

## 3D VISIBILITY ANALYSES USING BIM & GIS INTEGRATION

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### ABSTRACT:

Visibility is a significant parameter for defining, developing, and evaluating space in the AEC (Architecture, Engineering, and Construction) Industry. Therefore, visibility is considered when designing visually comfortable buildings. Visibility is also a significant parameter in building appraisal. Therefore, in this study, visibility was examined through 3-dimensional (3D) isovists, which are thought to represent the human perception of vision. Visibility was examined regarding spatial openness and mathematically calculated “visual openness indexes” were developed for building valuation. The analysis area was selected in Istanbul, and the urban model was created by using Geographic Information System (GIS) data in Building Information Modelling (BIM) software. Due to, economic reasons affecting different stakeholders in building valuation, it is necessary to create an accurate urban model. For this reason, in the study, the process of obtaining current and accurate GIS data covering the world from open sources is preferred. Then, the process of correctly transferring GIS data to BIM is explained. A sufficient urban model for analysis is created. To calculate the openness indexes, the dormitory in the Golden Horn was modelled in BIM, and different rooms' openness indexes were calculated. Some solutions have been presented to ensure the modelling process with large file sizes and in the calculation of visibility factors. To allow different AEC stakeholders to calculate these indexes, modelling, and calculation is done within BIM. Eventually, it was calculated how much the building users cognitively perceive the openness of the view, and a mathematical comparison of the different rooms' openness indexes was provided.

### 1. INTRODUCTION

Visibility has a significant impact on human perception and cognition, it also plays a crucial role in defining space and measuring the environment. Therefore, in the field of architecture and urban design, visibility is taken into consideration from the beginning of building design to the completion of building construction to create meaningful spaces. In real estate valuation, visibility is analysed to evaluate building design and user satisfaction. This analysis is defined as "goodwill" and is one of the key variables in real estate valuation. It has been revealed that the concentration of residential areas has negative psychological effects on people (Evans Gary W. et al., 1996) and people prefer large views (Suleiman et al., 2013). The presence of high-rise buildings and obstruction of view also negative effect on the prices of the building. (Guliker et al., 2022). Therefore, designing visually more comfortable buildings with facade design openings that provide uninterrupted access to the view and building orientation that provides a wider view can be considered as an important criterion in building evaluation, and the scores of human-centred designs can be compared through visibility.

Evaluating visibility qualitatively by asking building occupants whether they like the view or not, is a traditional way of building evaluation method. It may cause subjective evaluations and create a variety of results since cultural values and personal perceptions vary among people. For instance, Yanılmaz and Tavşan (2021), achieved a proportional value for a view quality and satisfaction factor when they investigated the view factor qualitatively in their article. However, this value can be improved by investigating the visibility of different factors and getting the exact results for these factors.

Articles searching visibility, quantitatively or qualitatively, describe visibility in different terminology due to different sectors having different purposes in visibility analysis. To sum up, visibility is divided into different topics, and different methods of analysis are applied. Articles, addressing visual openness (visibility, spatial openness index, view access, density) (Shakibamanesh, 2022; Fisher-Gewirtzman, 2018; Koltsova et al., 2022; Suleiman et al., 2013), visual exposure (visual privacy) (Shach-Pinsly et al., 2011; Zheng et al., 2022), intervisibility (Suleiman et al., 2011), visual comfort, view clarity and view quality notions (Yang et. al, 2005; Ko et al,2021), or sense of human such as surprise (Al-Jameel and Al-Moula, 2023) conduct analyses using different methods such 2D visibility, 2D isovist, 2D VGA, 2D viewshed, viewshed on voxel model, 3D isovists, 3D visibility (ray-casting), 3D viewshed. (Wu et al., 2023). the results are calculated by different algorithms on MATLAB (Suleiman et al., 2013; Aleksandrov et al., 2019) some created a custom component (Koltsova et al., 2022), some created a visible output such as heatmaps. (Al-Jameel and Al-Moula, 2023; Ünlü et al., 2022). Environmental data is also changed for analysis such as meshes, surfaces, polygons, points, polyhedral or voxels etc.

