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Original Research Article

The Role of Spatial Visibility on the Visitor Density in Exhibition Complexes

(Case Study: Iran- Iraq War Museum)*

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Abstract

Problem statement: Understanding and redefining the relationship between spatial configuration and the way audiences perceive and interact with their environment is a key area of knowledge in the architectural design process. In this context, the ISOVIST theory, based on analyzing and translating spatial characteristics and geometry, provides an operational framework to explore this relationship. However, it appears that the topological content of space has received less attention in this field, leaving some layers of the designer's perception and audience experience obscured.

Research objective: This study aims to formulate and structure the geometric analyses of the Isovist theory to explain the relationship between spatial visibility variables and visitor presence density. It seeks to redefine the geometric-topological layers within cognitive-behavioral frameworks of space to better understand architecture.

Research method: This study used quantitative and analytical methods to examine the correlation between variables and values in the Iran-Iraq War Museum exhibition complexes. Field observations were conducted by timing and tracking visitor stop-and-move patterns using CCTV cameras. Data analysis utilized machine learning techniques based on regression models and significance testing for correlation. The study employed the concept of a topological graph of cognitive-behavioral systems, focusing on various museum sections, including exhibition, interactive, simulation, and recreational spaces.

Conclusion: The findings indicate diverse patterns of interaction between spatial configuration and visitor behavior across the museum's four areas. Factors such as Z radial, 3d integration, visual dispersion, uniform distribution of the field of view, and curvilinear forms play a central role in forming audience experiences. The results suggest that specific and independent analyses of museum spaces based on their functions provide a more accurate understanding of the relationship between space and user behavior. Furthermore, this study underscores the necessity of critiquing and revising the space syntax theory to expand its applicability in the realm of non-geometric and topological cognitive-behavioral systems.

Keywords: *Architecture, Spatial Research, Spatial Computation, Cognitive-Behavioral System, Topology, Machine Learning.*

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Introduction

General visitors in exhibition spaces and museums often move without a predetermined destination, altering their paths based on real-time experiences and spatial perceptions. Understanding and recognizing these diverse behavioral patterns requires insight into how spatial structures interact with human behavior. This highlights the importance of designing exhibition spaces as a medium for the reciprocal influences between the audience and the environment.

Transitioning from the terminology of "environment" and the expanded concepts of theorists from the 1960s to the 1980s (Aram & Bazrafkan, 2019), spatial researches, focus on space as an interdisciplinary platform, and provides a basis for advancing spatial-centric studies and computations. This creates a convergence of experiential, rational, and collective streams. These developments in the design and critique of space contribute to a cognitive-behavioral orientation in translating and interpreting architectural space.

The cognitive-behavioral approach, as one of the most significant orientations in this field, considers the audience's experience and understanding of space to stem from their sensory and motor actions in interaction with the environment (Mallgrave, 2013; Eftekhari et al., 2023). In this perspective, architecture is not merely visual and shape-based; rather, it arises from the connection between perception, time, and human movement within space (Bazrafkan, 2017). Although other approaches, such as aesthetic, socio-cultural, and phenomenological theories (Bechtel & Churchman, 2002), also analyze the relationship between humans and space, this study focuses on the cognitive-behavioral approach to seek appropriate analytical tools that encompass all dimensions of this experience.

To thoroughly examine the relationship between space and cognitive-behavioral systems, it is crucial to simultaneously consider the geometric and topological dimensions of space, as each represents only a part of the experiential, rational, and social facets of space. These two complementary dimensions within the framework of mathematics, as a mediating discipline, portray distinct aspects of space and the experience

thereof (Adams & Franzosa, 2007; Harper, 2016). Therefore, they should be examined in an integrative, complementary, and interconnected manner.

Given the importance of spatial characteristics in shaping experiences, cognition, and social relations, the theory of space syntax emerges as one of the practical approaches in the domain of behavior-space systems, providing a set of quantitative, descriptive, and practical tools (Hillier & Hanson, 1984). The three main concepts of this theory are axial lines, convex space, and isovist polygon, each representing and analyzing a different aspect of space (Hillier & Vaughan, 2007). Among these, the analysis of isovist points, which examines the field of view from any position in space, has gained particular significance due to its capability to analyze visual relationships that shape users' perceptual and behavioral structures (Benedikt, 1979).

Despite the widespread application of the theory of space syntax in analyzing spatial structures and behavior, this approach has faced criticism. A primary focus on geometric analyses and limited attention to the topological and cognitive dimensions of space are among the issues raised.

Some critics emphasize these limitations, highlighting the need to consider the roles of individual, social, and cultural factors in shaping spatial behavior and perception (Montello, 2007). Nevertheless, recent developments in cognitive sciences have opened new horizons for utilizing space syntax techniques, leading to a better understanding of the relationship between cognitive phenomena and spatial features (Dalton et al., 2012).

The isovist theory, as one of the key concepts of space syntax, has undergone significant evolutionary changes since its introduction in the late 1970s, gradually shifting its focus towards examining spatial experience and user behavior (Franz & Wiener, 2005). This evolution has entered a new phase with advancements in computational technologies and the emergence of machine learning, leading to transformations in the analysis of isovist points. Today, there have been developments in simultaneously capturing and processing geometric analyses of space and the topological patterns of behavior (Poerschke, 2016). In this approach, individuals'

behavioral patterns and isovist polygons analyses are transformed into measurable quantitative data. The combination of these data through machine learning can reveal meaningful patterns between spatial features and the actual behaviors of visitors.

This study, by intertwining geometric and topological analyses and leveraging machine learning, aims to provide a comprehensive and holistic approach to analyzing visitor behavior in exhibition spaces.

Based on this, the main question of this study is: How can the integration of geometric and topological analyses lead to a more precise understanding of visitors' spatial experiences in exhibition spaces?

