rock Mosque. The work begins by converting raster images to vector images in relevance to their scales, accuracy, and functions using AutoCAD.

It is important to unify and experience each façade using six hierarchical levels of scale change. The choice of six scale levels represents a practical balance between clarity and feasibility; using fewer levels would not sufficiently reveal the hierarchical organization of local symmetries, while employing more levels would create unnecessary complexity and reduce accuracy given the manual nature of the analysis. The scales are represented as a lattice grid with horizontal scaling ratios (rh) of 0.1, 0.0625, 0.05, 0.04, 0.03125, 0.025, thereby ensuring a gradual and consistent subdivision of the façade width. The corresponding vertical ratios (rv) were 0.2, 0.1112, 0.09, 0.0712, 0.0555, 0.0454, adjusted to accommodate variations in façade height while maintaining a square grid. Subsequently, the façades were converted to an approximate binary (black/white) representation of occupied (solid) areas (squares) at each level of scale change.

Figures 5. and 6 show how changing the scaling ratio affects the number of shaded squares (resolution) in the Taj Mahal façade. At each level of scale change, the number of horizontal versus vertical squares are different.

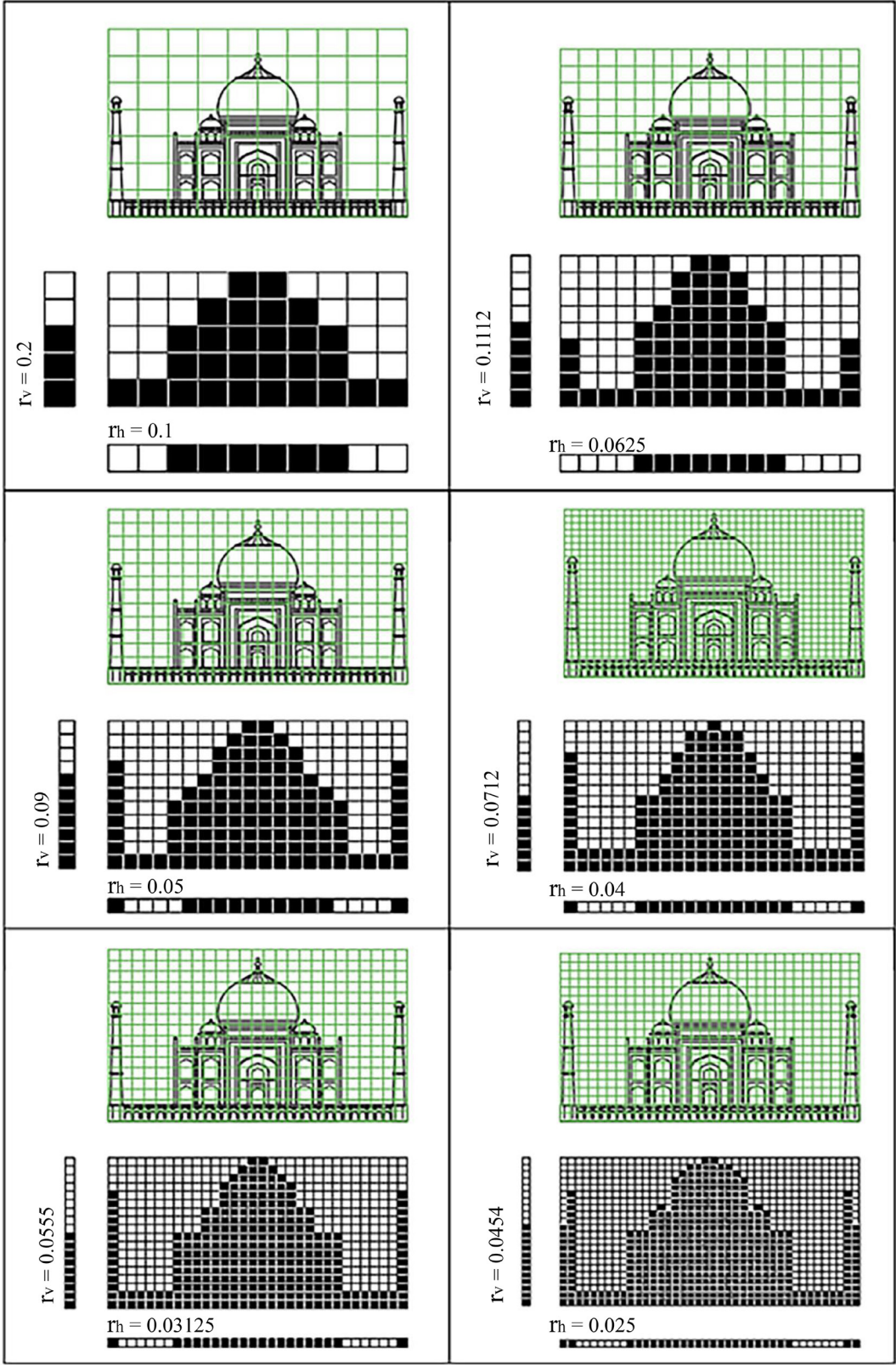


Figure 5. Multi-levels of scale change (resolution) for the Taj Mahal façade.

