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Analysis of Spatial Considerations in Norman Foster's Architectural Design: A Case Study of Three Museums

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ABSTRACT

Architectural trends dictate the varying design characteristics of organizing horizontal plans, with spatial considerations perceived as the most influential factor. This research focused on these spatial considerations, which exhibit distinct features compared to other factors. A review of modernism and postmodernism trends revealed emergent factors that both influenced and were influenced by architectural thought during these periods. These factors were categorized into several aspects, including spatial, functional, and technical considerations-fundamental considerations encompassing numerous characteristics. The work of architect Norman Foster was examined, specifically his design characteristics relating to spatial considerations in the design of museums (Narbo Via, Da Tong, and Carre De Art). An analytical methodology was employed, utilizing AutoCAD and Depth Map software to measure variables and statistical software to analyze data, interpret results, and draw conclusions. Spatial considerations were analyzed at two levels: plans and the building shape, in both two and three-dimensional spaces. The research concluded that Foster's approach predominantly utilizes the layering characteristic (restricted to two layers) and deviates from centrality. These were identified as the most critical design characteristics of spatial considerations in organizing horizontal layouts at the two-dimensional level.

1. INTRODUCTION

The narrative of 20th-century architecture is predominantly one of the evolutions of modernity and the various responses it elicited. The term "modern" is widely used to denote concepts or objects from our era or those that are new and contemporary. However, since the 1920s, "modern" has been allocated a specific definition by a group of architects who aimed to dissociate from historical precedents and pioneer an entirely new and unique approach reflective of their era. Spurred by World War I, these modernist architects deemed the old European methods as failures and historical styles-developed in response to unrelated past conditions-as obsolete. They endeavored instead to conceptualize a completely new aesthetic, driven by the demands and opportunities of novel materials and structural systems such as reinforced concrete and steel frames [1].

In contrast, in the face of an intense yearning to reconnect with their origins and adhere to their past, many architects advocated for postmodernist architecture. They acknowledged the insufficiency of abstraction to cater to the emotional and historical requisites of building design. This architectural trend, which characterized things as being near, uniform, and homogenous, gained traction in America in the 1970s. It also fostered a connection between society and the ocean, as well as between buildings and history [2].

Architectural construction is often guided by various contradictory influences. In this context, architects eschewed scientific logic and intellectual order in resolving architectural challenges. Instead, they selected design principles suited to the local environment, meeting all its requirements without compromising function. Each architectural element was rigorously scrutinized and reviewed during the design process. The design began not with formal expression, but with addressing functional logic and design judgments pertinent to the environment and inherent values, culminating in visual expression [3]. Therefore, the organization of horizontal plans is a critical starting point in architectural design, as it scrutinizes issues related to the relationship between building design and their flexibility in use [4]. It orchestrates events, functions, and their execution, reflecting on buildings and the relationship between spaces to produce a cohesive, integrated organization [5]. It studies the compatibility of the need and human activity in building use with the individual architectural space allocated for this need and activity, offering a comparative study between different types of human activities, their needs, and the architectural spaces designated for them [6]. This makes the organization of plans an effective means to meet functional needs [7].

These influences inevitably reflected on the architectural plans of buildings, resulting in variations in their organization in tune with changes in architectural trends. This study aims to explore this variation in the organization of horizontal plans in contemporary architecture, with a focus on spatial considerations. The importance of this research lies in its ability to empirically investigate this phenomenon in plans, a tangible phenomenon observable in architectural theories. Thus, this research seeks to uncover significant design characteristics that may be influential or causative of this variation, falling under several considerations, primarily

spatial considerations, encompassing a set of fundamental design characteristics in plan organization. To this end, various literatures addressing this topic will be examined to identify knowledge gaps. These studies will be related to research on spatial considerations in organizing horizontal plans in modern, postmodern, and contemporary architecture.

2. LITERATURE REVIEW

2.1 Architecture space from modern to construction

The research examined the architectural space in the modern and deconstruction trends through a comparative analytical approach of the works of its major representatives, represented by the works of Mies van der Rohe as a representative of modernism, and Frank Gehry as a representative of deconstructivism, in five aspects of spatial analysis. These aspects are spatial determinants (from the determined to the indeterminate), spatial design (from regular to irregular), spatial form (from geometric to non-geometric), interior-exterior relationship (from simplicity to complexity), and spatial structure (from the machine age to the digital revolution). The results of the study revealed the contrast in the spatial characteristics between both movements. Modernism is characterized by clear horizontal and vertical determinants that are easily distinguishable. It creates an independent entity with spaces designed within a clear structural module and strict geometric forms, characterized by simplicity and expressing function and spatial organization through open and comprehensive plans. On the other hand, deconstructivism, as seen in Gehry's works, lacks determinants as the organic forms of spatial configuration are difficult to discern, and thus it lacks modular design principles for its spaces and regular and clear geometric forms. This results in complex and ambiguous relationships between spatial elements and a complex and incomprehensible spatial form. However, both types of spaces demonstrate the significant role of technology in achieving their architectural direction on various levels.

We can conclude that the study has highlighted some characteristics related to spatial considerations (regularity, geometric, and simplicity) and the mechanisms for achieving them in both modernism and deconstructionism by studying the works of prominent architects in each movement (Mies van der Rohe in modernism and Frank Gehry in deconstructionism) [8].

