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Article

Investigating mass-space system to achieve an optimal model for analysing visibility among residential buildings and public open spaces using three-dimensional isovist

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ABSTRACT

Urban designers have paid a lot of attention to view quality recently to enhance the standard of the urban environment for people to live in. This study was conducted to achieve an optimal model of visibility among buildings and public spaces. To this end, three indices, i.e., "view from public space to the surrounding space", "view from the building to adjacent buildings", and "view from the building to open space", were investigated, considering the physical-spatial structure and visual privacy. To represent physical space and analyse views, three-dimensional isovist was used in this study to quantitatively evaluate the visibility of the neighborhood unit scale. First, three categories of physical characteristics that affect vision were established: "spatial layers," "properties of mass-space components," and "spatial qualities." Next, spatial qualities were explained to evaluate, select, and relate them to each of the isovist variables. Isovist variables effective in measuring the three research indices were identified using the Delphi technique and six variables of volume, area, perimeter, obstruction, length of minimum, and maximum line of sight in three sites in the north of Persian Gulf Lake in Tehran were evaluated. The findings demonstrated that factors like severe spatial enclosure, high building density, proximity of blocks, block shape, building height distribution, and uniform skyline increased the visibility of buildings, leading to weak visual privacy and a diminished view of open space from inside buildings and public spaces. The site with the best conditions for optimal visibility was found using the sum of quantitative visual values, and an integrated model for calculating optimal visibility was then introduced.

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INTRODUCTION

In the design and construction of urban spaces and residential places, optimal visibility is either neglected or not appropriately considered. Ignoring this issue typically lowers the quality of densely populated urban environments. Most of the time, architects and urban designers aim for the best views of their buildings to the surroundings without taking into account the detrimental effects of their structures on the views of other buildings, public spaces,

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and the surrounding context, all in an effort to please investors. From the visual perspective, it is very imperative to notice the following three issues while locating buildings and designing their three-dimensional form:

- View of buildings to each other and the amount of their visibility to adjacent buildings and spaces;
- View of buildings to surrounding open spaces; and
- View of urban spaces in the surrounding areas.

The use of integrated models by urban designers that take into account and assess the three aforementioned strategic points of view is essential for accurate mass identification and placement in urban configuration as well as for producing efficient and ideal forms in urban landscape. Pinsly et al. (2011) offer an integrated model for evaluating buildings' visual exposure with regard to visual privacy and their visual openness to the view in open spaces using the geometric features of isovist (Shach-Pinsly, Fisher-Gewirtzman, and Burt, 2011). The model presented by Pinsly et al. has made a significant advancement in optimising the design of physical aspects of cities by taking into account the view of buildings (visual exposure) and view of the surroundings (visual openness to view). However, sometimes, designers do not pay enough attention to the visual quality in important public spaces. As a result, the current study aims to address the question of how to use an integrated model to measure optimal visibility in buildings and public spaces in a way that can cover and evaluate all three of the aforementioned strategic views. This is because it is crucial to provide optimal visual quality for both public spaces and buildings. The spatial attributes of a built environment include visual qualities. Physical structure and its effects on the landscape and urban view have always been taken into account.

In the 1970s, two main approaches emerged in the visibility analysis context: view shed in terrain and landscape analysis and the concept of isovist in architecture and urban spaces (Lin, Lin, and Hu, 2013:228).

According to Turner (2003), "We might use visibility analysis to talk about morphological aspects of the built environment, to talk about how people can move through or interact with the visible space, or to learn the importance of objects placed there" (Bendjedidi, Bada, and Meziani, 2018:95).

TYPES OF STRATEGIC VIEWS RELATED TO BUILDINGS AND URBAN SPACES

From the visual aspect, in designing a three-dimensional form and locating buildings, it is very important to pay attention to three issues: (1) View of public spaces to the surrounding open spaces, (2) The building-to-building view concerning visual privacy, and (3) View of buildings to surrounding open spaces, which are further detailed in all three issues will be paid.

View of Public Spaces to the Surrounding Open Spaces

Openness to near and distant views influences the quality of life and the environmental quality in a densely built urban environment (Fisher-Gewirtzman, 2012:1). The indoor-outdoor relationship, the microclimate of open spaces, and thermal comfort based on urban radiation due to sky obstruction are all negatively impacted by the high building density, decreasing width to height ratio, and size of open spaces (Kaya and Mutlu, 2017:5).

The spatial openness index is one of the leading indices for morphological and open space perception analysis. The volume of open space is potentially seen from a given point. This index's significance is to express the volume of space in the visual sense and other spacious qualitative attributes such as openness to natural light, air, and near and distant views (Fisher-Gewirtzman and Wagner, 2003:39).

The SOI (Spatial Openness Index) can explore spatial configurations' visibility and permeability and enable the ranking of alternative spatial arrangements. The alternative is ranked by the measured volume of open space potentially observed from given points of view inside the buildings and looking out to the area around considering geometrical and morphological terms (Shach-Pinsly, Fisher-Gewirtzman, and Burt, 2006:307).

The Building-to-Building View Concerning the Visual Privacy

Territory strengthens the sense of distinction, privacy, and individual identity. The territory is formed by continuous control over certain parts of the physical space by an individual or a group (Madanipour, 2003:39). Different communities have their own mechanisms for controlling privacy, creating various private spheres in which people live (Alkhazmi and Esin, 2017:8941).

As a subset of the concept of privacy, visual privacy is a crucial factor in organising space in cities' architecture and design. Visual privacy is defined as the ability to conduct the home's everyday activities without being seen and without fear of being observed by those outside the home (i.e., neighbours and passers-by) (Alkhazmi and Esin, 2017:283). Visual privacy can be achieved by defining boundaries and territories in the physical environment.

The distance between buildings is the main factor affecting visual exposure (Shach-Pinsly, 2010:166). Distances between buildings are the main component affecting visual openness and exposure in the urban environment (Shach-Pinsly, Fisher-Gewirtzman, and Burt, 2011:251).

View of Buildings to Surrounding Open Spaces

Views of buildings have an impact on a number of things, including residential preferences, people's physical and mental health, buildings' economic value, and the safety of the surrounding communities.

Contemporary psychological studies confirmed the positive effects of having natural scenes view on reducing stress compared with having scenes view of the built environment (Qiang, Shen, and Chen, 2019:92).

Being able to be seen by passing vehicles, buildings, or pedestrians might boost perceived safety and discourage potential offenders (Foster and Giles-Corti, 2008:243). According to Jacobs (1961), having "eyes on the street" is crucial for creating secure neighbourhoods. The relationship between space and crime is emphasised by Newman's (1972) "defensible space" theory (Shach-Pinsly and Dalit, 2019:2).