Source: (The authors).

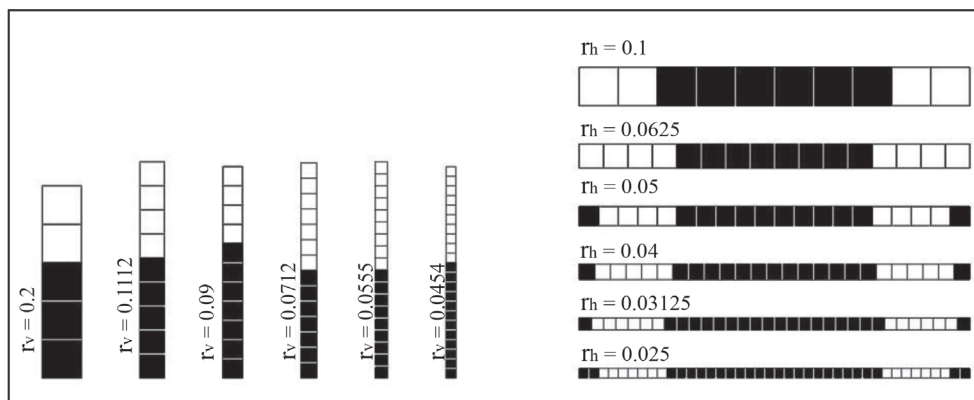


Figure 6. The resultant horizontal and vertical strips' patterns of the Taj Mahal façade.

Source: (The authors).

Christopher Alexander (2002) analyzed strips as seven connected squares to calculate local symmetries, which allowed for the identification of 21 connected sub-sets. For each pattern, these sub-sets were examined for internal symmetry. The most symmetrical pattern showed nine symmetrical sub-sets (SS=9), see (Figure 7). He tested an additional factor that took into account the length of the symmetries, but it was not strongly consistent with perceived coherence, which means that number, not size, is the most important factor in characterizing symmetry (Alexander, 2002). According to the method used by Alexander (2002) "The 35 Pattern Game" the resultant strips would provide reliable reference patterns for subsequent analysis.

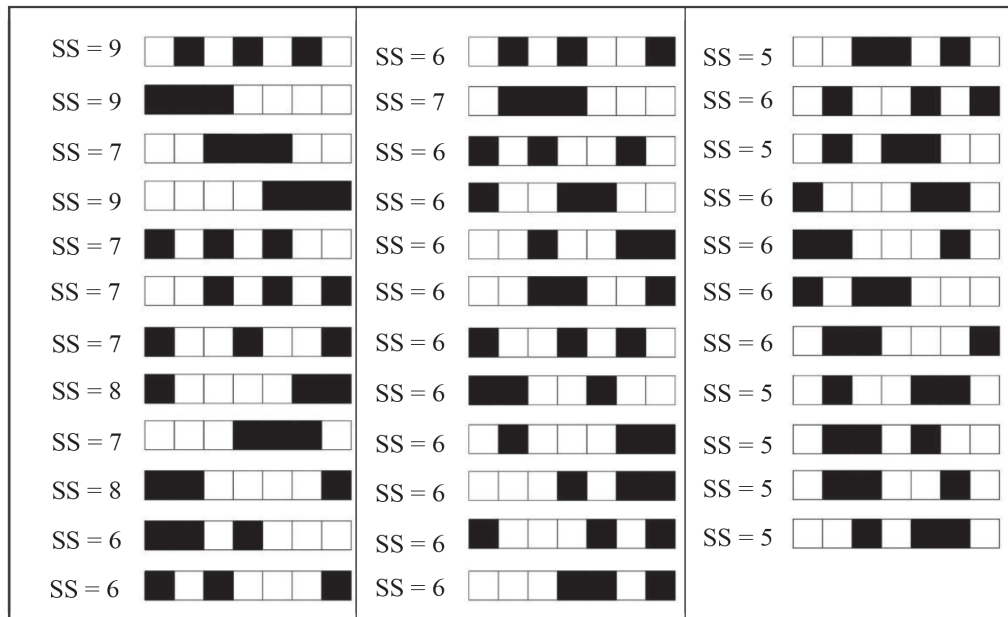


Figure 7. The number of local symmetries for each strip of "35 Pattern Game" of Christopher Alexander.