To address this question, the study examines the role of spatial perception variables in the density of visitor presence across four types of spaces in the Iran-Iraq War Museum, including exhibition, interactive, simulation, and recreational spaces. Distinguishing these spaces based on the different natures of interactions and engagements within them allow for a more accurate identification of the factors influencing visitor experiences. The findings of this study could serve as a guideline for designing exhibition spaces and enhancing the diversity of visitor experiences.

Research Background

A review of research achievements in the field of spatial and cognitive-behavioral systems provides a suitable foundation for framing the problem and the necessity of conducting this study. Among these, the theory of “space syntax,” introduced by Hillier and Hanson in the 1970s and 1980s, holds a prominent position. This theory focuses on the relationship between spatial structure and social dynamics (Hillier & Hanson, 1984; Hillier, 2007) and analyzes the geometric configuration of space

in three states: axial lines, convex space, and isovist polygon (Hillier & Vaughan, 2007). The isovist field is one of the key concepts in the theory of space syntax, first introduced in 1979 by Benedikt as the isovist theory. He explained the geometric structure of this concept through the analysis of isovist polygons (Benedikt, 1979). Then, in 2001, Turner and his colleagues proposed the idea of Visibility Graph Analysis (VGA) as a topological perspective on

the isovist polygon, allowing for the analysis of visual connectedness among a set of points in space (Turner et al., 2001). The theoretical developments of the isovist polygon are summarized in a timeline diagram (Fig. 1).

In the past decade, three-dimensional analyses of isovist points have expanded (Bhatia et al., 2013; Varoudis & Psarra, 2014). These analyses facilitate the examination of spatial visual connectedness across various geometric and topological dimensions and relationships.

Recent studies in this area have addressed the combination of space syntax analyses with other approaches. For instance, Omer and Kaplan integrated space syntax analyses with agent-based modeling to achieve a better understanding of the impact of spatial features on behavior (Omer & Kaplan, 2017). Additionally, Jabi and his colleague in 2021 presented the concept of a content-context topological graph by merging these analyses with computational design, which can lead to the development of intelligent tools for topological analysis of space in the design process (Jabi & Chatzivasileiadi, 2021).

Previous studies have also demonstrated the effectiveness of the isovist theory in analyzing visitor behavior in exhibition spaces. For example, Turner and

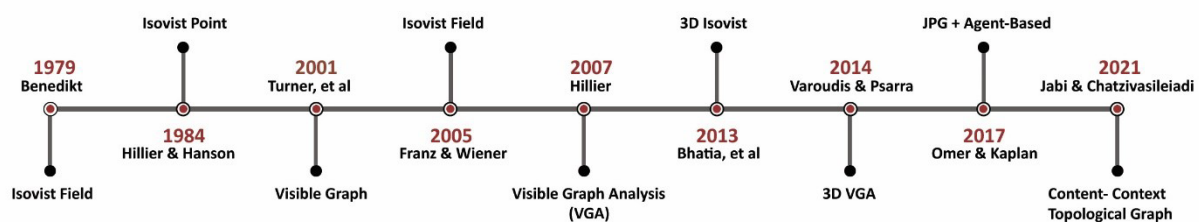


Fig. 1. Timeline of the formation and evolution of the isovist theory. Source: Authors.

Penn found a significant relationship between isovist parameters and the statistical dispersion of visitors in a study of the Tate Gallery (Turner & Penn, 1999). Franz and Wiener revealed the connection between features of spatial vision, emotions, and visitor navigation in galleries by integrating isovist analysis with cognitive science theories (Franz & Wiener, 2005). Furthermore, Lazaridou and Psarra emphasized the importance of three-dimensional spatial configuration in shaping movement patterns and visitor experiences in museums (Lazaridou & Psarra, 2015).

A review of the research background indicates the significance of the theory of space syntax, as well as geometric and topological structures, in the domain of spatial and cognitive-behavioral systems.

Theoretical Framework

The theoretical studies of this study are based on three main axes: refining the concepts of geometry and topology in spatial analysis, examining the capacities of the isovist theory in connection with these concepts, and detailing the position of this theory alongside complementary approaches in explaining spatial experience in exhibition spaces. This framework, while constructing a coherent foundation, follows an interdisciplinary approach linking architecture and cognitive science. The relationship and interaction of these concepts are presented in (Fig. 2).

- **Explanation of geometry and topology concepts in spatial analysis**

Geometry and topology are two complementary branches of mathematics that provide a theoretical framework for analyzing spatial features. Geometry focuses on the quantitative measurement aspects of space, such as distance, angle, and area (Gray & Ferreirós, 2021). In contrast, topology addresses the qualitative and structural relationships among spatial elements, such as connectedness and adjacency, which cannot be measured in other systems (Adams & Franzosa, 2007). The simultaneous application of these two orientations facilitates a comprehensive analysis and translation of spatial structures, providing a basis for explaining the connection between spatial configuration and human experience.

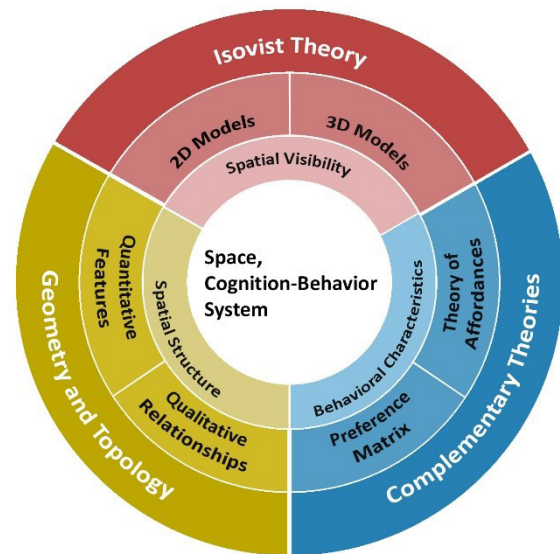


Fig. 2. Formulation of the concepts in the theoretical framework of the study. Source: Authors.