Studies demonstrated that buildings with a view of open space would be more attractive to buyers and renters and bring more value to the real estate market (Meziani, Ghazal, and Hajjdiab, 2015:2). Morphological features and spatial configuration impact the view of a building to its surrounding space. Pinsly (2010) states that physical factors such as block layout and height, distance, and shape of buildings and public open spaces such as parks among buildings affect visual openness (Shach-Pinsly, 2010:180).

ISOVIST: A SUITABLE APPROACH FOR REPRESENTATION AND ANALYSIS OF SPACE VISIBILITY

Isovist is one of the most common techniques in the field of visibility analysis. This technique describes quantitatively how space is represented in terms of the volumetric structure of a scene.

Two-Dimensional Isovist

A spatial concept and measurement known as an isovist are used to represent visibility and its visual properties in the built environment (Kim & Kim, 19:74). Prior visibility research has been separated into urban and rural disciplines. Studies of the urban environment typically rely on isovists (Bartie et al., 2010:519). Tandy (1967) presented the idea of isovists, which Benedikt expanded further, to measure the observable space. The collection of all points in 2D isovists that are observable from a particular place in space that pertains to an environment (Motamedi et al., 2017:250). An isovist's size and shape are specific to its surroundings and vantage point, and they are subject to change as the observer moves (Benedikt, 1979:54). Isovist is independent of viewpoint and observer-oriented (Shakibamanesh, 2013: 187).

Isovist fields are generated by creating isovists at regular intervals within a defined space; then, the results will produce an area representing the generated isovists' sum attributes (Lonergan and Hedley, 2016:2). Isovist polygon can be described by geometric measures such as area, perimeter, obstruction, and variance. Geometric measurements like as area, perimeter, obstruction, and variance can be used to define isovist polygons. Its area measures how much space is visible from a particular location. Its perimeter length measures how many surfaces are visible from the location. Its variance describes the degree of perimeter dispersion in relation to the original location. Its skewness describes the asymmetry of such dispersion (Oliva, Park, and Konkle, 2011:110).

When part of the area is cut off, the isovist will have two types of solid and occluding boundaries. Solid boundaries are chords for which locomotive permeability is blocked (the proverbial brick wall), and occluding boundaries are projections of sightlines and indicate regions hidden from visual perception but would permit locomotion by a possible enemy (Stamps, 2005:738). The obstruction index specifies the perimeter in the mass section's length.

The 3D Isovist

Along with the advancement of isovist's analytical tools, the isovist description indices were also improved from two to three dimensions. The 3D field of view is specified by the 3D isovist. It is visible from a 360-degree rotating vantage point as well as from the ground to the sky. Compared with the definition of a 2D isovist, which considers a plane parallel to the ground, this new definition refers to the real perceived volumes in a 3D space (Morello and Ratti, 2009:842).

In fact, a two-dimensional and three-dimensional isovist representation of space can give a more accurate analysis of physical space.

A quantitative index called the Spatial Openness Index measures the volume of open spaces that could be seen from

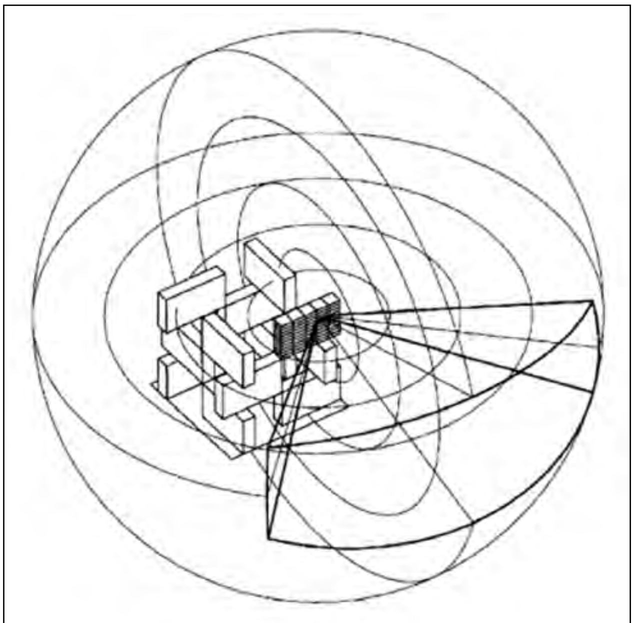


Figure 1. Spatial openness index (SOI); Source: (Fisher-Gewirtzman and Wagner, 2003:39)

a particular position (Fisher-Gewirtzman and Wagner, 2006:78).

A quantitative statistic, the SOI is expressed using 3D visual-spatial data. It calculates the amount of open space that could be viewed from a specific location (Fisher-Gewirtzman et al., 2005:30). The Spatial Openness Index can also be described as a three-dimensional isovist (Figure 1).

RELATIONSHIP BETWEEN PHYSICAL CHARACTERISTICS AND VISIBILITY INDICES

The mass-space system presents a general concept of urban physical structure, which constitutes a set of complex systems. Understanding the structure of the complex system as well as its effects and relationships with other variables requires careful investigation of the basic elements