2.2 Subjective and objective in the architecture of modernity and postmodernism

Examined the spatial considerations, both subjective and objective, of the designer and their impact on the architectural design process and output through a comparative study of Villa Savoye by Le Corbusier from modernist architecture, and Villa Vanna Venturi by Robert Venturi from postmodern architecture. The study indicated, through analyzing Villa Savoye, that it represented pure functionality that emerged during the modernist, characterized by new design features such as the use of the free plan in the floor plans, vertical connections between interior spaces, and the integration of interior and exterior spaces through rooftop gardens and large windows. On the other hand, Villa Vanna Venturi deviated from the functionalist principles of modernism and reflected the subjective expression of the designer by connecting it with the past and returning to symmetry in the plan, axiality, and centrality, as well as complex interior spaces in the plan, which resulted in a more enclosed and contained character rather than openness.

Based on the foregoing, it is evident that spatial considerations such as openness in horizontal plans, openness in interior-exterior, the shape of plans, and the movement axes are influenced by the creative designer and their subjectivity, as well as the objective factors such as the surrounding context and the balance or preference between them [9].

2.3 Interior architectural design among the plurality of intellectual concepts in the century twentieth (A comparative case between modernist architecture and postmodern architecture)

Ainbousi addressed the design characteristics of organizing plans from multiple perspectives (the relationship between interior spaces, interior walls, and the relationship between interior and exterior) by comparing and analyzing the works of modern architects (Le Corbusier, Gerrit Rietveld, Mies van der Rohe, Frank Loyd Wright, Walter Gropius) in modern architecture, and the works of postmodern architects (Bofill, Portoghesi, Venturi, Stirling, Graves) in postmodern architecture. Ainbousi discussed the relationship between the following aspects:

- Horizontal plan in modern architecture was characterized by a lack of symmetry, open plan, and separation between public and private spaces, and the use of multi-functional space, while in postmodern architecture it was characterized by symmetry, axiality, and emphasis on the central void and dualistic concept in organizing the plan and single-function spaces.
- Interior walls in modern architecture were characterized by spatial separation using movable partitions and visual separation using fixed partitions, and elimination of partitions to achieve visual and kinetic connection, while in postmodern architecture they were characterized by separation and containment of spaces.
- The relationship between interior and exterior in modern architecture was characterized by the use of the flowing space, while in postmodern architecture it was characterized by the use of the intermediate space between open spaces known as "the courtyard".

Based on the previous discussion, the study concluded that there are several spatial considerations in modern and postmodern architecture, such as the openness between interior spaces and the relationship between interior and exterior spaces. It also highlighted partitions between spaces and how they are employed, as well as the impact of the shape of the plan on the spatial distribution of plans in terms of symmetry, asymmetry, straightness, and transformational axes [10].

2.4 Contemporary architecture and technology: Critical view to the effects of digital technology on architectural trends at the beginnings of twenty-first century

Focused on the functional and spatial organizational aspects of plans in contemporary digital and technological trends in the 21st century, which have resulted in changes in the functional type of buildings, reflected in the organization of plans due to the evolution of lifestyles resulting from

technological advancements in integrating multiple functions or spaces under one roof or in one building.

One of the other influences on the organization of plans is the elimination of some functions or spaces from the plans, reducing their areas, replacing large spaces with smaller spaces due to their unnecessary need, or permanently replacing them with modern means, such as smaller spaces for archives in administrative buildings or smaller waiting halls instead of large waiting areas.

As evident from the above, the research focused on the impact of architecture on the evolution of lifestyles, the emergence of technology, and how it reflects on the organization of horizontal plans in terms of spatial components (addition or elimination) and areas (increase or decrease), as well as the changing of functions (introduction, cancellation, or integration of functions). This indicates some of the spatial considerations, such as the relationship between openness and the shape of the plan, (with a particular emphasis on functional zoning and changes in spatial areas) [11].

2.5 Spatial modernist architectural artistic concepts

Discusses the concept of architectural space in general, including interior space, open plan, and the relationship between interior and exterior spaces in modernity and the pioneers of modernist architects such as Le Corbusier, Frank Lloyd Wright, and Mies van der Rohe. The study explores how this relationship has evolved and how it is influenced by specific factors. The research also discusses the integration of interior spaces with the external environment, the blending of boundaries between them, and the simplification of functional links between interior spaces, as well as the expansion of mutual relationships between them.

The main characteristic of modern architectural space is freedom and independence. The modernist architectural space is characterized by open space and defines degrees of freedom of space and planning based on historical, cultural, and social factors. Early proponents of this concept, such as Le Corbusier, Frank Lloyd Wright, and Mies van der Rohe, had their ideas about free space and open plans.

The “open” plan embodies the idea of freedom through independent walls from the building’s border, flexible partitions, and flexible division of large spaces. It allows for the flexible organization of the individual’s functional environment, with the possibility of changing the number and location of areas, as well as spatial freedom without familiar boundaries (windows and walls). It not only allows for the creation of non-private interior spaces but also adds to them the interaction with the external space due to the transparency visible through the façade. The transparent façade creates maximum access to natural light and communication with the environment and embodies the idea of owning a large space.