- **Capacities of the isovist theory in analyzing spatial structure**

The isovist theory serves as an orientation for analyzing the connectedness of spatial visibility, where its structures shape users' perceptual and behavioral patterns (Dawes & Ostwald, 2021). The evolutionary process of this theory, focusing on the geometric and topological characteristics of space, offers a comprehensive framework for understanding human experiences tied to space.

Benedikt elucidated the geometric structure of this theory through the analysis of an isovist polygon (Benedikt, 1979). The geometric features of this polygon, such as area, perimeter, and circularity (Franz & Wiener, 2005), alongside the topological concept of occlusivity (McElhinney, 2020), provide the means for analyzing spatial structure. Circularity, by creating contiguous uniformity in the isovist field, expands perceptual stability (Dubey et al., 2022) and individuals' aesthetic preferences (Vartanian et al., 2019). Conversely, the degree of occlusivity, by creating abrupt changes in the isovist field (Benedikt, 1979), evokes curiosity or surprise and visual confusion in the audience (Dubey et al., 2022).

Subsequent developments in isovist theory, through the introduction of visibility graph analysis methods (Turner et al., 2001) and metrics such as integration and

dispersion, expanded the depth and breadth of analyzing topological structures of space. Integration indicates the average length of visual radii (Franz & Wiener, 2005), while dispersion expresses the standard deviation of visual radius data from the mean and clarifies how data are distributed throughout the space.

Recent studies have highlighted the role of features such as ceiling height and volumetric complexity in shaping user perceptions by extending the application of isovist theory to three-dimensional spatial structures (Meyers-Levy & Zhu, 2007). In this context, methods such as three-dimensional isovist analysis (Bhatia et al., 2013) and its related graph (Varoudis & Psarra, 2014), along with concepts like embodied 3d isovist (Krukar et al., 2021) and volumetric characteristics of space (Ali & Mustafa, 2023), have been developed to deepen the understanding of architectural space complexity and the connection between geometric-experiential dimensions of spatial perception.

Overall, the isovist theory, by expanding into three-dimensional dimensions and simultaneously considering geometric and topological structures, provides a framework for analyzing users' spatial perception. These developments create opportunities for integrating this theory with other theoretical domains to enrich the explanation of spatial experience.

• Complementary isovist theories in explaining spatial experience

A comprehensive understanding of how the spatial configuration of exhibitions influences visitor experience requires simultaneous attention to isovist theory and other related orientations. In this context, theories of environmental affordances, environmental preferences matrix, and the concept of interactivity, alongside the variables of isovist theory, offer a suitable framework.

The theory of environmental affordances emphasizes the role of the environment in creating opportunities for actions for individuals (Gibson, 1979). Features such as enclosure, spaciousness, and the possibility of interaction with spatial elements can create

different behavioral patterns in various sections of the exhibition (Forrest, 2013), aiding in the understanding of the relationship between spatial features and visitor behavior. The theory of environmental preferences, focusing on the perceptual qualities of the environment such as coherence, complexity, legibility, and mystery (Kaplan & Kaplan, 1989), introduces indicators like spaciousness, openness, complexity, and spatial order (Franz & Wiener, 2005). Simultaneous attention to this theory and isovist analysis can lead to a deeper understanding of how visitors perceive and prefer spatial characteristics.

In addition to perceptual qualities, the three-dimensional aspects of space also affect visitors' information processing. For example, spaces with higher ceilings facilitate the relational processing of information, while spaces with lower ceilings enhance item-specific processing (Meyers-Levy & Zhu, 2007). In this context, it is important to pay attention to components such as integration and spatial depth, which influence visitors' movement and stopping patterns in museums.

In exhibitions with a high level of visual integration and low spatial depth, the time spent and interaction of visitors with the exhibits increases (Psarra et al., 2007). Additionally, the visibility of exhibition elements determines the level of active participation of visitors (Wineman & Peponis, 2009).

The emergence of interactivity in museums is also achieved through enhancing engagement, active participation, and deep learning of the audience (Allen, 2004). Attention to this set of characteristics can help increase the time spent and the deep involvement of the audience with the exhibition content. Ultimately, the integration of complementary approaches with the geometric-topological structures of the isovist theory provides a comprehensive framework for analyzing and enhancing the quality of visitors' experiences in exhibition spaces. This framework will guide optimal and efficient design by identifying spatial features and how they affect behavior. The variables of the theoretical framework and their interactions are presented in (Fig. 3).

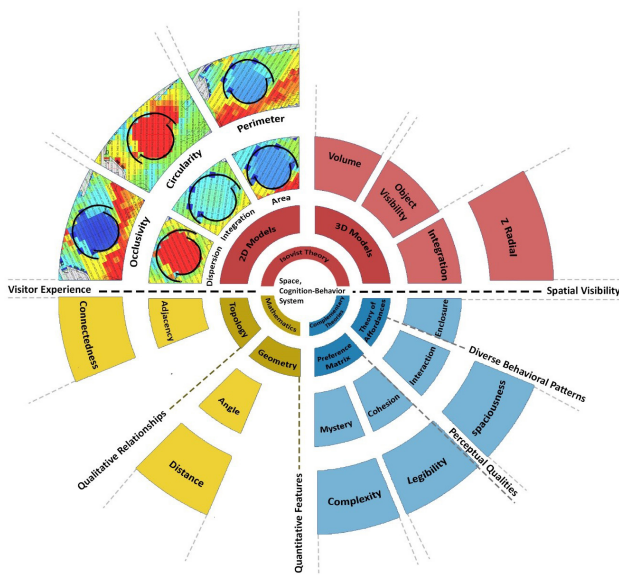


Fig. 3. Variables and the interaction between them in the theoretical framework of the study. Source: Authors.