Source: (Alexander, 2002).

In the same way, Figure 8 illustrates another example of calculating local symmetries where the black subsets represent symmetrical patterns, while the blue subsets do not. These examples show how a pattern can be divided into subsets and used as pattern strips that can be empirically verified to measure the relationship between the sub-symmetries and coherence (Alexander, 2002)

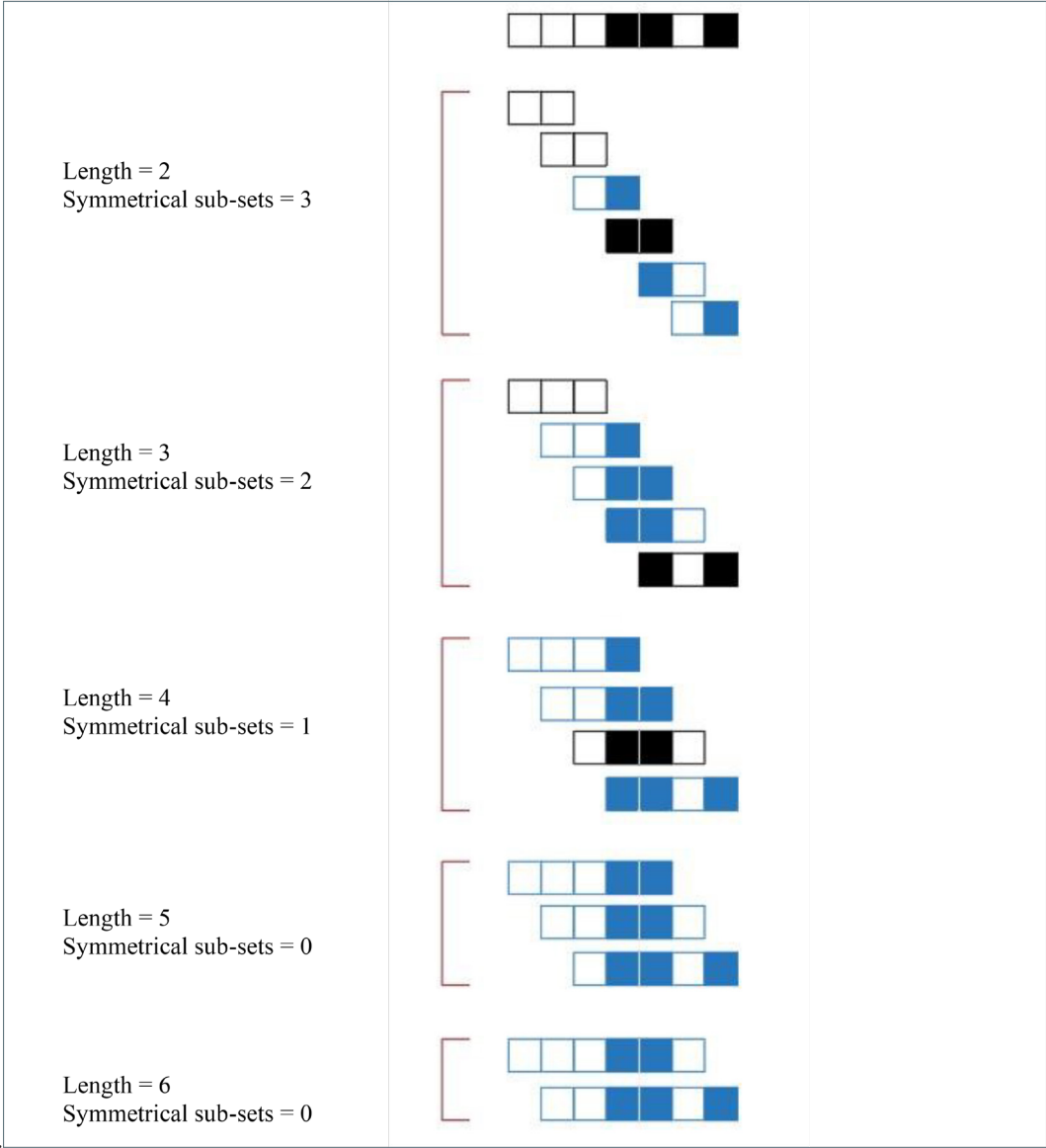


Figure 8. An illustrative example to estimate the number of sub-symmetries in a strip of 6 sub-sets of symmetries.
Source: (The authors).