Based on the above, we deduce that the foundation of free space is the open plan, and this space is known as “interior architectural space” which is a void between building masses that protects and covers them from the outside, as a static and dynamic space for human movement and activities that occur inside.

Through reviewing the study of spatial concepts and their utilization methods by pioneering standards in modernity, it becomes apparent that it focuses on certain characteristics as follows:

- Simplifying functional connections by integrating individual rooms into one space.
- Expressing the disappearance of boundaries between the interior and exterior in the form of topographic continuity of external and internal spaces.
- Establishing the relationship between architecture and the natural environment through interaction between the interior and exterior spaces, through the “flow” of the interior space to the outside and the exterior space to the inside [12].

2.6 Between specificity and openness: How architects deal with design-use complexities

The research discussed the relationship between technology and social life, and the extent of their impact and development, which is reflected in design and usage, resulting in certain complexities for standards during the design process.

The study revealed that the evolution of technology and social life affects the design of buildings and usage, thus necessitating consideration of changes in the design process and the nature of functional relationships within it. The study also highlighted that floor plans are most affected by continuous changes in technology and social life and the resulting changes in response to these developments. Therefore, floor plans should be characterized by flexibility, and two of the most associated characteristics with flexibility are openness and privacy.

Architects emphasize the importance of providing flexibility and freedom in space so that the design can adapt. Therefore, their designs should be specific but at the same time open. The more specific the design, the more challenging it becomes for the building or space to respond to the unexpected and new, such as diverse uses and changing social and technological contexts.

Considering future use from the perspective of openness is a consideration in the design of all types of buildings. It is necessary to create a building that can respond to what is new and unexpected, to create a highly flexible building that can be used in different ways without requiring major changes or repairs, repeatedly.

Based on the above, we can conclude that openness in designs is a strategic approach to dealing with the emergencies of architecture, by adapting and customizing them in different ways through changing contexts (technological changes and changes in social life) to achieve flexibility. While openness and privacy may sometimes seem conflicting, as completely separate lines of thought in developing privacy and openness, it is important to understand the relationships between human architecture. How buildings, through their physical characteristics, affect the existence and work of people. And how this knowledge finds its way into their designs.

This guides future research on how to support specific theories and concepts for architects in dealing with the complexities of design used during the design process, by:

- Understanding the relationships between humans and architecture.
- Implementing this understanding in design discussions.
- Communicating with the client and design team about the social role of their designs [13].

2.7 Layering as an architectural operation: Peter Eisenman's House II

The study examined layering as one of the characteristics of horizontal plans organization in architectural design and it is

considered that layering is an element of space and structural organization, and explained its importance to the structure of the building from the structural point of view, so the research identified two functions for layering: organizational and structural. The study explains that layering is the process of organizing diverse architectural elements by defining relationships between them, that is, arranging everything in layers.

The study showed the possibility of producing a building based on the layering and organization of spaces within the layers, any change in layers affecting the entire composition and organization. The study explained as well that layers create spaces so that the components of architectural space are (layers and depth). Another characteristic associated with layering is transparency and its impact on layering. The higher transparency in the layers, the greater the overlap between them and the higher the layering continuity between spaces.

The study demonstrated that the creation of layers to design relationships within plans by identifying spaces and organizing layers in two methods:

- overlapping method (arranging layers in space).
- Second: intersection method (interlocking layers).

We conclude from the foregoing that layering organizes relationships between layers in the spaces in two ways: Intersection and overlap, and it is also the characteristic of architectural products at the organizational level of the plans and at the structural level of the building, so the layering is one of the characteristics of space and technical considerations [14].

2.8 Space as configuration: Patterns of space and culture

The study examined the relationship between the organizing of a plan and the social and cultural factors that influence it, as well as how the human lifestyle and environment are reflected in the spatial configuration of buildings. The research defined it as "an organizational process that connects the built environment, human experience, and spatial behavior, as there is a type of interaction between them". The configuration revolves around the shape of space, and the research defined spatial organizations as "consisting of several organizational units in which different living patterns occur, thus conducting communication between them".

The spatial organization characteristics in urban plans vary from one culture to another, such as the Turkish or French housing configurations, which differ from other types of houses, due to different lifestyle patterns. Therefore, organization and design in buildings rely on human behavior, which is studied in architectural behavior to provide a deeper understanding of the social experience. Thus, there are constraints on spatial plans. Moreover, the organization of spaces is related to social activity in two ways:

- The spatial plan reflects a social pattern.
- Space can shape a social pattern.

This highlights the variation in horizontal plans based on cultural, social, and human behavioral dimensions from one pattern to another and from one society to another. The study addressed these variations through spatial considerations (openness-the shape of plan), functional considerations (zoning-separation between public and private), and technical considerations (the structure used from one environment to another) [15].

3. RESEARCH PROBLEM

While there are studies on Foster's works and museum architecture, few have examined the shape of the plans and spatial layering aspects in depth. This study aims to address this gap by analyzing the spatial considerations in Foster's Museum plans.

So, the research problem lies in "There appears to be a lack of systematic analysis on the spatial designs employed by Norman Foster in museum architecture". In particular, the classification and utilization of horizontal plans in Foster's Museum plans remain unclear.

4. RESEARCH OBJECTIVES

(1) To identify the patterns of space organizing and circulation in Norman Foster's Museum architecture.

(2) To examine the role of central space and identify the orientation of planning in organizing the spatial plans of Foster's Museums.