Proposed Research Model

The proposed model of this study aims to restructure and enhance geometric and topological analyses in the spatial and cognitive-behavioral systems. The origin of this model is the idea of a topological graph of cognitive-behavioral patterns, suggested to address the shortcomings of common analysis methods in this field. Although existing analytical methods address certain topological features of space, they focus more on its geometric characteristics. This limitation hampers their ability to fully explain the complexities of visitor experiences in exhibition spaces.

The proposed model and system consider space as a continuum that records and analyzes the temporal and movement sequences of users' activities. The flexibility of this system to adapt to diverse conditions allows for the discovery of hidden behavioral dimensions that remain concealed in geometric analyses.

To test the effectiveness of this system, the Iran-Iraq War Museum has been selected as a case study, designed at a large scale to showcase the works and memories of the Iran-Iraq War (1980-1988). This museum comprises seven main halls organized in a linear circulation pattern and spatial sequence. The spatial configuration of the complex facilitates continuous visibility and movement along the path. This feature, along with the diversity in ceiling heights and geometric changes along the route, creates a complex spatial organization, enabling a comprehensive examination of the variables of isovist theory in two-dimensional and three-dimensional analyses.

For a more precise analysis of the relationship between spatial configuration and visitor behavior, the museum spaces have been divided into four categories based on the nature of interaction and spatial engagements: exhibition space, interactive space, simulation spaces, and recreational spaces. This distinction, which is one of the innovative aspects of the study, leads to a better understanding of each category of spaces. Images related to the diverse collections of the Iran-Iraq War Museum are presented in (Fig. 4).

In this regard, the main research question examines the

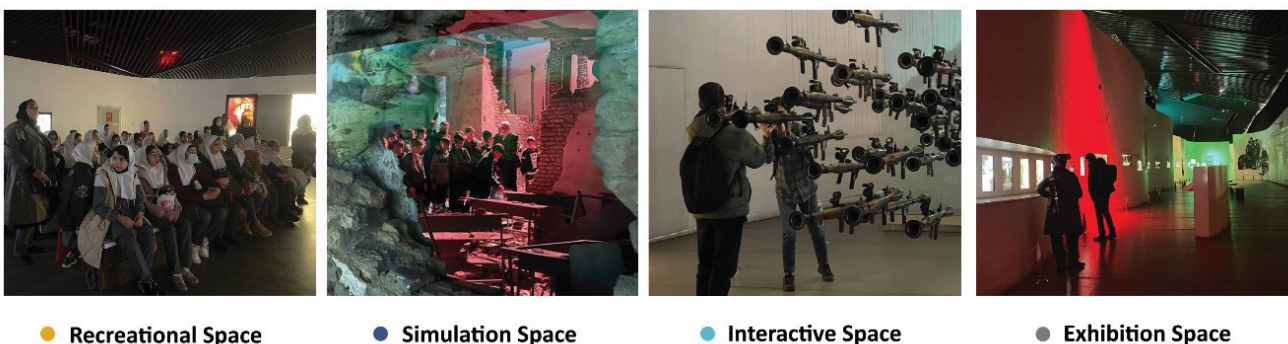


Fig. 4. Images related to the diverse spatial assemblages of the Iran-Iraq War Museum. Source: Authors archive.

impact of isovist analysis variables on the percentage of time users spend in this categorization of museum spaces. The hypothesis states that in each category, certain isovist variables can influence the duration of visitors' stays.

Alongside analyses related to isovist points, the method of exhibit representation is also considered as another independent variable. This variable, which pertains to the spatial arrangement of elements within the museum, includes factors such as types of spatial assemblages, emotional labeling, light intensity, and sound levels. Emotional labeling is based on the theme of each exhibited work. Light levels are measured in lux, and sound intensity is measured in decibels across different museum spaces.

Thus, the independent variables include isovist points analyses and the method of exhibit representation in two-dimensional and three-dimensional forms. The dependent variables include the duration and patterns of stopping and movement of visitors in the exhibition spaces (museum). Additionally, the mediating variables include estimated age, gender, group size, total visit time, crowd level, and the status of accompanying guides.

The analysis of the data in this study also employs machine learning techniques based on regression models and significance testing of correlations (Greene & D'Oliveira, 2005). Through random forest regression and by examining the importance of independent variables on the target feature (visits percentage), it was determined that among the criteria of the exhibit representation method, the impact of types of spatial assemblages on visitors' time is very high, while the other variables in this domain have a minimal impact on visit duration.

Examining the correlation between isovist points' criteria and the percentage of time users spend in the spaces, while articulating the geometric and topological aspects of the spatial and cognitive-behavioral system, can analyze users' behavioral patterns in space and provide a model for recording, analyzing, and designing. Accordingly, the operational model of the stud is presented in (Fig. 5), which will

have the capability for expansion and implementation in various exhibition samples, and its results will assist in generalizing the model.