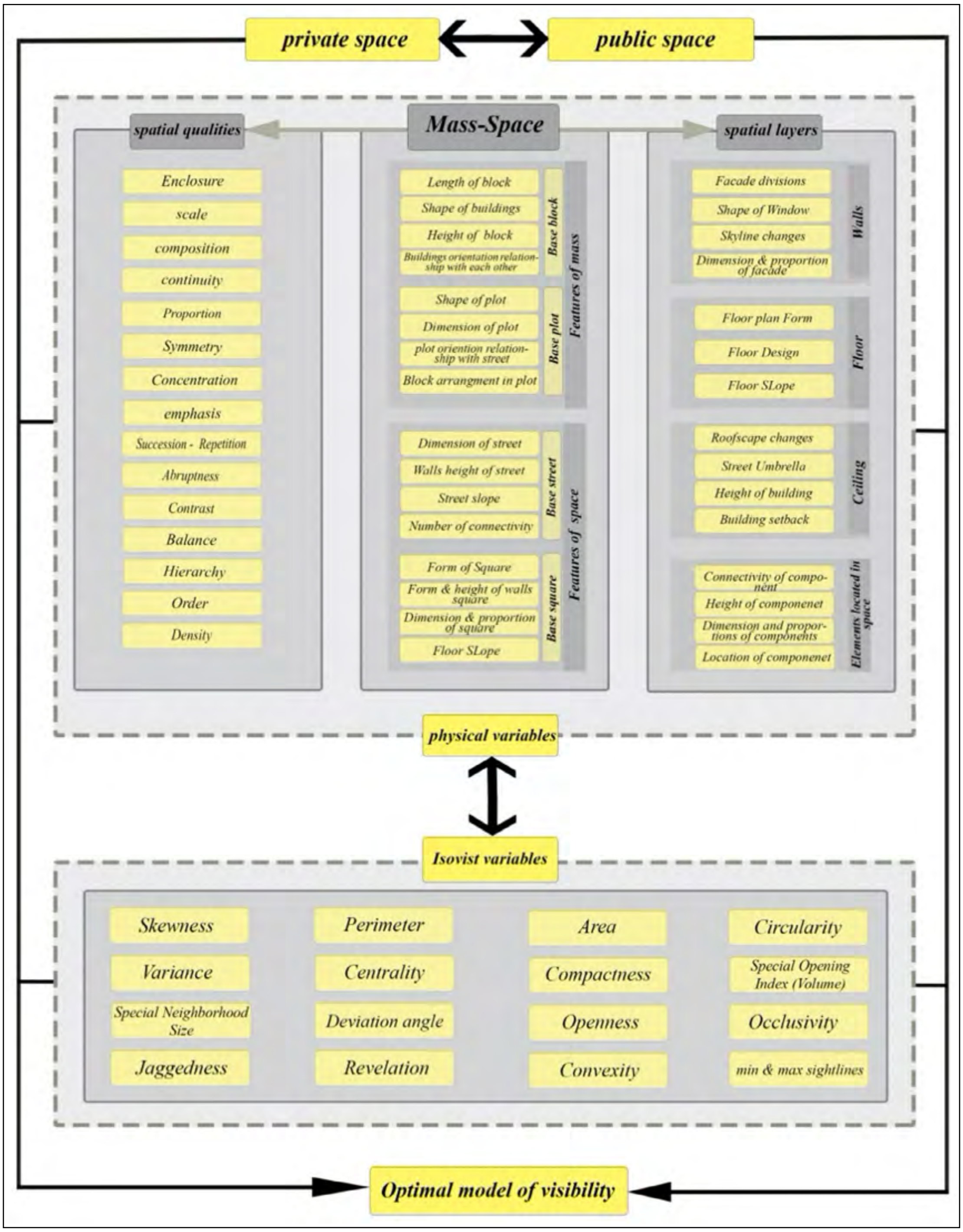


Figure 2. Relationships between physical variables and visibility variables; Source: adopted from (Benedikt, 1979; Fisher-Gewirtzman et al., 2005; Batty, 2001).

and components and their interactions. Physical factors affecting view and landscape can be divided into three categories, namely "features of mass-space components," "features of spatial layers," and "features of spatial qualities."

- "Features of mass-space components": Mass-space can be defined in relation to urban form. The features of mass-space components describe general design and features such as the shape, dimensions, and proportions of urban form components, i.e., block, plot, street, and square.
- "Features of spatial layers": This category describes the physical elements and the urban landscape components, including walls, floors, ceilings, and elements located in space.
- "Features of spatial qualities": Spatial qualities such as enclosure, scale, composition, and density express the location of urban form components and the relationships among them.

Given the breadth of the above factors, only the effect of some "spatial qualities" on the optimal physical-spatial "visibility" was examined in this study. Figure 2 shows the relationships between physical variables and visibility variables concerning achieving the optimal visibility measurement model.

DEVELOPING A MODEL FOR EVALUATING RESEARCH INDICES

In this study, an attempt was made to develop an integrated and quantitative model for achieving optimal visibility that would cover the three objectives of a good level of visual privacy in buildings, visibility of open spaces adjacent to buildings, and view to open spaces and non-built public spaces. Considering the effects of each spatial quality on the physical landscape of urban spaces and the nature of each quantitative isovist descriptors, physical spatial variables with visibility variables were adapted to the proposed model. For instance, high building density obstructs the observer's view to open and non-built spaces. According to the definition of spatial openness index, as the volume of open space which is visible from a given point of view and can be used to analyse the configuration of a built space or general open space in terms of spatial openness (Fisher-Gewirtzman et al., 2005), it can be concluded that the effect of density on visual and landscape can be assessed by isovist volume. As a result, for the isovist evaluation and analysis of the three strategic viewpoints indicated earlier, the formic spatial variables in the model shown in Figure 3 that correlate to each isovist variable are identified.

MATERIALS AND METHODS

In this section, the process that was followed in order to arrive at the findings of the research is broken down into its component parts and detailed step by step.

General Methodology

Using the model created for this study, the logical connection between the variables of physical structure and visibility will be examined. When evaluating the view from public areas to the surroundings, the view from the building to nearby buildings, and the view from the building to nearby open space, isovist variables were identified using the Delphi technique to produce more accurate results. The three-dimensional isovist technique was used to physically represent the examined regions and evaluate visibility in urban areas and views. Due to features like the potential for dynamic changes in modelling, the potential for detailed analysis, the availability of ready-made algorithms for isovist analysis, and the capacity to complete analysis in the shortest amount of time, the Grasshopper plugin for Rhino was used to analyse and evaluate isovist variables.

Selection of Isovist Variables to Measure the Three Indices of the Study

To create the optimal visibility model, the Delphi technique was applied twice. The first task given to the fifteen urban designers was to rate the significance of each of the three indices—view from public space to surrounding open space, view from the building to other buildings, and the view from the building to adjacent open space—in urban and residential spaces using a Likert scale. The greatest score was given to views from public spaces to their surroundings, followed by views from buildings to nearby buildings that were related to visual privacy and views from buildings to other spaces.

The variables that experts thought would have the biggest impact on measuring the three indices under examination were identified in the second part, which applied the Delphi technique. The experts rated six criteria based on three research indices: volume, perimeter, area, obstruction, length of maximum sightline, and length of minimum sightline on a five-point Likert scale (Table 1).

The Case Study

The buildings in Tehran's District 22 that are on the northern side of the Persian Gulf Lake were included in the study sample. Three samples were chosen for evaluation and analysis in this section based on differences in the volumetric diversity of blocks, the number of floors, diversity of mass and space composition, the orientation of blocks relative to one another, and the shape and size of the open space next to the buildings. This was done in order to perform the analysis and introduce the best sample of visibility. Threats to the view of public open spaces and buildings include obstruction of the view of open space and