(3) To analyze the methods of achieving openness and connectivity between layers in Foster's Museum plans.

5. THEORETICAL FRAMEWORK

Table 1 shows the theoretical framework.

Table 1. Theoretical framework

Considerations	Main Characteristics	Secondary Characteristics	Variables	Values
Spatial Considerations	The shape of the plans	Centrality of planning	Comprehensiveness centrality	Visitor movement Visual experience for visitors The centrality of the layout for movement axes
			Partial centrality	The centrality of the plan: Centrality of the remaining spaces
		Orientation of planning	Axis pattern	Longitudinal Grid-based Cross-sectional
			Axis straightness	
			Axis transformation	
			Axis directionality	
		Lobes of the Plan	Number of lobes	
			The formal similarity of lobes	

		The functional content of lobes (blocks)	
	Symmetry	Degree of Symmetry	Complete Symmetry Partial Symmetry Lack of Symmetry
Spatial layering	Level of Layering	On the Level of the Overall Plan (shape) On the Level of the Main Space (Spatial)	Number of Layers
	Regularity of Layers	The extent of Layer Regularity The similarity of Regularity Between layers	
	Connectivity between Layers		Escalators Stairs Elevators

6. PRACTICAL STUDY

6.1 Case studies

(1) Narbo Via Museum: shown in Figure 1.
(2) Da Tong Museum: shown in Figure 2.
(3) Carre De Art Museum: shown in Figure 3.

Figure 1. Narbo Via Museum (N.V.M)
(For more details follow the link: https://www.archdaily.com/973483/narbo-via-museum-foster-plus-partners.)

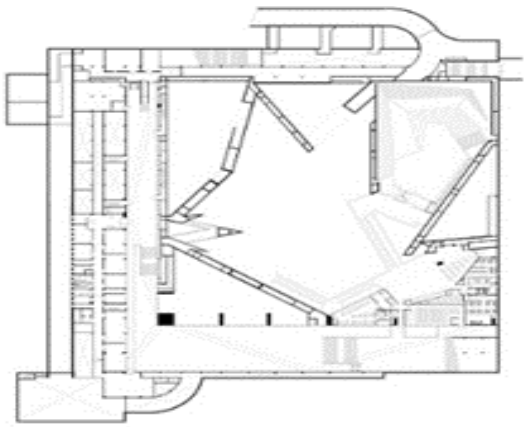

Figure 2. Da Tong Museum (D.M)
(For more details follow the link: https://www.archdaily.com/974628/datong-art-museum-foster-plus-partners.)

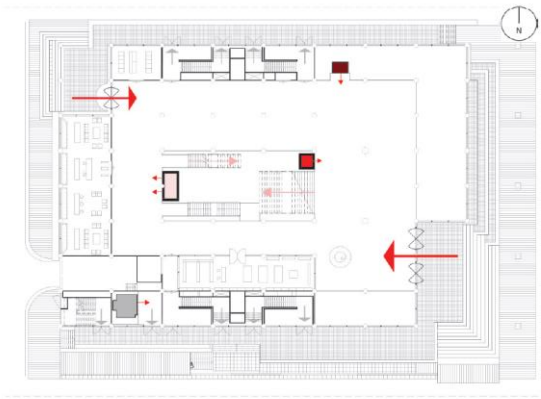

Figure 3. Carre De Art Museum (C.D.A.M)
(For more details follow the link: http://architecture-history.org/architects/architects/FOSTER/OBJ/1993,%20Carr%C3%A9%20d%27Art,%20N%C3%AEmes,%20France.html.)

6.2 Measuring the property of the shape of the plan

This variable is measured by two other variables.

(1) 'Comprehensiveness centrality' variable

This variable was measured using two methods.

In The first method, the variable was measured using AutoCAD software, relying on measuring distances from the center of entry space, at the level of the main space, using the "Distance" tool provided by the software, which calculates distances for the lengths of visitor paths in all the spaces visited by the visitor in the plan (distance from the entry to the intended space).

Then, the standard deviation for each museum was calculated to interpret the results more accurately, and then the results were compared between the two groups of museums. The higher the value of the standard deviation for distances, the higher the centrality of the main space, and the higher the value, the lower the centrality of the main space.

And other methods, the variable was measured using Depth Map software, relying on analyzing the kinetic-structural properties of the floor plan by integration, calculating the integration values for each point in the plan for the entrance of spaces visited by the visitor in the layout, at the level of the main space. Then, the standard deviation for each museum was calculated to interpret the results more accurately, and then the

results were compared between the two groups of museums. The lower the value of the standard deviation for integration values, the higher the centrality of the main space, and the higher the value, the lower the centrality of the main space.

- The results obtained from both methods are compared to measure the variable.

(2) 'Axis straightness' variable

The variable was measured using Depth Map software, relying on analyzing the axial Maps of the floor plan, which is one of the analyses provided by the software, and calculates the integration values for each line in the layout. Then, the arithmetic mean of line integrations for each museum was calculated to interpret the results more accurately, and then the results were compared between the two groups of museums. The lower the mean value of the integration values, the higher the axis straightness, and the higher the value, the lower the straightness of the floor plan.

6.3 Measurement of the characteristic of spatial layering

This property is measured by three variables.