Based on this method used by Alexander (2002) in what he called “Pattern Game 35,” our research adopted the same methodological basis in analyzing the façade of architectural buildings. The strips resulting from dividing the façade into successive measurement levels (see Figures 9 and 10) represent an application of Alexander’s method and provide a reliable empirical framework for examining sub-symmetries.

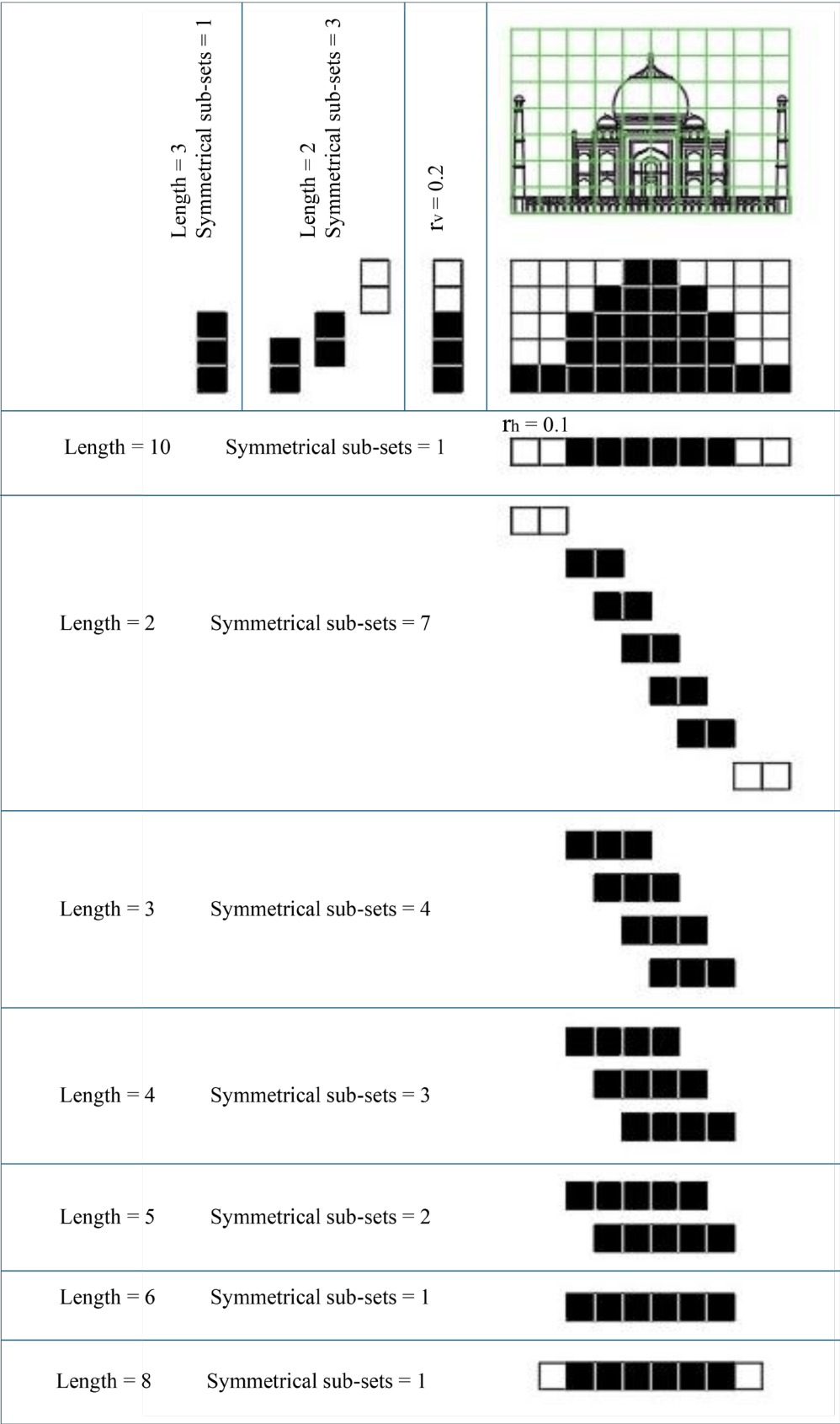


Figure 9. An illustration of sub-symmetries estimation of Taj Mahal façade at horizontal scaling ratio ($r_h = 0.1$) and vertical scaling ratio ($r_v = 0.2$), where ($SS_h = 19$) and ($SS_v = 4$).

Source: (The authors).