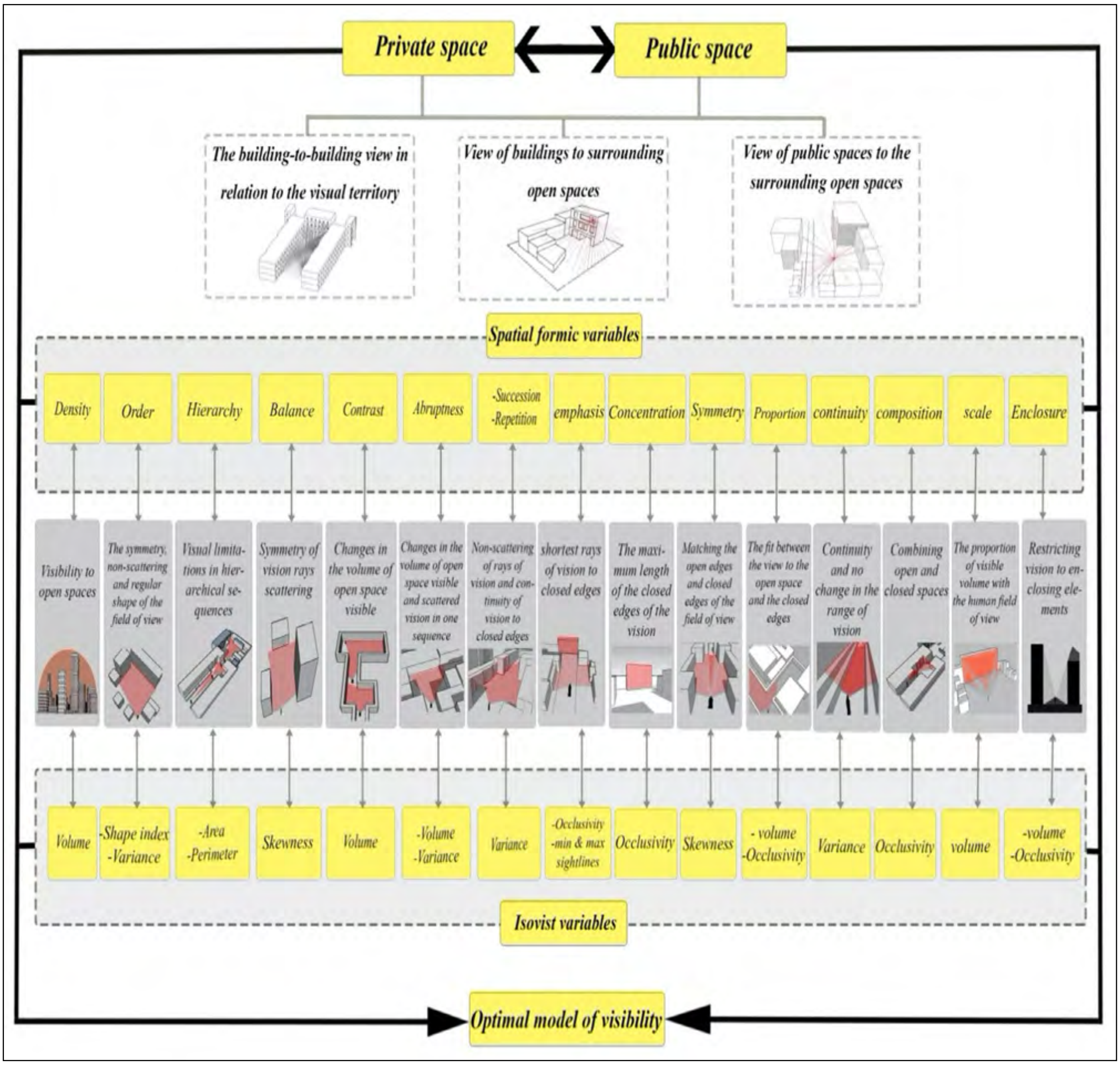


Figure 3. The model developed to evaluate research indices.

Table 1. Final scores of research indices and selected isovist variables

Indicators	View From the Building to Adjacent Open Space					View From the Building to Building					View From Public Space to The Surrounding Open Space				
Coefficient importance of indicators	0.64					0.82					1				
Variables	Max radius of view	Occlusivity	Area	Perimeter	Volume	Minradius of sightline	Occlusivity	Area	Perimeter	Volume	Maxradius of sightline	Occlusivity	Area	Perimeter	Volume
Coefficients	0.88	0.61	0.95	0.78	1	0.9	0.58	1	0.63	0.76	0.72	0.66	0.94	0.73	1

Figure 4. Location of selected research areas.

a lack of visual privacy as a result of the construction of dense structures in the northern half of the lake in the form of skyscrapers and high-rise residential complexes. This region has been chosen as the case study because of this (Figure 4).

ANALYSIS OF ISOVIST VARIABLES

In this section, the steps of analysing and extracting isoistic variables about three research indicators will be explained separately.

Evaluation of Isovist Variables Concerning View from Public Open Space to the Surrounding Space

Using a method connected to the two-dimensional isovist component, the numerical values of two-dimensional isovist variables such as perimeter, area, occlusion, length of maximum, and minimum sightlines were determined from the observer's point of view in a public open space. As seen in Figure 5, two-dimensional isovist maps with colour values indicating the lengths of the lowest and maximum sightlines were created for each location using the Rhino software. The isovist volume index was then calculated (Figure 6) in the form of spheres made up of lines of view along the 360-degree line of the observer's view using the three-dimensional environment of the research areas and the algorithm corresponding to the three-dimensional isovist components in the Grasshopper plugin (Table 2).

Evaluation of Isovist Variables to Measure View from the Building to Adjacent Buildings Concerning Visual Privacy

In order to assess the 2D isovist variables pertaining to measuring view from the building to adjacent buildings,

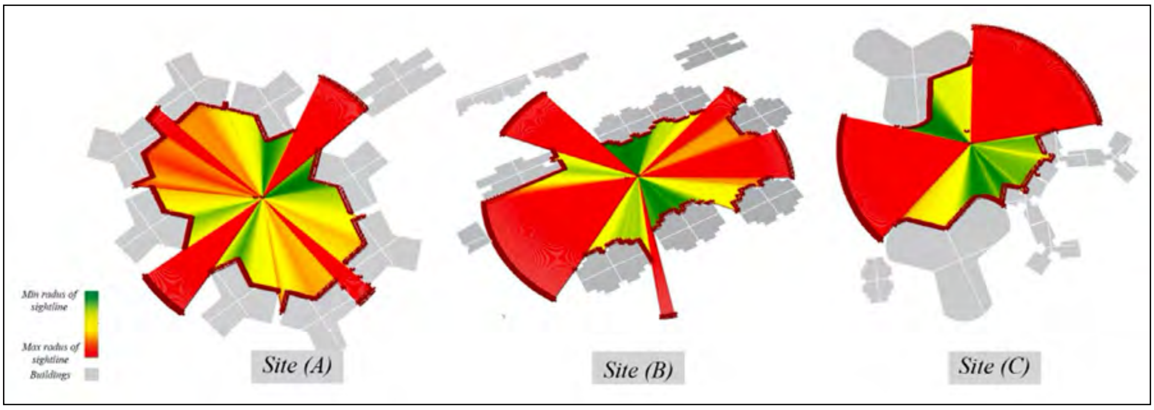


Figure 5. Two-dimensional isovist map for the view from public space to the surrounding open space.