Among these methods, isovists is one of the most used visibility analysis methods, generally used in built-environment. The isovists method was isovists was first used for viewshed analyses presented in 3D to record a landscape by Tandy (1967). The viewshed is the set of all cells of the topography that are visible from vantage point (Petrasova et al, 2018) and commonly utilized for intervisibility in rural area with raster data (De Floriani and Magillo, 2003). Isovists was introduced by Benedikt (1979) to the architecture discipline using Gibson's idea of “visual flow” (1966). The isovists defined by Benedikt, as “a set of all points

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that is visible from a specific observer point within the environment". As the observer point changes, the shape and the size of the isovists sets are changed which in turn depends on the new environment's visual-spatial qualifications. Therefore, it is suggested that the isovists measure the visual sense of the observer while describing the environment. Benedikt reduced isovists in 2D and used in isovist fields. It should be noted that isovists do not account for visual information such as shadows, colour, and texture in the original presentation of Benedikt in 1979. Then, this developed to visibility graphs by De Florian et al. (1994), used by Batty, (2001) and Turner, (2001) following evolved to a 3D environment by Fisher-Gewirtzman and Others (Fisher-Gewirtzman, et al., 2005).

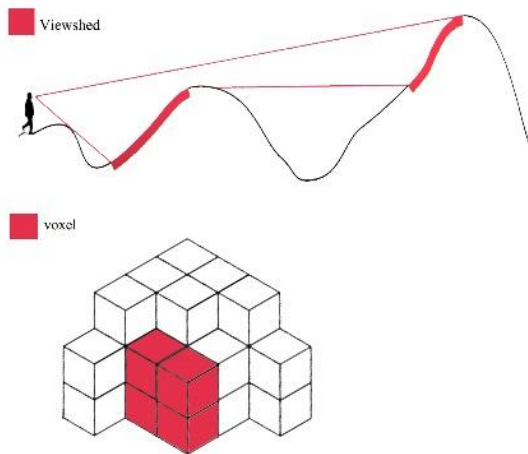


Figure 1. Viewshed and voxel difference.

The other most used visibility analysis method is grid-based analysis using 2D grids or 3D voxels which are 3D cells in a gridded representation of 3D space. For example, the Spatial Openness Index (SOI), developed by Fisher and Others which calculates the sum of visible area quantitatively using grid-based system (Fisher-Gewirtzman and Wagner, 2003). The advantage of voxelization is unified data type which facilitates 3D analysis but using large data volume is expensive due to it prevents creating required number of voxels in real-size geographic scene (Gorte, 2023). Morello and Ratty used 3D voxels to calculate isovist-matrix (2009) which shows visibility of each voxel in the space. Fisher-Gewirtzman et al., (2013), also used voxels to reduce the analysis timing in their search. The algorithm used for voxel is compelling for complex geometry whereas vector-based analysis has a high potential to be accurate and efficient, since it allows modelling the environment including the important elements and creating required set of points. Another merit of vector-based approaches is architectural models are generally authored using a vector-based design tool (Goldstein et al., 2023).

The visibility analyses are performed in many software with many different measurement methods depends on the purpose of the valuation study. For instance, in ArcGIS, visibility analysis can be done using line-of-sight analysis and the visible area can be viewed from a 3D model. In QGIS software, viewshed analysis can be done on a raster layer, such as a Digital Elevation Model (DEM) file. This allows users to perform intervisibility analysis in the field but does not allow users to add or subtract different parameters to calculate or obtain intersection points and lengths. Supermap is another GIS software calculates viewshed and intervisibility. Some software such as Bentley and Civil3D also allows visibility analysis for roads to see the sight distance,

allowing users to get visible areas from any location on a surface. Depthmap is another tool for getting visibility analyses with the aim of understanding space syntax in two-dimensional data. However, although many different software and many different methods are used, such analyses are strictly formatted to achieve visibility analysis in a single format. DeCoding Spaces and LadyBug are plugins in CAD, creates visibility analysis but applying the analysis in BIM can be done few processes. AVEVAL in BIM uses 3D isovist but calculating preferred VASA (Voxel-based Architectural Space Analysis) on the other hand, a new package used in BIM visual programming software for visibility analysis, uses the voxelization method and allows large data and variety of analysis but calculates visibility based on mathematical calculations approximately.