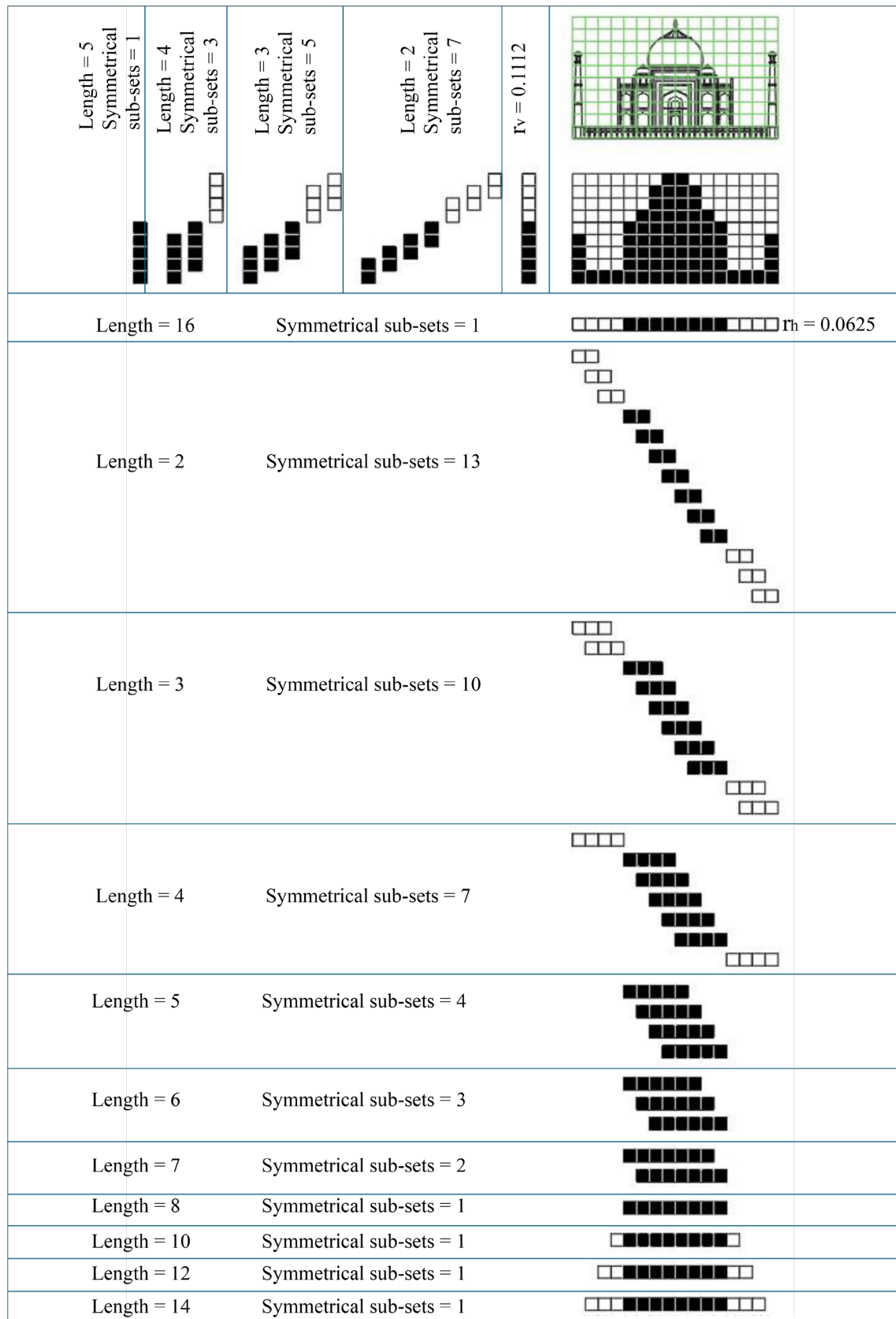


Figure 10. An illustration of sub-symmetries estimation of Taj Mahal façade at horizontal scaling ratio ($r_h = 0.0625$) and vertical scaling ratio ($r_v = 0.1112$), where ($SSh = 44$) and ($SSv = 16$).

Source: (The authors).

Horizontal and vertical sub-symmetries were distinguished and counted separately for each façade through a systematic examination at multiple scaling ratios, from large elements to fine details. The cumulative number for each type of sub-symmetry was then estimated.

Subsequently, the grand total of symmetries for each façade was calculated. This total encompassed the cumulative numbers of horizontal (SS_h) and vertical (SS_v) sub-symmetries, as well as the global symmetry (GS) of the façade (bilateral symmetry around a main central axis), which was considered as one additional symmetry element, as shown in Table 1. This “total symmetries” represents a quantitative indicator of overall and partial symmetrical organization and was used in subsequent analyses to determine the coherence index (CI).

Table 1. Six levels of scaling ratio (*r*) for the Taj Mahal façade and its total symmetries calculations.