Method and Process of Research

This study falls within the category of spatial research and spatial computations, employing quantitative and analytical methods (Tabibi et al., 2009) to explore the correlation between significant spatial features and the percentage of visitor attendance. For this purpose, using random forest regression, the isovist points' variables with the highest importance concerning the target feature (percentage of visits) have been selected for each of the exhibition, interactive, simulation, and recreational spaces. Subsequently, the relationships were established, and the correlation of the isovist spatial variables with

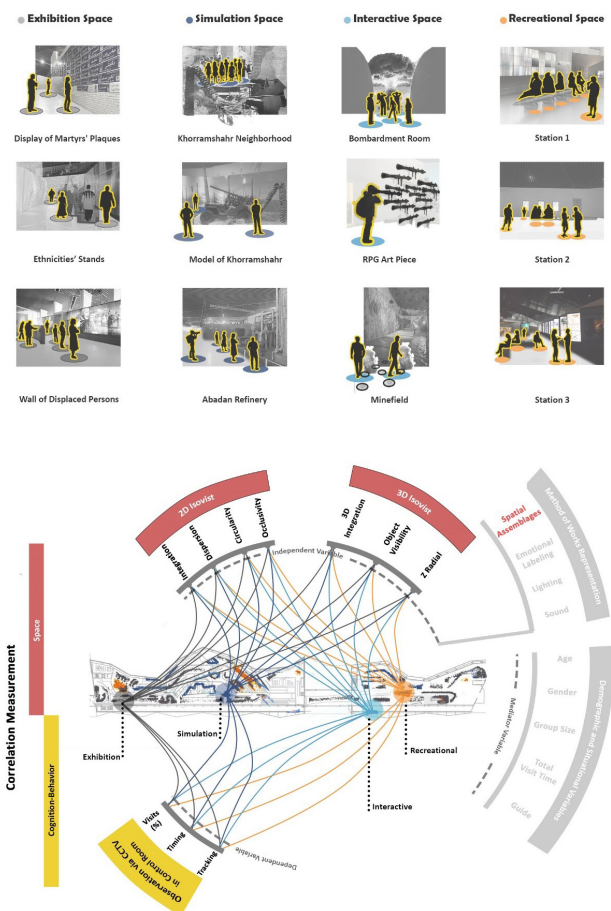


Fig. 5. Operational model of the study examining the correlation between isovist points' criteria and the percentage of user visit time in spaces. Source: Authors.

the percentage of visitor attendance was analyzed using Python 3.7 software.

It is important to note that due to the linear configuration of the Iran-Iraq War Museum, the use of some common spatial analyses, such as convex space analysis, is not effective. Therefore, the main focus is on two-dimensional and three-dimensional analyses of isovist points.

The field surveys in this study involve observation, timing, and tracking of the stopping and movement patterns of visitors in the exhibition spaces (museum) (Zeisel, 2006), conducted through CCTV cameras in the museum’s control room. The location of visitors is recorded every 10 seconds as a point on the museum plan, based on which the percentage of visits by users in each space is calculated.

To calculate the percentage of visits, the museum plan was first divided into a grid of 8,700 squares, each measuring 1 by 1 meter. The visit percentage for each square is determined by the number of groups that visited that point relative to the total number of visiting groups. The resulting numerical value ranges from 0 to 100, indicating the percentage of visits from specific points. The rationale for defining this variable is that the impact of visits by a particular group may significantly affect the density of recorded points, while other groups may not visit that space.

A heatmap depicting visit percentages for all recreational, simulation, interactive, and exhibition spaces is presented in (Fig. 6). Additionally, a three-dimensional chart of the visit percentage across the length and width of the museum plan is shown in (Fig. 7). The information regarding the two-dimensional and three-dimensional graphs of isovist points was calculated using Rhinoceros 7 and Grasshopper 1.0.0007 software. In these analyses, considering the field surveys, the maximum identifiable radial length in the museum is 60 meters, with only 14% of the recorded data exceeding this value. Consequently, the data framework has been set with a maximum radial length of 60 meters. The heatmap of the two-dimensional isovist points’ analyses is illustrated in (Fig. 8).

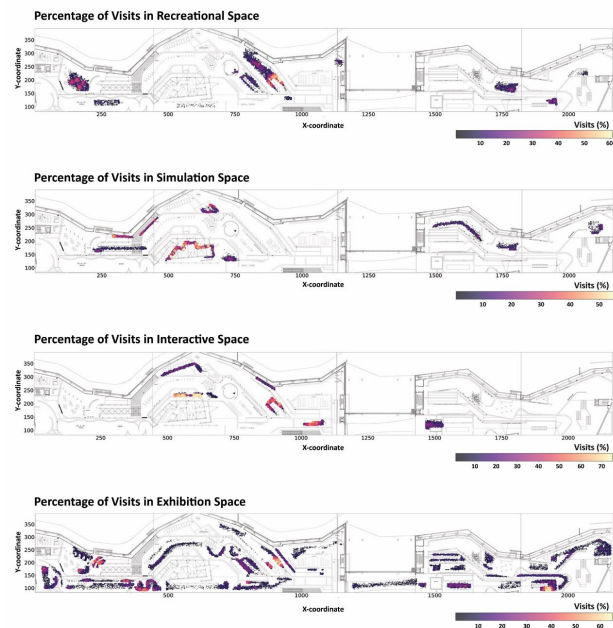


Fig. 6. Heatmap of visit percentages in recreational, simulation, interactive, and exhibition spaces. Source: Authors.

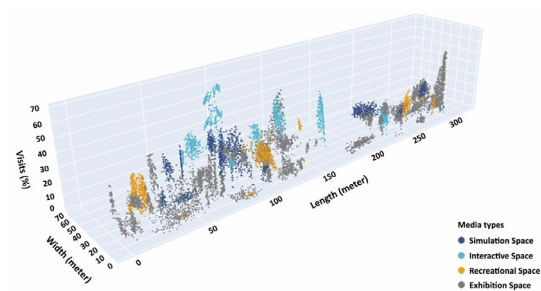


Fig. 7. Three-dimensional chart of visit percentages across the length and width of the museum plan. Source: Authors.