(1) 'Layering level' variable

This variable was measured as a qualitative variable with two values (layered, non-layered) determined in the theoretical framework, at the main space level, by calculating the percentage of layering level, calculating the number of layers in the main space of all museums, and then calculating the percentage of layering level for each of the three separate case studies for comparison between designed and expanded museums.

$$The\ proportion\ of\ the\ level\ of\ layering = \frac{Number\ of\ (Layered)(Non-Layered)}{Total\ Cases} \times 100 \quad (1)$$

(2) 'Layer regularity' variable

This variable is measured by the indication of two variables.

- Range Variable of Layer Regularity: This variable is measured by the percentage using the grid squares method (which involves overlaying a grid of squares on the space to be measured to determine the number of complete and incomplete squares to assess layer regularity) at the level of the main space and the space of the layers for all museums. The higher the Percentage value, the higher the regularity, and the lower the value, the lower the regularity.

$$The\ range\ of\ layer\ regularity = \frac{The\ number\ of\ complete\ squares}{Total\ squares} \times 100 \quad (2)$$

- Layer Similarity Variable: This variable is measured using the statistical software (Minitab), through the Fisher exact test, which measures the extent of similarity or difference in the given data between the two layers in terms of significant differences or lack thereof, based on the significant value of the test (0.005). Then, the percentage of the difference between the two layers is calculated for all museums. The lower the percentage of differences for layer similarity, the higher the similarity, and the higher the percentage, the lower the similarity.

$$Null\ hypothesis\ H_0: p_1 - p_2 = 0$$
$$Alternative\ hypothesis\ H_1: p_1 - p_2 \neq 0$$

(3) 'Layer overlap' ratio

This variable is measured using the percentage of the overlapping area between the layers (the overlap between two layers), at the level of the main space and the subsidiary space for all museums. It is calculated by taking the area of the larger layer and the area of the overlapping portion between the two layers.

$$The\ ratio\ of\ overlap\ between\ layers = \frac{The\ area\ of\ the\ overlapping\ portion}{The\ area\ of\ the\ larger\ layer} \times 100 \quad (3)$$

7. RESULTS AND DISCUSSION

7.1 Analysis of the results related to the characteristic of the shape of the plan

7.1.1 Analysis of the results related to the variable (comprehensiveness centrality)-(the main space)

Table 2. Comprehensiveness centrality variable data

No.	Distance Value by AutoCAD		
	Narbo via	M. Da Tong	M. Carre De Art
A	5.78	4.18	3.3328
B	6.13	59.42	28.4761
C	15.35	69.41	52.6614
D	22.22	110.03	30.5689
E	29.37	122.37	35.4927
F	55.77	180.78	-
G	63.38	267.11	-
H	84.35	284.997	-

From the results of the analysis related to this variable, as shown in Figures 4-7, and Table 2, it is evident that the three museums differ in the values of their averages. The main space in the Carrè de Art Museum showed the highest centrality, where the value of the difference between its cases was more homogeneous (17.73) than the other museums. The centrality values in the Narbo Via and Da Tong museums were close to each other (with differences of 29.13 and 17.73, respectively). However, the Da Tong Museum was observed to have the lowest centrality (99.94) among the three museums.