Vertical				Horizontal			
r_v	SS _v	Cumulative SS _v	Cumulative GS _v	r_h	SS _h	Cumulative SS _h	Cumulative GS _v
0.0454	111	111	0	0.025	287	287	1
0.0555	72	183	0	0.03125	191	478	2
0.0712	42	225	0	0.04	105	583	3
0.09	27	252	0	0.05	63	646	4
0.1112	16	268	0	0.0625	43	689	5
0.2	4	272	0	0.1	18	707	6
Total symmetries		985					

Source: (The authors).

The scaling law governing the relationship between the mutual scaling ratio (*r*), as an independent variable, and the cumulative number of sub-symmetries (SS), as a dependent variable in architectural façades was explored. The analysis reveals a log-linear tendency as an identifying feature of a power law relationship. The (*R*²) values ranged from (0.7) to (0.9), indicating the distribution of sub-symmetries across scales generally follows a power law pattern (Table 2 and Figure 11).

Table 2. Logarithmic values of the horizontal and vertical scaling ratio and sub-symmetries, and the resulting coherence index (CI) for the Taj Mahal façade.

(r_v)	Log (r_v)	Cumulative (SS _v)	Log Cumulative (SS _v)	(r_h)	Log (r_h)	Cumulative (SS _h)	Log Cumulative (SS _h)
0.0454	-1.342	111	2.045	0.025	-1.602	287	2.458
0.0555	-1.255	183	2.262	0.03125	-1.505	478	2.679
0.0712	-1.146	225	2.352	0.04	-1.398	583	2.766
0.09	-1.041	252	2.401	0.05	-1.301	646	2.810
0.1112	-0.954	268	2.428	0.0625	-1.203	689	2.838
0.2	-0.699	272	2.435	0.1	-1.000	707	2.849
CI_v	0.5275			CI_h	0.579		

Source: (The researchers).

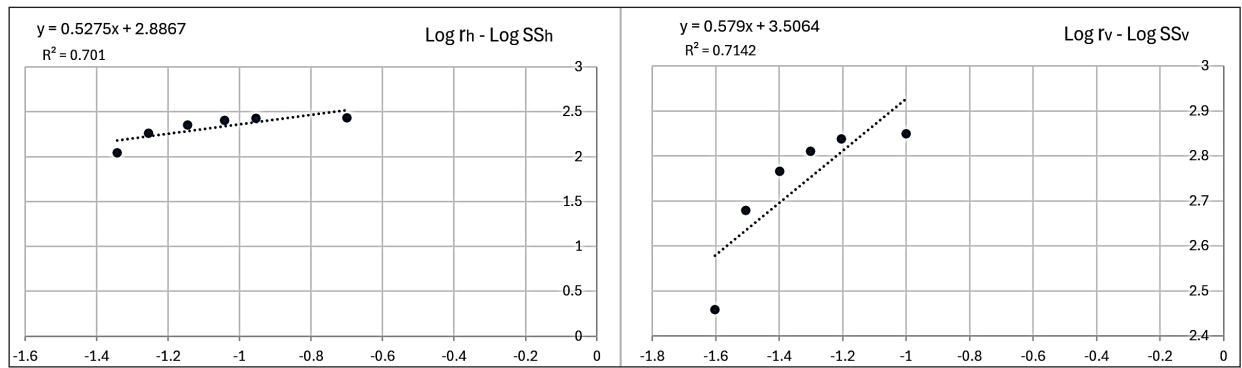


Figure 11. A regression analyses to estimate the horizontal and vertical (CI) index for the Taj Mahal façade.

Source: (The authors).

The common scaling ratio horizontally and vertically, as well as the number of cumulative sub-symmetries were calculated to determine the (CI) coherence index for the façades (Table 3 and Figure 12).

Table 3. Logarithmic values of the common scaling ratio and cumulative sub-symmetries and the resulting coherence index (CI) for the Taj Mahal façade.

Common (r)	Log (r)	Cumulative (SS)	Log Cumulative (SS)
0.04	-1.39794	217	2.33646
0.05	-1.30103	356	2.55145
0.0625	-1.20412	442	2.64542
0.1	-1	488	2.68842
CI	0.7087		

Source: (The authors).