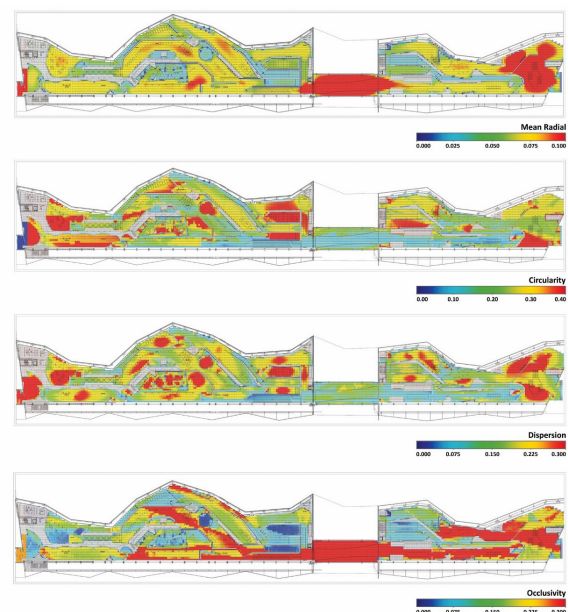


Fig. 8. Heatmap of two-dimensional isovist points’ analyses. Source: Authors.

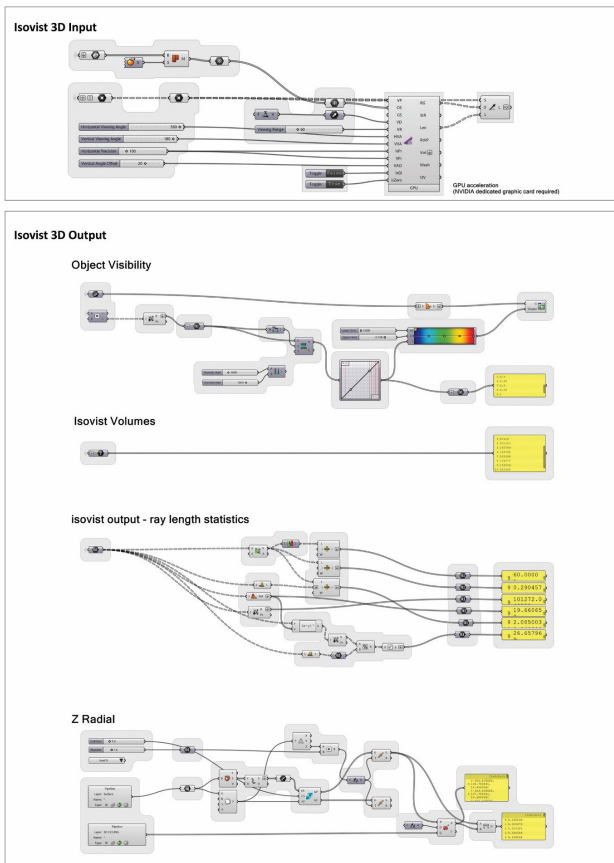


Fig. 9. Details on how to calculate variables related to three-dimensional isovist points' analyses. Source: Authors.

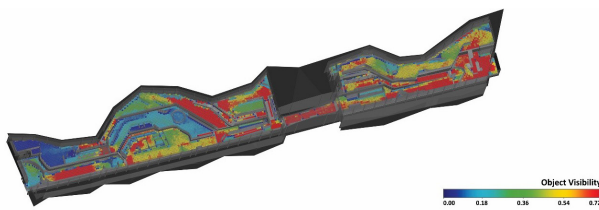


Fig. 10. Heatmap of three-dimensional object visibility analysis criteria. Source: Authors.

Regarding the criteria for three-dimensional isovist points' analysis, and considering the height variation in the examined museum, the height criterion along the z-axis from the viewer's eye to the museum ceiling has also been included in the examined parameters. Details about the method of calculating variables related to the three-dimensional isovist points' analyses are presented in (Fig. 9), and the heatmap of the three-dimensional object visibility criteria analysis is shown in (Fig. 10).

Findings and Discussion

The location of 140 visitors was recorded every 10 seconds as a point on the museum plan. A total of 41,161 points were recorded, with 40 components of the spatial and cognitive-behavioral system calculated separately for each point. These components include 17 criteria for two-dimensional isovist points analysis, 9 criteria for three-dimensional isovist points analysis, 4 criteria for internal spatial arrangement, 6 demographic and situational criteria, overall density, and total visit percentage.

In total, 1,646,440 data points were recorded, and categorized into four groups based on the types of spatial assemblages in the museum. In each category, variables with high importance regarding the target feature (percentage of visits) were selected. Significant variables included mean radial, three-dimensional integration, circularity, dispersion, occlusivity, object visibility, and Z radial. Details of the correlation between each of these variables and the percentage of visits in each category are presented separately through linear regressions in (Fig. 11). The regression function was performed in Python using the STATSMODELS library.

To test the significance of the correlation relationships, Pearson correlation coefficients (P.C.C) and regression coefficients (Coef) were used. The Pearson correlation coefficient measures the linear correlation between two random variables, ranging from -1 to 1. In large datasets, $|1|$ indicates perfect correlation, $|1 \text{ to } 0.75|$ indicates high correlation, $|0.75 \text{ to } 0.25|$ indicates moderate correlation, and $|0 \text{ to } 0.25|$ indicates low correlation. The regression coefficient represents the slope of the regression line, indicating the effect of the variable in the linear equation (Greene & D'Oliveira, 2005; Akoglu, 2018). The measurement and establishment of correlation relationships for significant isovist points' variables with the percentage of visitor attendance in four categories of spatial assemblages are as follows.