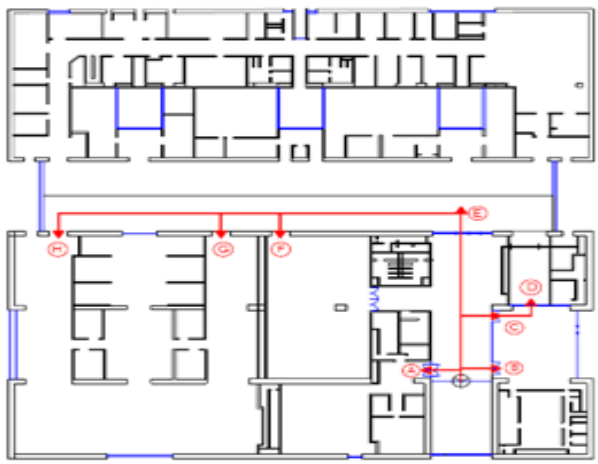

Figure 4. N.V.M analysis plan

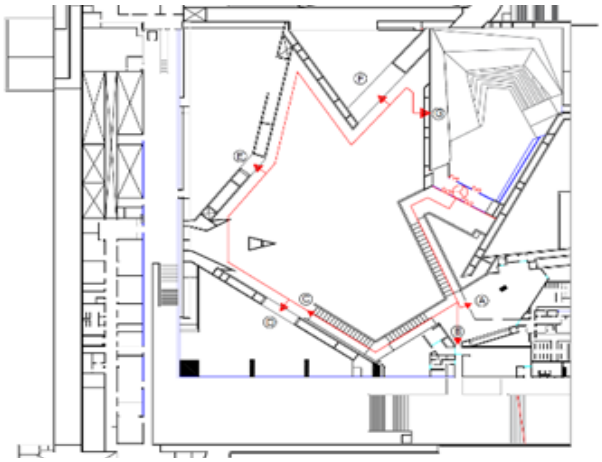

Figure 5. D.M analysis plan

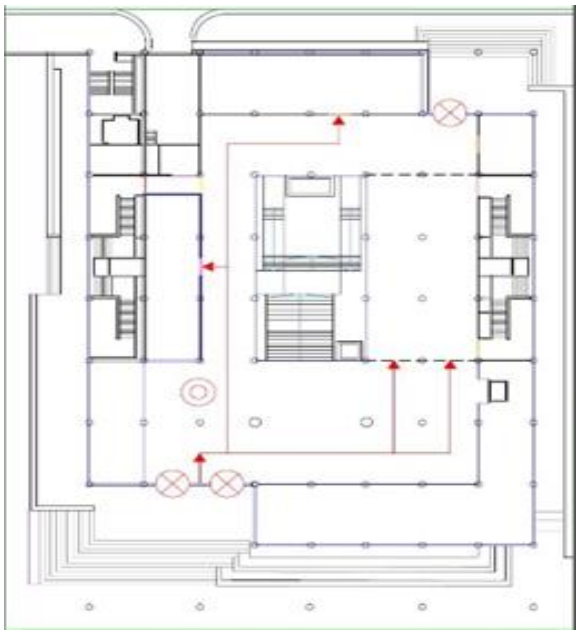

Figure 6. C.D.A.M analysis plan

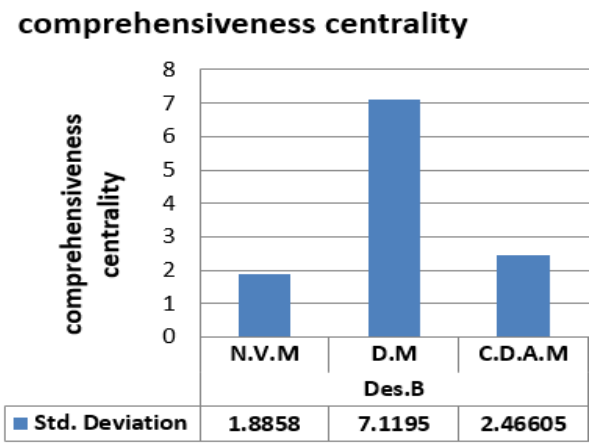

Figure 7. Illustrates the graphical charts for the measurement rate of comprehensiveness centrality

7.1.2 Analysis of the results related to the variable (Axis straightness)-(Overall plan)

Results of statistical analysis for the variable of axis straightness as shown in Figures 8-11, and Table 3 reveals that there is a convergence in the values of straightness rates in the plan between the museums Narbo Via and Da Tong (3.91% and 4.04% respectively). However, the values of alignment rates in the Narbo Via Museum are characterized by homogeneity. The results also indicate variation in the Carre de Art Museum compared to other museums regarding this variable, as its alignment rate was higher (18.71%).

Table 3. Axis straightness centrality variable data

No.	Integration		
	Narbo via	Da Tong	Carre De Art
0	4.97731	2.93809	18.5346
1	5.60648	2.8645	19.4601
2	3.39362	4.54641	19.8076
3	3.32807	6.27289	13.6552
4	2.36514	4.17605	19.917
5	4.62289	5.46572	20.838
6	3.68084	5.3865	20.778
7	3.22504	3.70742	19.9445
8	5.23927	2.35606	19.8895
9	3.87172	2.37109	19.5923
10	3.90207	2.9615	13.4139
11	4.05025	-	-
12	4.32392	-	-
13	4.06495	-	-
14	4.17093	-	-
15	3.38849	-	-
16	3.85506	-	-
17	3.78983	-	-
18	5.0674	-	-