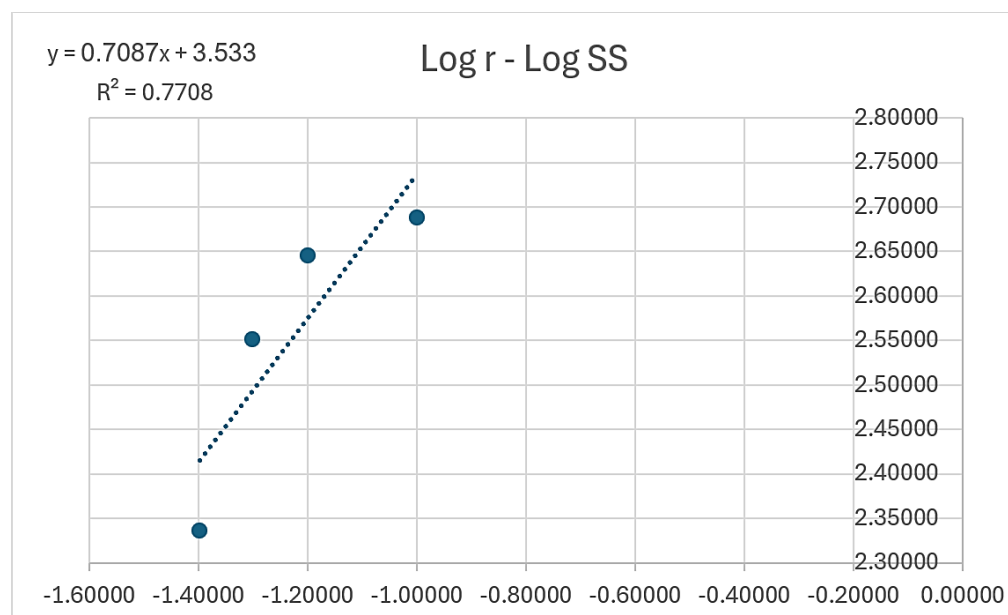


Figure 12. Regression analyses to estimate (CI) index for the Taj Mahal façade.

Source: (The authors).

Figure 13 shows the façades for the five architectural examples noted above, that were carefully selected to represent diversity in terms of time period, spatial context, and the function they serve, with the aim of providing a comprehensive sample for analysis.

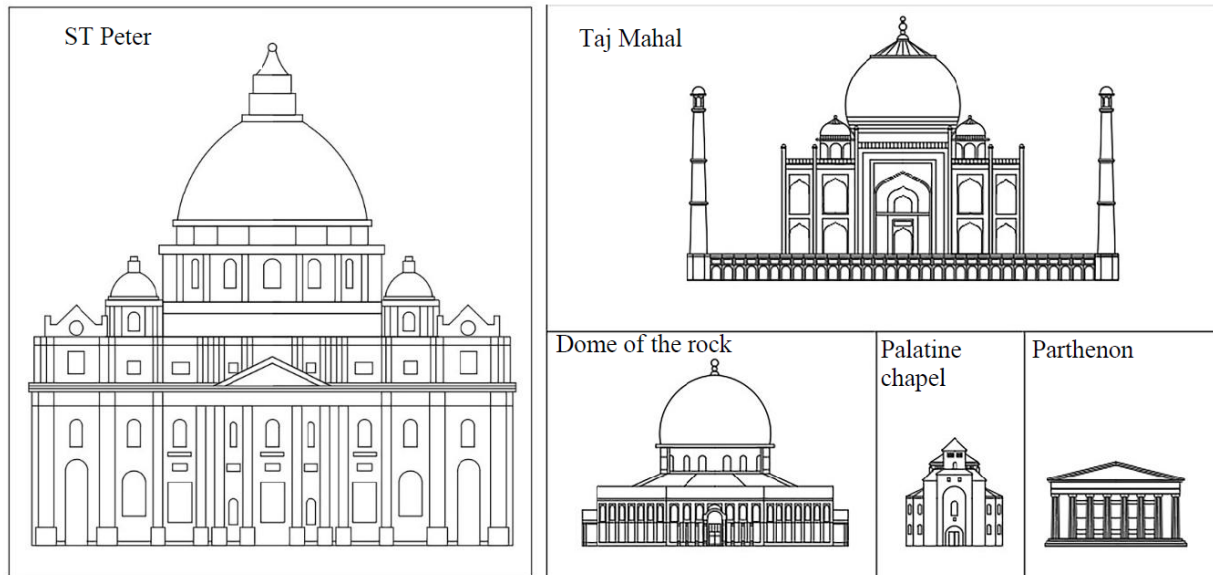


Figure 13. The five façades used in analyzing and calculating sub-symmetries and estimating the coherence index.

Source: (The authors).

Table 4 illustrates the horizontal and vertical sub-symmetries, in addition to the global symmetries of each level of scaling ratio, which together result in the total symmetries, as well as the coherence index for each façade derived from the shared ratios among them. The results show that the coherence index (CI), which is based on sub-symmetries and their distribution across different levels of scale change, was higher for façades with more sub-symmetries and lower for façades with fewer sub-symmetries, supporting our claim that coherence is strongly related to the number of sub-symmetries.