In the Architecture, Engineering, and Construction Industries, schematic design involves many design decision-making processes, such as creating the building program in line with the wishes of the stakeholders' requests and making design decisions according to urban factors, structural requirements, sustainability, and energy efficiency requirements, visibility analysis is postponed to the design stage. Additionally, these processes are often short-term and one-off (Zlatanova and Isikdag, 2016). Therefore, examining the current urban model and the building model simultaneously to design visually comfortable buildings and increase user comfort in terms of visibility is needed. Thus, the decision-makers can see the possible errors that may arise in the further steps in the building design phase. Also, in schematic design, building design can be shaped according to building rating systems evaluation methods. Since, most of the building rating systems such as LEED v4.1, give credit for direct access to the view (U.S. Green Building Council, 2020). Additionally, to evaluate goodwill, creating a three-dimensional (3D) urban model is needed since valuation practices today also require 3D property and environmental data (Kara et al., 2021). Therefore, BIM and GIS information is needed to combine for evaluating building and built environment relationships. Although, both GIS and BIM's early development was derived from a Computer-Aided Design (CAD) system, their transition to information modelling went through different processes (Wu et al., 2019). GIS has been used by urban designers and local authorities to handle urban-scale projects, on the other hand, BIM is used by AEC sector professionals for building-scale projects. Due to, these disciplines using different technology and data, it is required to understand the similarities between BIM and GIS while mapping GIS to BIM (Wu et al., 2019). GIS evolved to work with data referenced by geographic or spatial coordinates. GIS allows presenting a variety of geographic information in several different data models (Trodd et al., 2005). BIM allows the presentation of detailed information and using object-based data scheme (Wu et al., 2019). Data interoperability between BIM and GIS is not available by a single open data standard. Concisely, both differ in the structure of data, in the representation of geometry, in the level of development, and in the coordinate reference system. Therefore, many researchers have been working on enhancing interoperability since integrating data is still a challenge (Guyo et al., 2021). Because different professionals have been using software related to their profession, AEC professionals require visibility analysis method created in BIM. For these reasons, developing a calculation method for visibility and implementing a visibility calculation method in BIM software, may facilitate the work of AEC sector professionals to define visibility and enable them to obtain an objective value of appraisal.

## 2. METHOD

In this study, to evaluate the building design and user satisfaction in terms of visual comfort and visibility, visible area and distance are taken into consideration using 3D isovists in BIM. It is explained how to create and perform visibility analyses for an urban model, modelled in BIM by combining BIM-GIS data. In the study average radial of isovists and percentage of uninterrupted isovists are investigated for searching visual openness. The research location was selected in Eyüp on the European side of Istanbul, Türkiye where the Golden Horn started. The Golden Horn divides this area into 3 different lands and the west side of the area has two hills, a total of 4 hills are located. These are all intervisible from each other. In this area, the main research area was chosen on the northeast side of the area which is behind of the Bilgi University's campus. The area was divided into sections and created separately. So that, natural and artificial elements would not be a challenging factor in the modelling process because of large file sizes. Only required GIS data are modelled in 3D using BIM software.

In the BIM, a building project is created only in the schematic design level, the roof and the windows are added. Selected building rooms' visual openness factors have been investigated. This location was preferred for the study due to its dense population, sloped topography and widely varying distances in visibility. The building facade, which is oriented to Golden Horn, has increased open view distances since the sloped topography prevents buildings from obstructing each other's views. When the living area is oriented towards the sloping topography and the building is surrounded by many other buildings the visibility distances are shortened. The other reason for choosing the research area is, that the place can be easily understood by people since the Golden Horn. In the research area, the university area and the residential areas are located there together. The building was chosen to examine the difference in visual openness value between the upper and lower floors and in different facades.

The evaluation method for visibility in the BIM environment has been created on visual programming software. In the study, 3D isovists that reached up to the point which was defined as the horizon line has been created from a vantage point to the horizon point using a spherical coordinate system. Total of the points creates latitude-longitude lattice on a sphere. The precision of the LOS analysis method is increased when the 3D isovists sets are increased. The more isovists are created, the area is divided into smaller parts, letting users get more accuracy in visible area calculation.

An accurate representation of the building and its environment is required for the analysis process. For comprehensive analyses, the model must include both geometric data and non-graphic attributes (Ofluoglu and Isikdag, 2021). The datasets that are needed in the study from GIS are the topography elevations, topographic boundaries, trees, and buildings located in the research area. The buildings should include height values as a non-graphic attribute besides the geometric data of building footprints. The datasets that are needed in the study from BIM are the location of the building and facade design of the building. By superposing GIS information and the BIM model, the resulting city model can become available for analysis.