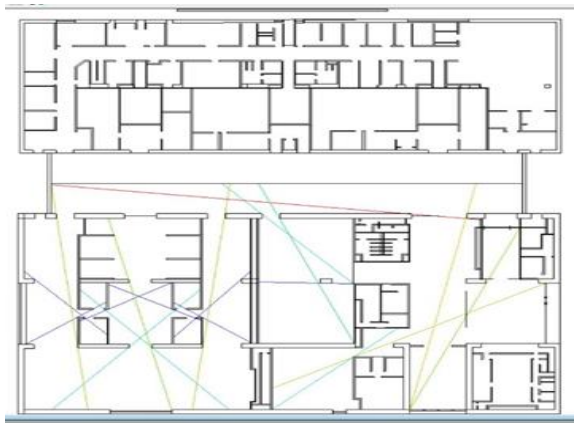

Figure 8. N.V.M analysis plan

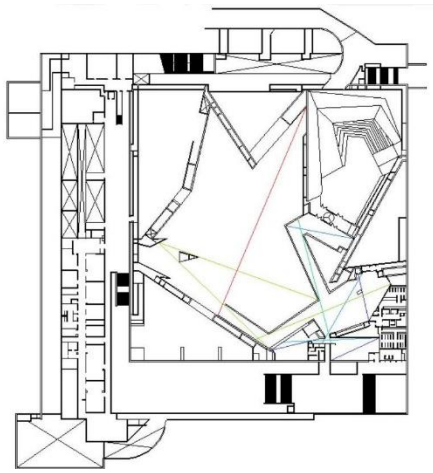

Figure 9. D.M analysis plan

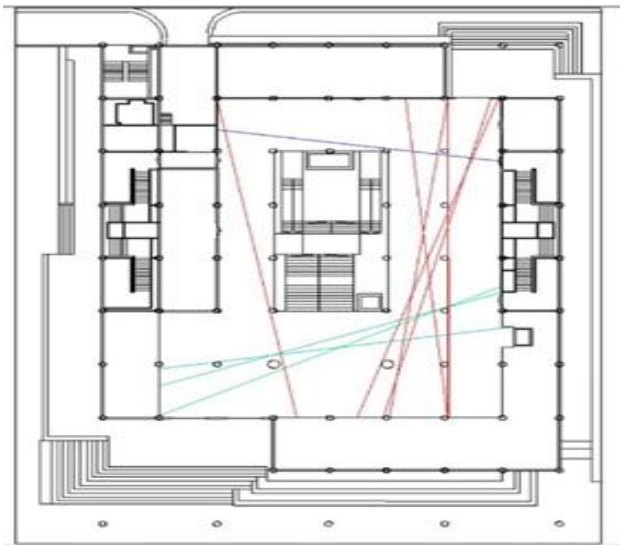

Figure 10. C.D.A.M analysis plan

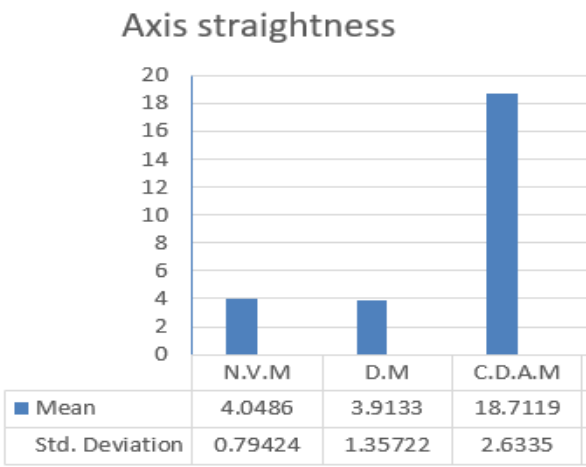

Figure 11. Illustrates the graphical charts for the measurement rate of axis straightness/Overall plan

7.2 Analysis of the results related to the property of spatial layering

7.2.1 Analysis of the results related to the variable (level of layering)-main space

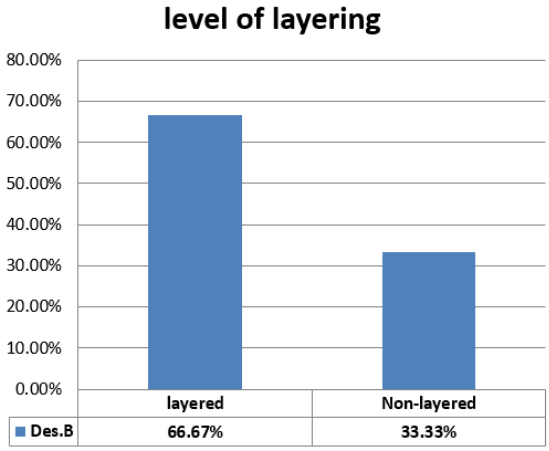

Figure 12. The charts illustrate the measurement rate of the level of layering

It is observed from the results of the analysis as shown in Figure 12, Table 4 for the analysis of the variable "level of layering-main space", that the percentage of layering is higher in four museums, representing (66.67%) of the study cases, with these two cases converging in the number of layers (two layers). However, the presence of layering is only observed in the Narbo Via Museum, representing only (33.33%) of the cases.

Table 4. Level of layering in museums variable data

Variables / Study Cases			N.V.M	D. M	C.D.A.M	Results
layered	Spatial layering	Level of layering	-	●	●	66.67%
Non-layered			●	-	-	33.33%
No. of Layers			1	2	2	

7.2.2 The analysis of the results for the variable (layer regularity)-main space

In this variable, two sub-variables are included.

(1) Analysis of the results for the variable (extent of layer regularity):

The results of the analysis, as shown in Figure 13, Table 5 revealed that the values of layer regularity rates for the main space were close among the three museums for the first layer, with the highest value of 90.79% observed in Narbo Via Museum, while the lowest values were observed in Carre de Art Museum (80%). The second layer was found in two museums and showed variation between them, with Da Tong Museum exhibiting lower regularity (59.1%).

Table 5. The extent of layer regularity variable data

Layers No.	Da Tong Museum		Carre De Art Museum	
	Complete. Sq. no./tot. sq. no.	Average	Complete. Sq. no./tot. sq. no.	Average
Layer 1	42/71	59.1%	84/105	80%
Layer 2	1019/1194	85.3%	162/176	92.05%

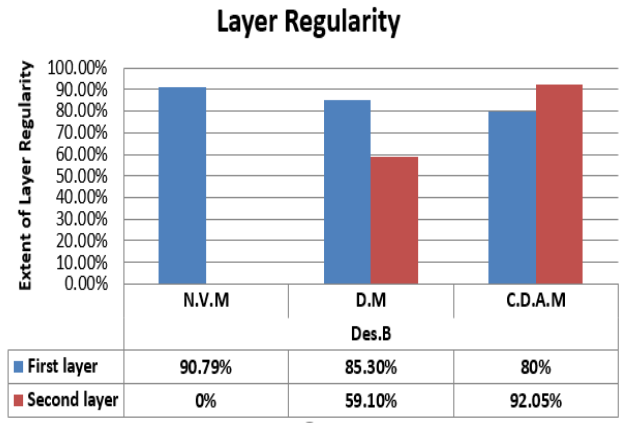

Figure 13. The charts illustrate the measurement rate of the extent of layer regularity

(2) Analysis of the results for the variable (similarity of regularity between layers):

Through the practical study, it was found that layering of the main space was present in two museums, and when observing the results for this variable in them as shown in Figure 14, it was found that the similarity of regularity

between the two layers varied in Da Tong and Carre de Art Museums, with the lowest values of similarity rates observed in them (0.26 and 0.22 respectively), which were supported by Fisher Exact Test with p-values of 0.000 for Da Tong Museum and 0.005 for Carre de Art Museum.