Table 4. Summary of (CI) index values and total symmetries quantities for each façade.

	Palatine Chapel	St. Peter's Basilica	Parthenon	Dome of the Rock Mosque	Taj Mahal
Cumulative (SSh)	1560	969	441	391	272
Cumulative (SSv)	1389	1035	813	657	707
Cumulative (GS)	6	6	7	6	6
Total Symmetries	2955	2010	1261	1054	985
Coherence Index (CI)	0.86	0.85	0.78	0.77	0.70

Source: (The authors).

The results in Table 4 confirm that façades with greater total symmetries across the six levels of scale change recorded higher (CI) values, and vice versa. In the case of the Taj Mahal façade, despite the clear overall symmetry, the total number of symmetries across multi-levels of scale change was lower compared to other cases, which led to a lower (CI) value. From a complex networks perspective, a high cumulative number of sub-symmetries is equivalent to an increase in the number of “nodes” (centers) and their links. Therefore,

the lower cumulative sub-symmetries mean a weaker network of interconnected centers, i.e., a structure is less “alive” in Alexander’s sense. Consequently, overall symmetry provides visual stability, but it is not sufficient by itself to produce coherence unless the structure is supported by rich levels of local symmetries. In contrast, the Palatine Chapel achieved the highest (CI) value because the number of total symmetries across the six levels of scale change is the largest. This forms a more robust network of interconnected centers, where smaller centers reinforce the larger ones in a clear hierarchical structure, so that wholeness emerges as a property resulting from this organization across scales. According to this reading, the coherence index becomes an indicator not only of the quantity of symmetries but also of the quality of their organization within the scaling hierarchy. As for the Parthenon, St. Peter’s Basilica, and the Dome of the Rock Mosque, their values came in the middle ranges. These results are consistent with the thesis of scaling hierarchy, where more elements occur on the small scales, fewer on the medium, and a rare few represent the whole, and the more this hierarchy is supported by larger cumulative numbers of sub-symmetries, the more the overall coherence is enhanced. That is, the most coherent façades follow a distribution similar to the patterns of living natural systems and deviation from this pattern is associated with a decrease in (CI).

These results support our hypothesis that architectural coherence is not determined by overall alignment alone, but arises as a result of the cumulative number of sub-symmetries and their hierarchical organization across multi-levels of scale change. The greater this cumulation is in a hierarchical order, the stronger the network of centers becomes, and the more the property of “wholeness” emerges in the façade.

8. Conclusions

This research partially may explain how the qualities of “life” or “wholeness” arise in good architectural design, as it quantitatively explores the relationship between the number of sub-symmetries, as subtle structural components in façades, and the concept of coherence. The research emphasizes the possibility of considering coherence as an objectively measurable property rather than just a personal impression and the results supported the fundamental claim that the distribution of these sub-symmetries across different scales is not random, but follows an organized mathematical structure that is inherently linked to overall coherence. The study revealed a clear dynamic: the smaller the scales we move to, the richer the sub-symmetries become, suggesting that the fine fabric of façades carries high levels of repetitive organization. More importantly, the results showed a strong and direct relationship between the total number of sub-symmetries and the degree of architectural coherence. This implies that increasing the density of these symmetries effectively contributes to enhancing overall coherence. Consequently, we conclude that architectural coherence transcends being a descriptive and abstract concept, becoming a structural property that can be quantitatively measured. This property relies heavily on the density and distribution of sub-symmetries. The organized distribution of these symmetries, especially on smaller scales, represents a crucial factor in achieving coherence that goes beyond mere superficial harmony to include a sense of depth and structural integrity. This conclusion provides a scientific basis for understanding how precise structural organization, through sub-symmetries, can enhance the overall sense of coherence and wholeness, opening avenues towards more informed design approaches that transcend intuition.

Based on these findings, we recommend expanding the scope of analysis to include a wider range of diverse architectural products and styles in different design contexts. We also suggest continuing to develop innovative analytical and design tools, possibly AI-based, capable of automatically analyzing and measuring

the value of coherence based on the distribution of sub-symmetries, providing designers with quantitative and objective feedback that contributes to enriching the design process and improving the quality of the built environment.

Human Subjects

This study did not involve human participants or human data

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Data Availability Statement

All data generated or analyzed during this study are available from the corresponding authors upon reasonable request.

Use of Generative Artificial Intelligence (AI) and AI-Assisted Technologies

No generative AI or AI-assisted technologies were used in the preparation of this manuscript.

Author Contributions

Maram h. Al-Taher: conceptualization, methodology, formal analysis, investigation, data curation, writing, original draft. **Hassan Al-Guesbi:** conceptualization, methodology, supervision, validation, writing, review and editing.

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