It is intended to use open-source data which contains the data mentioned earlier worldwide to create an urban model. The main reason for using open-source data is to create a globally valid workflow for importing GIS into BIM. In addition, open-source data can be transferred to BIM through a package created for the

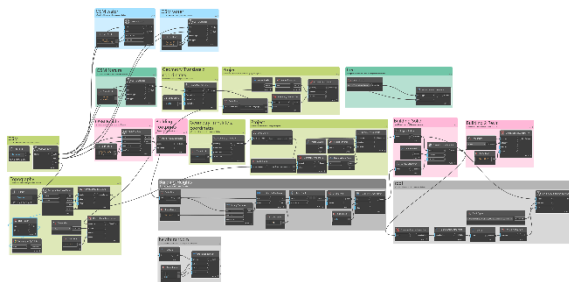
use of GIS data in BIM software, thus facilitating manual model creation processes. To download cadastral data, open-source mapping sites are investigated. Many cities such as Toronto, Los Angeles or sites such as AURIN, Lacity, Vic, datacityofchicago, share cadastral data openly. Cadastral data can be also downloaded from OpenStreetMap (OSM). OSM is one of the well-known examples of Volunteered Geographic Information (VGI) which describes crowdsourced geoinformation introduced by Goodchild (2007). OSM has some data provided by local authorities, mappers and companies (Biljecki et al., 2023). In OSM, data is classified using tag keys and values allowing users to add data. OSM data is also located according to its coordinates, making it easier to transfer the desired data into BIM and CAD. In addition, data can be easily updated, and possible errors can be checked and corrected.

In this study, OSM data is used because it is aimed to use a consistent data shared world widely, and because of this data can be used in a package of BIM visual programming software. Therefore, topographic boundaries, natural entities (trees), and building footprints are gathered from OSM. Since, building height data and building footprint data have not been processed fully in open sources and Bernard et al. is suggesting users to overcome this issue by completing the data with random values or by processing it manually (2022). That is why, building-related data has also been gathered from İstanbul Metropolitan Municipality sources. Building footprints are likely to have no height data in OSM. Also, in some places, footprints aren't fully processed. In this study, the near research area is manually processed on OSM. To get the right information from OSM, data is investigated, and some footprints and height attributes are added in the analysis area in OSM. The height values are taken from floor level values at the İstanbul Municipality's current map. The height of each floor of the buildings is accepted as 3 m. Therefore, the levels of buildings multiplied by three and manually added at the height keys of OSM buildings located near the research area. There were many buildings located away from the research area, to decrease the number of manual work, the height attribute isn't given from the local current map to these buildings rather a randomly created number is given to them in the visual programming software.

Digital Elevation Models (DEM) can be downloaded from many web portals and mapping sites of some governments such as "Osdatahub.os.uk", "Opendata.dc.gov", "Mapsforeurope.org", "Eurogeographics", "Portal.opentopography.org" and "Opendem" site. For instance, on the Opendem site, many open-format data are written while describing data formats and which locations have the data. DEM data can be downloaded from the United States Geological Survey (USGS) Earth Explorer, Japan Aerospace Exploration Agency (JAXA) Advanced Land Observation Satellite (ALOS) World, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model and from websites of companies that produce GIS data by paying a fee. It should be noted that DEM is a general term for elevation model and might include vegetation. Therefore, using a Digital Terrain Model (DTM) with high resolution for creating a topography is preferred. Most of the DEM shared in open sources, has a 30 m resolution for Türkiye such as SRTM, ALOS World. If more resolution is needed, Digital Surface Model (DSM) and Digital Terrain Model (DTM) can be achieved from local authorities. In this study, to get the latest and the most accurate model shared in open sources for Eyup, Shuttle Radar Topography Mission (SRTM) 1-arc seconds data is used. This data is chosen, because it can be opened in a visual programming software package too. To create Eyup's topography model, the Topography file is imported from

Earth Explorer site. The location is chosen from the map. Then the “SRTM 1 Arc-Second Global” file is downloaded in GeoTIFF 1 Arc-second format which is located in ‘Digital Elevation’ panel under ‘SRTM’ file type.

To combine BIM and GIS data in BIM, the workflow below is defined: first, project units of distance and length changed to meters. Secondly, the research area was divided into 3 to prevent crashes within the software and to work with smaller file sizes. For all 3 different area building footprints, topographic boundaries, natural elements gathered from OSM, by selecting and downloading the required areas in OSM file. The imported file includes geometric data in a points list of all elements. To bring GIS into BIM, visual scripting software has been used. (Figure 2). For each 3 different OSM file the next steps are followed: In visual scripting software OSM data are gathered in BIM by “File.Path” node. To get the location of OSM, “OSM.Location” node is connected to file. Then, data pulled into BIM by “OSM.OSMdata” node. To get the location of the topography, “Topography.ConstructLocation” node is used. Topography is created by using “Topography.CreateTopo” and converted to surface by using “List.Flatten” node, then by “Topography.ByPoints” node topography surface is created and exported to BIM as a mass by using “DirectShape.ByGeometry” node. That way the isovists can define the intersection point with topography.