In simulation spaces, regression results indicated an inverse relationship between mean radial and visits. To support this claim, the Pearson correlation coefficient (-0.31) and regression coefficient (-1.75) were calculated

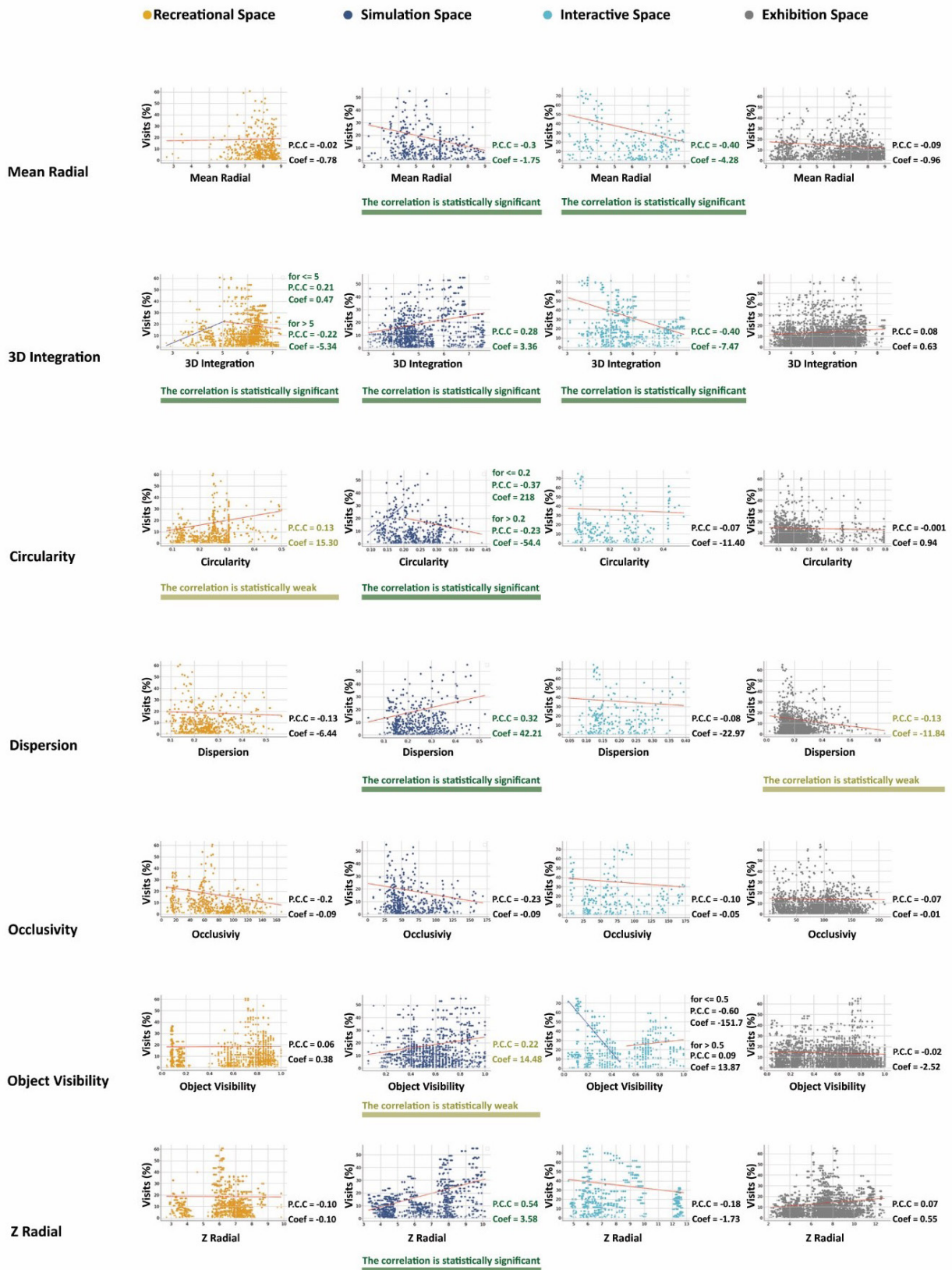


Fig. 11. Measurement and validation of the correlation between significant isovist points variables and the percentage of visitor attendance, categorized by types of spatial assemblages. Source: Authors.

in Python using the SCIPY library, indicating a moderate negative correlation. Additionally, in these spaces, the variables of three-dimensional integration, dispersion, and Z radial had a direct relationship with the level of visits. Analyzing the Pearson correlation and regression coefficients confirmed the presence of moderate positive correlation in all three variables. Furthermore, the variable of circularity exhibited a dual relationship with visits; it showed an ascending relationship up to 0.2 and a descending relationship thereafter, both consistent with the assumption of correlation.

In recreational spaces, three-dimensional integration displayed a dual relationship with visits. This variable showed a relatively ascending relationship up to 5, followed by a descending relationship, which aligned more closely with the correlation assumption. Additionally, in these spaces, a weak direct relationship between circularity and percentage of visits was observed, with a Pearson correlation coefficient of (0.13) and a regression coefficient of (15.30).

In interactive spaces, the variables of mean radial and three-dimensional integration exhibited an inverse relationship with visit levels. The Pearson correlation coefficient and regression coefficient for mean radial were (-0.40) and (-4.28), respectively, while for three-dimensional integration, they were (-0.40) and (-7.47). Therefore, a moderate negative correlation was established for both variables.

However, in exhibition spaces, only the analysis of the dispersion variable showed a low negative correlation, with a Pearson correlation coefficient of (-0.13) and a regression coefficient of (-11.84). A comparison of the regressions of isovist points' variables with the percentage of visits across different spatial assemblages is presented in (Fig. 12).

Thus, in simulation spaces, the two-dimensional mean radial showed an inverse relationship, while three-dimensional integration, dispersion, and Z radial exhibited direct relationships with the level of visits. The circularity variable also demonstrated a dual relationship with visit levels.

In interactive spaces, the two-dimensional mean radial and three-dimensional integration had an inverse

relationship with visits. Conversely, in recreational spaces, the non-linear relationship of integration and the positive relationship of circularity with visit levels were prominent. In exhibition spaces, dispersion showed an inverse relationship with visit levels.