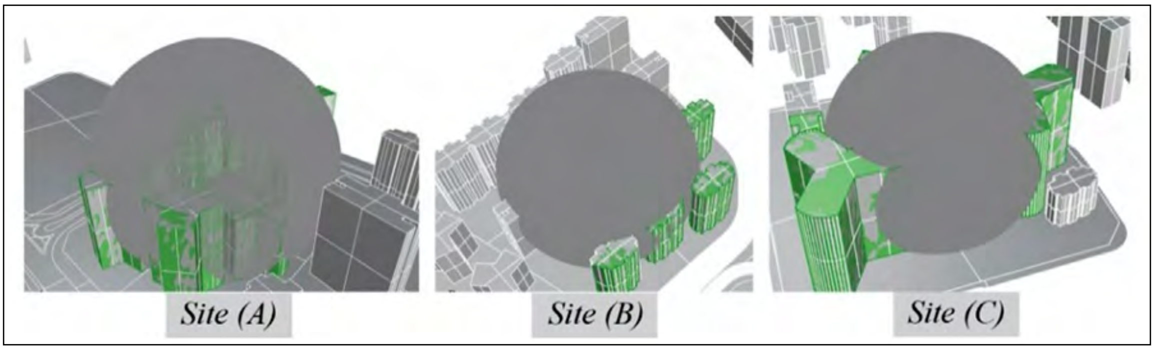


Figure 6. Three-dimensional isovist for the view from public space to the surrounding open space.

Table 2. Numerical values from the evaluation of isovist variables for the view from open public space to the surrounding space

Numerical values from the evaluation of isovist variables for view from open public space to the surrounding space	Isovist variables	Site (A)	Site (B)	Site (C)
	Volume	21268282	36633283	29332612/6
	Area	534216/05	712365/07	644919/17
	Perimeter	3551/06	6061/67	5412/29
	Occlusivity	890/22	680/96	650
	Max radius of sightline	380	453	576

a building in each of the three sites (A), (B), and (C) was chosen as the origin for the observer's point of view. Then, the upper, middle, and bottom floors of the buildings were separated. The chosen buildings' middle levels were designated from the observer's point of view, and studies were carried out from that side of the building. In Figure 7, the buildings selected from the viewpoint of the observer are highlighted in red (Figures 8 and 9, Table 3).

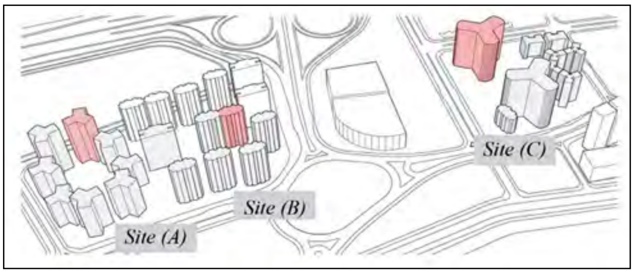


Figure 7. Selected buildings for placing observers in their middle floors for isovist calculation.

Evaluation of Isovist Variables Concerning View from the Building to Adjacent Open Space

Like evaluating the building's view of adjacent buildings, a specific place was chosen as the selected building to place the observer to assess the building's view to open space. Thus, the observer's point of view was placed on the selected buildings' middle floors, and then the view from the building to the adjacent open space was assessed (Figures 10 and 11, Table 4).

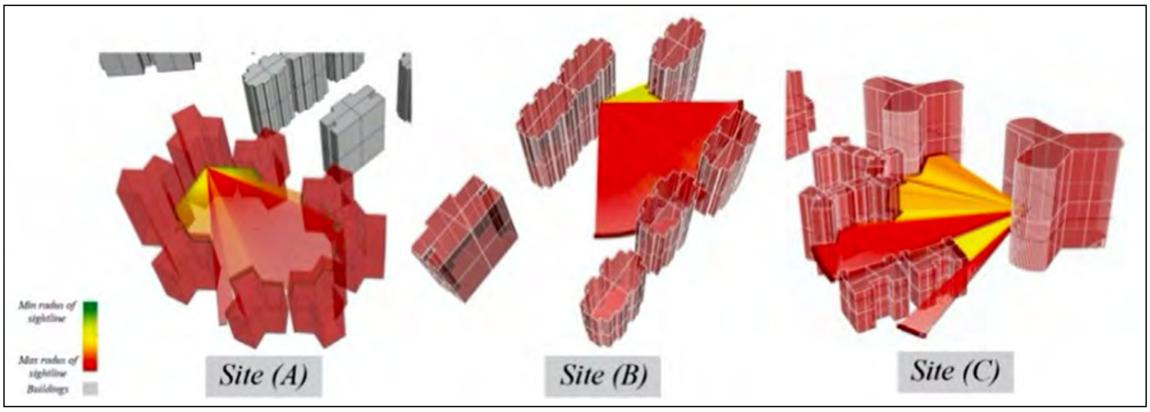


Figure 8. Two-dimensional isovist for the view from the building to adjacent buildings.

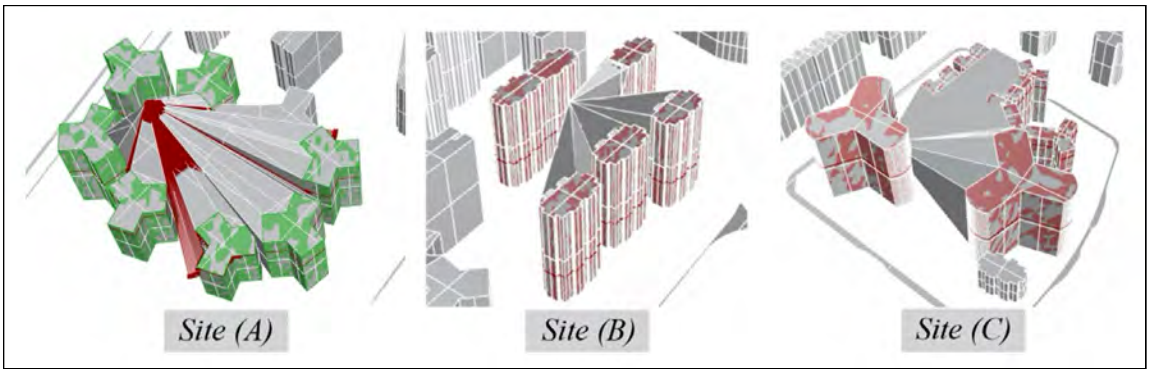


Figure 9. Three-dimensional isovist for the view from the building to adjacent buildings.