**Figure 2.** Creating built environment in BIM.

To create buildings, duplicating points of the building footprints in the OSM file are deleted. Points that represent building footprints corners are moved in the z axis above the topography. After, the distance between to topography and points are calculated, the points of each building footprints projected. The projection distance is selected as the maximum of the distances between the footprint points of each building and the topography points in the projection of these points. Maximum distance is selected to prevent buildings to projected a location that is higher from the topography. A polygon is created from each buildings point list. For main research area the buildings height values are pulled from OSM by height key using “String.Contains” node. That way height key is selected from the list.. Height data separated from colon punctuation mark by “String.Split” node and unnecessary values by using “List.TakeEveryNthItem” node. The height values is changed to number by using “String.ToNumber” node. The OSM data which are located away from the main research area, hasn’t building height values added or processed. The buildings’ height are created from “Math.RandomList” node and applied all buildings the numbers. The polygons are created from points and extruded using height distances created before. The roofs are also created on the top of the extrusion by selecting polygons of the building footprint and the elevation of the maximum point of the solids. Buildings are exported to BIM as building masses by using “DirectShape.ByGeometry” node. (Figure 2).

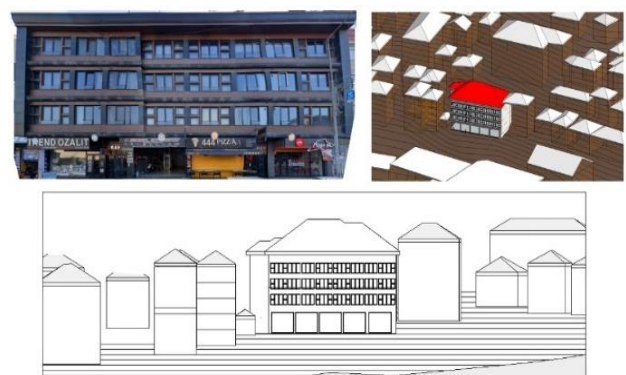
The coastline boundaries are constructed as points in OSM. This data is not imported to BIM from “DirectShape.ByGeometry” node. But Golden Horn is manually created by the points of natural water key when the OSM points became available for background preview in BIM canvas from visual programming software.

Trees are also constructed as points in OSM in the natural: tree key. Points of trees are placed over topography and according to their distance to topography the points are projected on topography. Trees are created as a mass created like tree and exported to BIM by using “Family.Instance.ByPoint” node. That way, three different GIS file created in BIM in three different BIM file. Therefore, creating the model became easier since all data can’t be imported at the same time due to software capabilities. Also, dealing with large files became easier. Then the models are linked manually using reference buildings and imported to one BIM file using “bind” option for analysis to be done (Figure 3).



**Figure 3.** BIM GIS model combined.

To create the BIM model of the dormitory, the mass created from GIS file is used. Mass surfaces is converted to walls. The window openings are added as the building photo. The building floors are added in three meters distance to put the observer element on the floor. The building is modelled in Level of Detail (LOD) 200 to decrease the file size (Figure 4). To prevent isovists to calculate room sizes, vantage points are created outside of the building in front of the window (Figure 7).



**Figure 4.** Photo of the building and BIM model of the building.

Visibility analyses are held in a node-based visual programming interface in BIM software (Figure 6). To get the urban model in the BIM, GIS data and BIM data are imported in the same BIM file translated into a visual programming interface using “Select Model Elements” and “Element.Geometry” nodes. The urban model became ready for visibility analyses.

Due to, line-of-sight analysis is based on rays that start from the observer location (vantage point) and reach out to every point in the 3D space. The spherical coordinate system is used, as mentioned before to create the 3D isovists. Spherical coordinates can create every direction in 3D space. It describes a point or a vector in space with an  $r$  distance from the centre, the phi ( $\varphi$ ) angle in the  $x$  and  $y$  plane starting from the centre and the theta angle ( $\theta$ ) starting from the centre in  $z$  vector to the vector itself. The theta angle is between 0 and 180 degrees and the phi ( $\varphi$ ) angle is between 0 and 360 degrees (Figure 5) (Arfken, 1985). To obtain a very detailed analysis, it is aimed to get maximum number of directions from the observer point. Good precision is reached when 64800 tracing rays created to execute analysis (Suleiman et al.,2011).