Conclusion

This study aimed to identify and explain the relationship between spatial visibility variables and visitor density in the Iran-Iraq War Museum. For this purpose, four categories—simulation, interactive, exhibition, and recreational spaces—were statistically analyzed, revealing different patterns of the variables' impact on visitor attendance.

In simulation spaces, the analyses identified a specific pattern. Three-dimensional integration, dispersion, and Z radial showed a direct relationship with the level of visits, while the mean radial exhibited an inverse relationship. These results indicate that attention to spatial integration, diverse viewpoints, and appropriate height enhances the appeal of the space and reduces visitor confusion. The analyses also suggest that a balanced use of curvilinear forms is important and helps contribute to visual diversity.

In interactive spaces, the mean radial and three-dimensional integration had a significant inverse relationship. This finding highlights the impact of precisely adjusting these variables on enhancing focus and deeper engagement among visitors.

In recreational spaces, the analyses indicate that creating an optimal ratio of spatial integration and appropriately using curvilinear forms is effective in meeting the resting needs of visitors.

In exhibition spaces, the variable of dispersion showed an inverse relationship with the level of visits, underscoring the importance of reducing the dispersion of sightlines and creating a more uniform distribution of the field of visibility to attract more audiences.

These quantitatively significant relationships, derived from the theoretical framework of the spatial and cognitive-behavioral system, emphasize the importance of differentiating and analyzing museum spaces based on the nature of their interactions. This approach facilitates

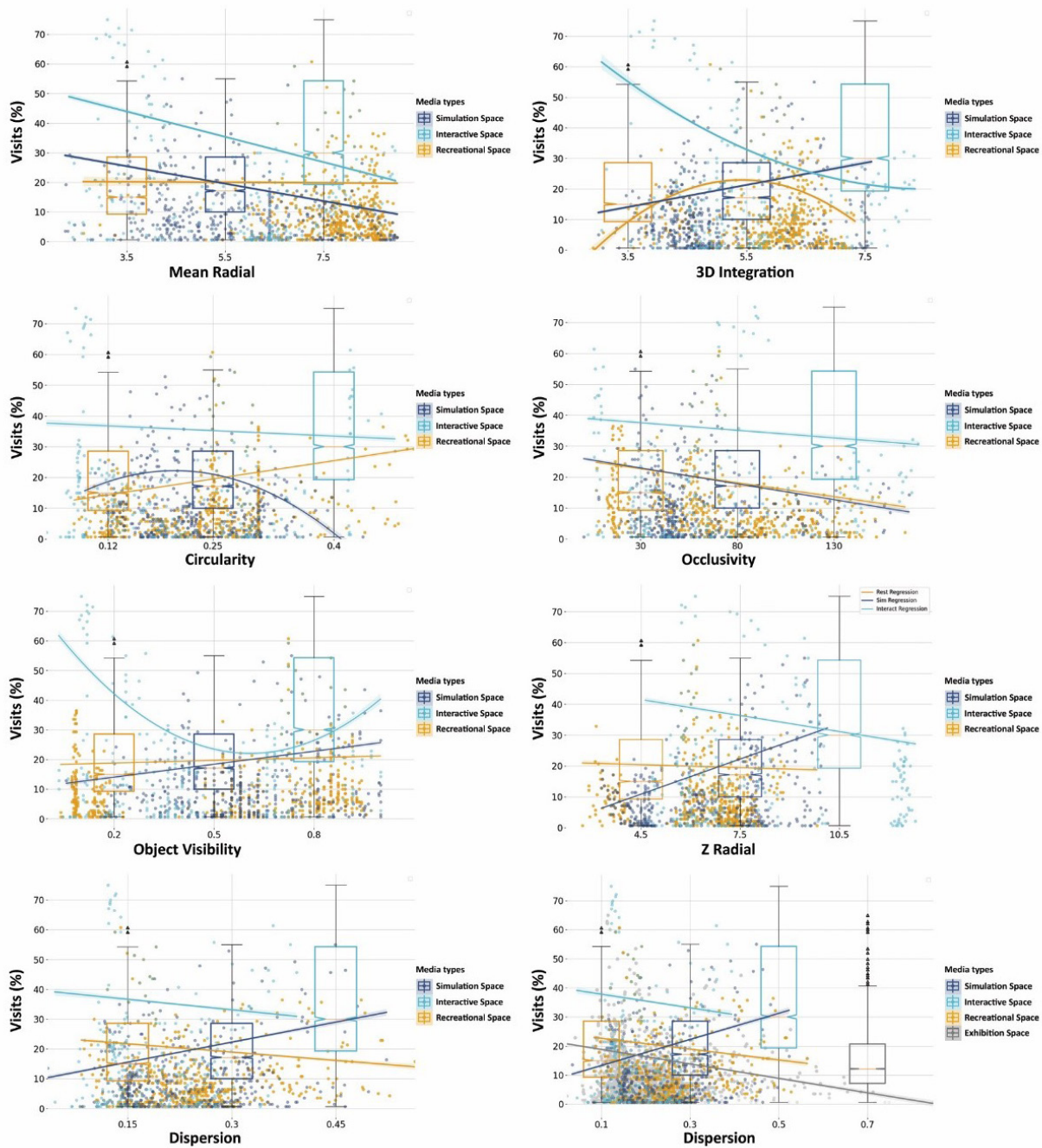


Fig. 12. Comparison of regressions of isovist points variables with visit percentages across different types of spatial assemblages. Source: Authors.

a more precise understanding of the factors influencing visitor behavior and opens a new pathway for spatial research in museums.

Although this study focused on a single case study, the generalizability of its methodology and analytical framework to other museums and exhibition spaces

lays the groundwork for expanding this approach in future research. Undoubtedly, the continuation of studies like this can strengthen our understanding of the interaction between audiences and spaces, offering novel avenues for designers and researchers in this field.

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