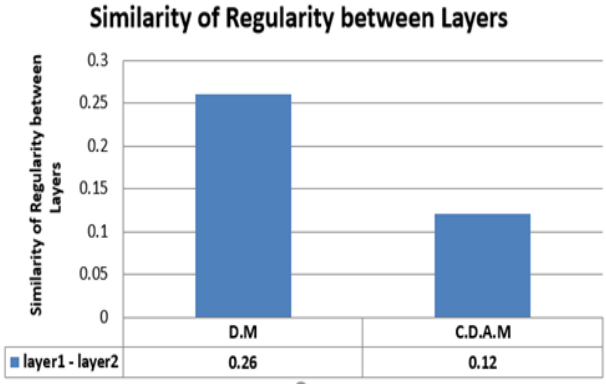

Figure 14. The graphical charts illustrate the rates of similarity of regularity between layers' measurements

7.2.3 Analysis of the results for the variable (layer overlap)-main space

The results of the analysis for this variable as shown in Figure 15, and Table 6 reveals variations in the proportion of overlap between layers in the museums. The highest rates were observed in the Da Tong Museum (95%), while the lowest rates were observed in the Carre de Art and Nubia House museums (41.77%).

Table 6. Layer overlap variable data

	Carre De Art Museum		Da Tong Museum	
	/	Percentage	/	Percentage
Integrated space area /Total space area	4640 / 4887.26	95%	287.2216 / 687.5786	41.77%

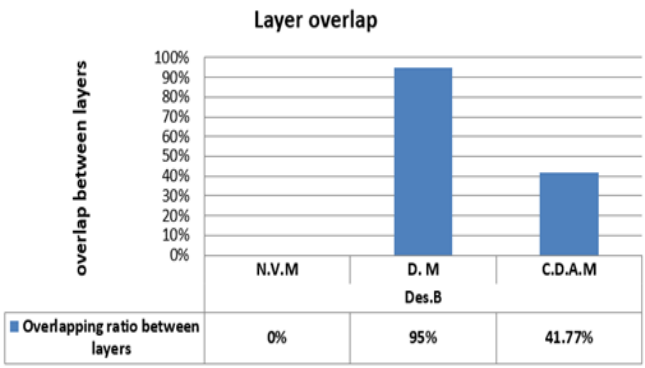

Figure 15. The graphical charts illustrate the rates of layer overlap measurements

8. CONCLUSIONS

Based on the research results, it is evident that the characteristics of spatial layering and comprehensive centrality are fundamental in museum design and the organization of their plans. Designers should capitalize on these features to enhance the visitor experience by achieving a broad and vertically open vision through the interconnectedness of layers and deviating from centering the organization to define specific visitor circulation paths throughout all museum spaces. Thus, these two characteristics can be adopted to achieve better designs in future museum architecture.

The practical results of the study highlight some characteristics that Norman Foster focuses on scientifically and precisely in spatial considerations, which are as follows:

(1) Norman Foster's architecture is distinguished by his design approach that deviates from the centrality of the main space in organizing the horizontal plan and moves away from both comprehensive and partial centrality. This confirms his inclination towards the characteristics of late modernism, which does not rely on the centralization of the horizontal plans in important spaces within the design.

(2) Norman Foster's architecture is distinguished by the high straightness of the circulation axes, which cover the entire dedicated spaces of the building for users, and by separating the main circulation axis intended for the function of the building from the other circulation axes for different parts of the building.

(3) Norman Foster's architecture is characterized by his employed property of layering (use of double-layer) in his museums, regardless of the number of floors or their regularity and similarity.

(4) Norman Foster's architecture is characterized by his approach to increasing the interconnectivity between layers within the same space to enhance vertical openness and visual and kinetical connection between levels. This feature is particularly important in museum designs to enhance attraction and engagement.

The scope of the study was limited to cultural buildings, especially museums, as they are the only buildings type that are not bound by restrictive design standards in composition and general planning during the design process. Museums reflect the culture and civilization of people and are limited to works within the same period, in similar urban sites.

However, the methodology limits focused solely on spatial considerations, disregarding other factors such as technological and functional considerations that were previously mentioned. Additionally, within the spatial considerations, there are other characteristics, such as openness, that were not addressed in the research. This is because including them would prolong the scope of the research and increase its complexity. For the research to be able to study comprehensively the characteristics of the shape of plan and spatial layering.

Future research can explore these aspects. By doing so, researchers can address aspects that have not been covered in their future studies.

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NOMENCLATURE

N.V.M	Narbo Via Museum
D.M	Da Tong Museum
C.D.A.M	Carre De Art Museum
Des. B.	Designed Building Museums