Table 3. Numerical values of isovist variables for the view from the building to adjacent buildings

Numerical values of isovist variables for view from the building to adjacent buildings	Isovist variables	Site (A)	Site (B)	Site (C)
	Volume	13723228/8	11936892	11062863/6
	Area	497280/67	308336/2	402822/3
	Perimeter	4449/8	3938/3	3388/22
	Occlusivity	781/22	674/3	614/96
	Min radius of sightline	74/9	93/9	104

Table 4. Numerical values of isovist indices for the view from the building to adjacent open space

Numerical values of Isovist indices for view from the building to adjacent open spaces	Isovist variables	Site (A)	Site (B)	Site (C)
	Volume	28223288/8	42338692	35862232/6
	Area	576352/37	838266/2	722862/3
	Perimeter	3846/6	6538	5872/26
	Occlusivity	889/93	632/33	594/5
	Min radius of sightline	605	742	923

ANALYSIS AND INTERPRETATION OF RESULTS

To complete this study properly, it is necessary to analyse the data collected to answer the research questions. In this section, each of the extracted data is analysed in the form of tables and graphs step by step.

Analysis and Comparison of the Variables' Values in Each Index

The volume, area, and perimeter variables in "view from the

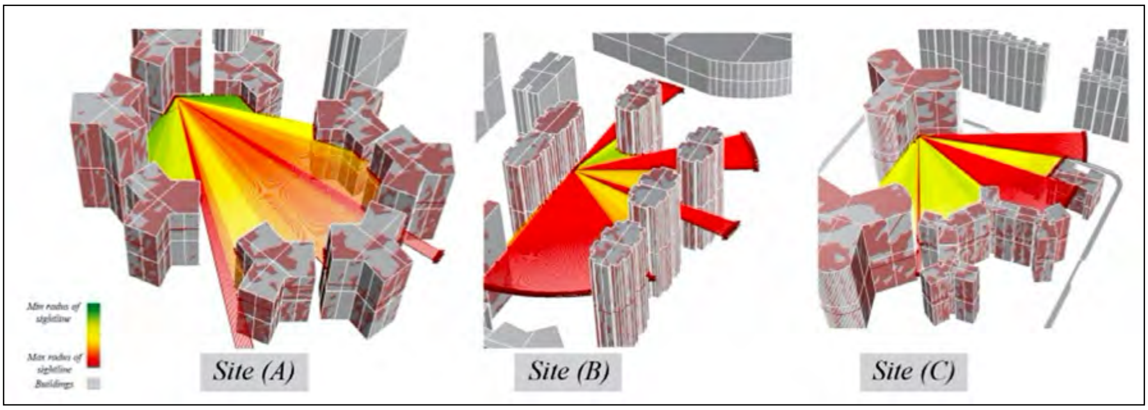


Figure 10. Two-dimensional isovist for the view from the building to the adjacent open space.

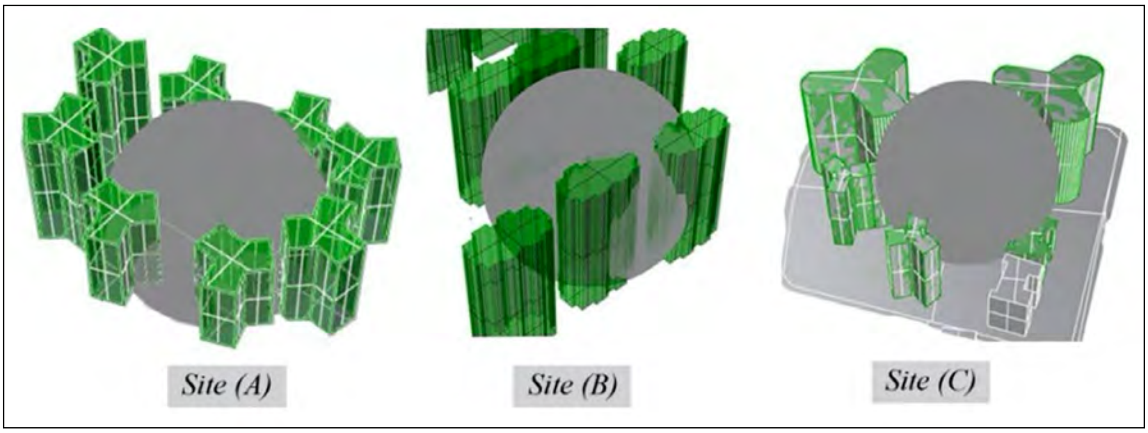


Figure 11. Three-dimensional isovist for the view from the building to the adjacent open space.

building to the surrounding open space" had higher values than the other two indices. That is because the building's view of the surrounding open space had a broader scope than the building's view of adjacent buildings. Unlike the view from public space to the surrounding open space, the observer was at a higher altitude in this view. Also, as shown in Table 5, in A, B, and C sites, the occlusivity variable in "view from public space to the surrounding open space" had a higher value than an obstruction in the other two indices (the highest value is in green and the lowest value is in yellow). According to the definition of occlusivity, and the part of the perimeter in the mass section, in "view from public space to the surrounding open space," the buildings completely obstructed the view of the open space because the observer was on the ground. However, in "view from the building to the surrounding space", the buildings that could obstruct the view were removed from the isovist barriers because there was a height difference between the building from which the observer looks around and the building of the origin. Therefore, the "view from the building to the surrounding area" had a smaller amount of obstruction.

Analysis and Comparison of the Three Indices in the Case Study Sites

Each of the indices and variable coefficients was used to compare the values of the isovist variables for each location. The result of multiplying the variable's rating raw data, the importance coefficient of the indicators, and the coefficient of the variable in each of the indices yields the final value written for each isovist variable in Table 6. The three indices' sums of each isovist variable were then computed in order to compare the locations.

Analysis of Isovist Variables for "View from Public Space to Surrounding Open Space" in Three Sites of Study

As the volume variable had a significant coefficient, it was used to compare "view from public space to the surrounding area" in all three sites. According to the definition of isovist volume, which describes the configuration of the public open space in terms of spatial openness, visual openness, and views of the surrounding open space, it can be stated that site B was in better conditions than the other two sites in terms of view to the open space, because it had the

Table 5. Evaluation of isovist variables

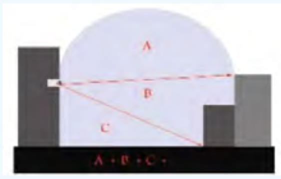
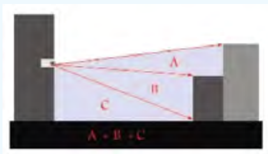
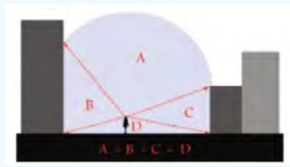
Evaluated sites	Normalised values of isovistic variables	 View from the building to adjacent open space	 View from the building to building	 View from public space to the surrounding open space
Site (A)	Volume	1	0.48	0.75
	Area	1	0.86	0.92
	Perimeter	0.86	1	0.79
	Occlusivity	0.99	0.87	1
	Max radius of sightline	1	–	0.62
	Min radius of sightline	–	0.72	–
Site (B)	Volume	1	0.28	0.86
	Area	1	0.36	0.84
	Perimeter	1	0.6	0.92
	Occlusivity	0.92	0.99	1
	Max radius of sightline	1	0.12	0.61
	Min radius of sightline	–	0.9	–
Site (C)	Volume	1	0.3	0.81
	Area	1	0.55	0.89
	Perimeter	1	0.57	0.92
	Occlusivity	0.91	0.94	1
	Max radius of sightline	1	–	0.624
	Min radius of sightline	–	1	–

Table 6. Evaluation and comparison of isovist variables in three case study sites

The sum of the similar isovistic variables for the three indicators	View from the building to adjacent open space		View from the building to building		View from public space to the surrounding open space		Isovist variables	Evaluated sites
	Coefficient Importance of indicators (0.64)	Variable coefficient	Coefficient Importance of indicators (0.82)	Variable coefficient	Coefficient Importance of indicators (1)	Variable coefficient		
47883503/02	18062904/832	1	8552316/188	76	21268282	1	Volume	Site (A)
1260355/476	350422/240	0/95	407770/149	1	502163/087	0/94	Area	
6811/261	1920/222	0/78	2298/766	0/63	2592/273	0/73	Perimeter	
1306/634	347/541	0/61	371/548	0/58	58/545	0/66	Occlusivity	
774/808	501/208	0/88	-	-	273/6	0/72	Maximum radius of sightline	
55/276	-	-	55/276	0/9	-	-	Minimum radius of sightline	
71169116/974	27096762/88	1	7439071/094	0/76	36633283	1	Volume	Site (B)
1432125/291	509665/849	0/95	252835/684	1	669623/758	0/94	Area	
10434/648	3975/104	0/78	2034/525	0/63	4425/019	0/73	Perimeter	
1016/991	246/861	0/61	320/697	0/58	449/433	0/66	Occlusivity	
744/054	417/894	0/88	-	-	326/16	0/72	Maximum radius of sightline	
69/298	-	-	69/2982	0/9	-	-	Minimum radius of sightline	
59178818/059	22951828/864	1	6894376/595	0/76	29332612/7	1	Volume	Site (C)
1376038/583	439500/278	0/95	330314/286	1	606224/019	0/94	Area	
8632/757	2931/432	0/78	1750/354	0/63	3950/971	0/73	Perimeter	
953/566	232/092	0/61	292/474	0/58	429	0/66	Occlusivity	
934/553	519/833	0/88	-	-	414/72	0/72	Maximum radius of sightline	
76/752	-	-	76/752	0/9	-	-	Minimum radius of sightline	

maximum volume. The combination of mass and space and the layout of the blocks that created a linear space on site B, alongside the less enclosed space of this site than the other two sites, and the height difference of adjacent buildings, increased the building's view of the open space (Figure 12).

Analysis of Isovist Variables for "View from the Building to Adjacent Buildings" Concerning the Visual Privacy

The area variable, which has the highest coefficient for evaluating building-to-building views concerning visual privacy, analyses visual exposure on the same floors. The isovist area assesses the visible area from the observer's point of view. The higher the isovist area's value, the higher would be the visibility, resulting in increased oversight of one building over other buildings and weaker private territory. Therefore, site B, which had the least amount of isovist area, was in a more favourable visual territory situation. Severe spatial enclosure, high building density in the form of high-rise buildings, minimal distances among building blocks, shapes with a sharp angle, and orientation of blocks less than 45 degrees relative to each other increased the "view from the building to adjacent buildings" on site A (Figure 13).

Analysis of Isovist Variables for "View From the Building to Adjacent Open Space"

The volume variable is of higher importance than other variables in evaluating "view from the building to the surrounding open space" and provides accurate information to interpret the results. According to the chart comparing volume in "view from the building to the surrounding space,"

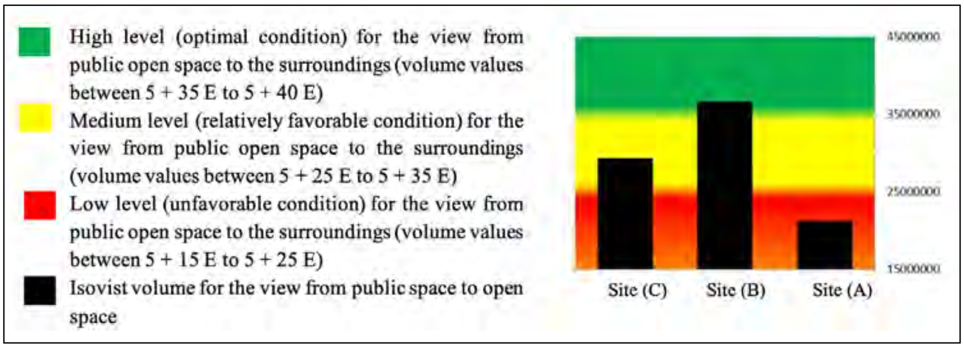


Figure 12. Comparison of the isovist volume for the "view from public open space to the surrounding open space".

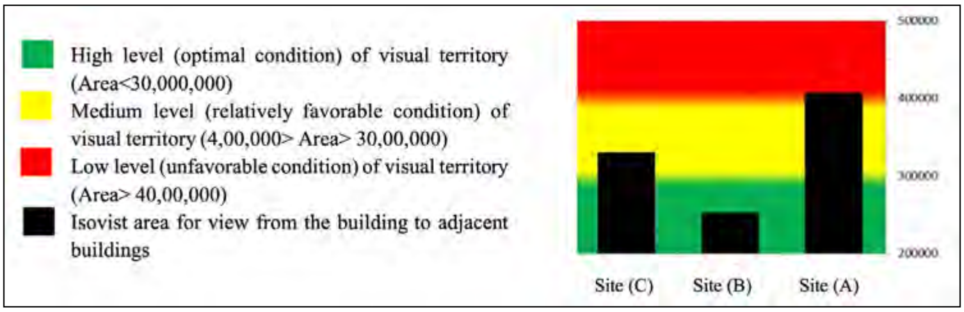


Figure 13. Comparison of isovist area values for "the view from the building to adjacent buildings".

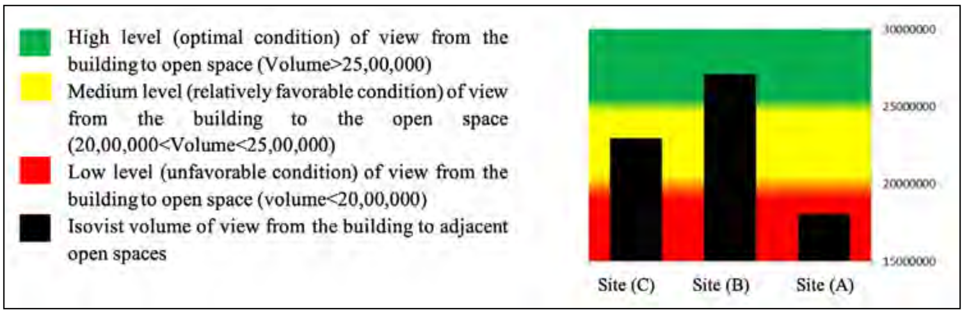


Figure 14. Comparison of isovist volume of "view from the building to the adjacent open space".

Table 7. Comparison of quantitative visual values in three research sites

The sum of the normalised	Result of Sum	Quantitative visual values						Evaluated site
		Maxradius of sightli	Minradius of sightline	Occlusivity	Perimeter	Area	Volume	
0/677	49/475152806	276/55	77/8084	130/6346	681/2611	1260/476355	47883/02503	Site (A)
1	72/185555753	298/69	74/0544	101/9916	104/64834	1432/291125	7116/9749116	Site (B)
0/834	605/2765454	752/76	93/5534	953/566	863/7572	1376/583038	5917/0598818	Site (C)

as in “view from public space to the surroundings,” site A had the lowest visibility volume due to its physical features such as severe spatial enclosure and limited height difference among adjacent buildings. According to the definition of isovist volume, describing the visual openness and extensiveness, it can be stated that site B, due to the height differences among adjacent buildings, had a more extensive view to open space from the observer’s point of view inside the building compared to the other two sites (Figure 14).

The Case Study Area in Terms of Optimal Visibility Among Public Spaces and Buildings

To compare and introduce the case study area that was more optimal in terms of three visual indices, including the view from public space to the surrounding area, the view from the building to adjacent buildings, and the view from the building to the surrounding open space, the total quantitative visual values were compared on the three sites (Table 7).

Performing analyses, comparing, and evaluating the visual variables of the three sites named A, B, and C and calculating the total quantitative visual values for all three sites showed that site B had the highest amount of visual values and a better status in terms of the three indices of view from public space to the surrounding open space, view from the building to other buildings and view from the building to open space. Thus, it is introduced as the site with optimal visibility.

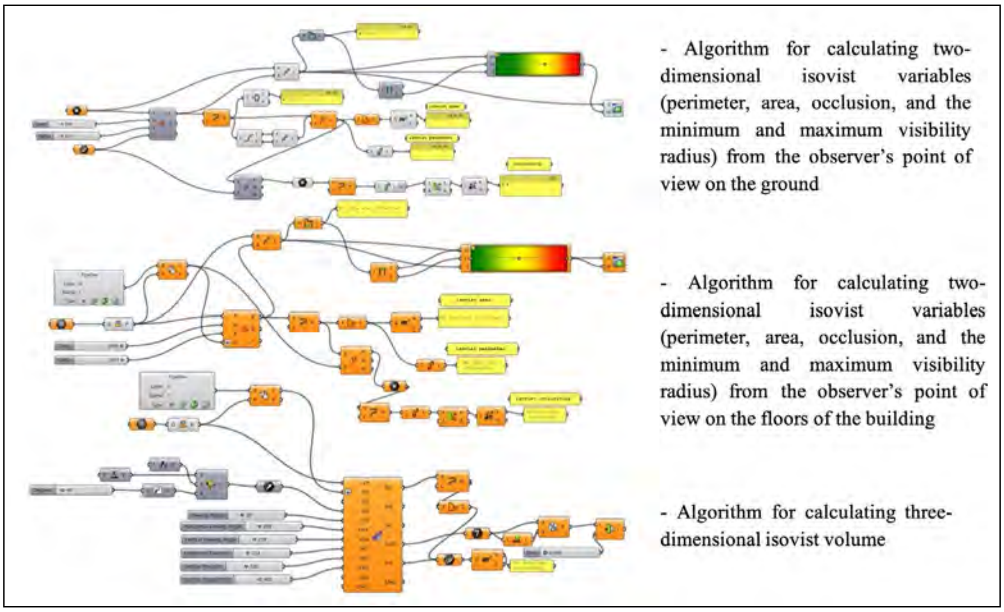


Figure 15. The optimal model of visibility between buildings and public spaces.

The Optimal Model of Visibility Among Buildings and Public Spaces

As a suitable technique for quantitative evaluation of the observer's viewpoint in urban areas on small and medium scales, isovist has received a great deal of attention in recent years and has a special place among quantitative analysis methods done by software. Grasshopper programming language provides the user with the ability to achieve the desired result by making dynamic changes. According to the analyses performed in the previous sections and evaluation of the three case studies through the Grasshopper programming language as well as the assessment of the analytical vision model, the visual analysis algorithm in Figure 15 is presented as an integrated model for measuring optimal visibility between buildings and public urban spaces.

CONCLUSIONS

Cities must concurrently offer two distinct urban lifestyles if they want to create better urban environments. The first kind is outgoing, extroverted, and social, whereas the second type is reserved and introverted. One of the most crucial aspects of quality in both public and private places is visual dimensions and related difficulties. Consequently, achieving optimal visibility between buildings and urban spaces is crucial. Physical dimensions can change public urban spaces' visibility and buildings' views through variation in the formal features of mass and space components, spatial layers, and spatial qualities. In this study, the isovist technique was used to investigate spatial qualities on visibility and representation of physical space. With the help of the Rhino parametric software and the Grasshopper programming language, the isovist variables of volume, area, perimeter, occlusivity, and maximum and minimum sightlines were calculated in three selected sites to evaluate the view from the public space to the surrounding open space, the view from the building to adjacent buildings related to the visual privacy, and the view of the building to adjacent open space.

The findings demonstrate that severe spatial enclosure, high building density in the form of high-rise buildings, proximity of the building blocks, and block shape make them visible inside the buildings and diminish the visual territory. The results indicate that diversity in the skyline and, consequently, height variations between buildings, which prevent height uniformity, boost the view of the open space and view to the sky from the observer's point of view both inside the building and in the public space.

This study was made to develop an integrated and quantitative model for achieving optimal visibility that would cover the three objectives of a good level of visual privacy in buildings, visibility of open spaces adjacent to buildings, and view to open spaces and non-built public spaces. The model created was then used to investigate the logical connection between the variables of physical structure and visibility. The effects of spatial qualities on public spaces and buildings' visibility were investigated. Simultaneously, the optimal visibility model was evaluated through a case study and then introduced as an integrated model.

- *This article is based on the MA Dissertation entitled "Analyzing the Mass-Space 3D Relationship to Achieve Optimum Visibility Between Urban Buildings and Public Spaces; Using 3D Isovist Technique (Case Study: Persian Gulf Lake, Tehran)" by Mahdiyeh Kokabi and completed under the supervision of Dr. Amir Shakibamanesh at Art University, Department of Urban Planning and Design in 2020.*

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