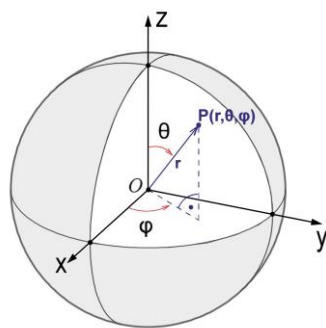


Figure 5. Creating isovists using spherical coordinates.

In the visual programming interface, to create visibility analysis (Figure 6), 3D isovists is created as follows: first the vantage point is created from the BIM element which is a family RPC file of a person from entourage library. It is chosen by “select model element” node from BIM element and gets its coordinates by “familyInstance.Location” node, therefore the vantage point is translated into the programming interface model. To modify the vantage point elevation, “geometry.Translate” node is used defining the modifying point will be in the direction in  $Z$  and elevation input is chosen from the number slider. The number input is chosen as 1.7m describing the observer’s eye height.

To create every direction from a vantage point, “Point.BySpherical Coordinates” node is used. To get all the angles for theta angle, a range between 0 to 360 degrees is defined and intervals are defined as an input, selectable from a number slider. To get all the angles for the phi angle, a range between 0 to 180 degrees is defined. The intervals are selected 1 degree to get a very detailed analysis. To prevent creating 0 degree two times the last 360 degree is deleted. The same applied in the  $z$  direction and the last 180 degree is deleted. That way, the precision is increased and total 64800 direction from the observer point is created to analyse the environment. The output data of “Point.BySphericalCoordinates” node has created a list that has a nested list in it, to get all points in a flat list, “List.Flatten” node is applied, that way the flat list including endpoints is created. To create 3D isovists, lines are created by “Vector.ByPoints” node that has connected to a start point of the observation point and in the direction of an end point from the endpoint list.

To collide isovists onto urban elements and get the intersection point locations with intersected elements, “RayBounce.ByOriginDirection” node is used. The bounce is defined as one for stopping the isovists from going further to the invisible part of the element. The rays are created in 3D view. To

make the intersected/collided isovists visible, “Line.ByStartPointEndPoint” node is connected to intersected points. The null values indicate that the isovists have no intersection points which shows the spatial openness and visible area has no limit within the defined radius of spherical points. This node also gives the elements that hits by isovists from the elements output of the node. The node also gives the number of isovists created and null values of point output give the isovists that don’t hit to any element.

To get the distance of the intersected element from a vantage point, a line created by “Line.ByStartPointEndPoint” node that connects to points of observer location and the points output of “RayBounce.ByOriginDirection” node. “curve.Length” node is applied to the line. To shorten the sight, the lines are cut off at a specified distance. Thus, 3D isovists are created in the defined distance.

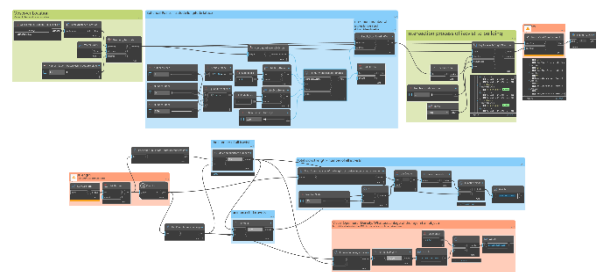


Figure 6. Visibility analyses.

Two different visual openness indexes are created from 3D isovists and to create the calculation, the information is gathered from 3D isovists.

**Visual Openness 1:** This coefficient calculates the mean of uninterrupted visible distances by calculating division of total isovists length to the number of all isovists created.

To find the visual openness factor, the sum of the length of isovists collided on built environment with the number of uncollided isovists multiplied by a specific distance is divided by the total number of isovists.

The equation is shown below (1).

$$VO1 = \frac{1}{2} \sum_{k=1}^n |l_{(n1)}| + |l_{(n2).r}|, \quad (1)$$

where

- $\Sigma$  = Sum
- $O$  = Visual Openness
- $l$  = Length of isovists
- $r$  = specified distance value (maximum visible distance)
- $n1$  = the number of isovists onto objects
- $n2$  = the number of isovists that do not collide with objects (which was cropped at the specified distance)
- $n$  = the number of isovists created from vantage point

To create this equation in visual programming software, The length of isovists are created from “Curve.Length” node. “The sum of the distance of intersected isovists’ length is created from the “Math.Sum” node.

To create an equation including the uncollided isovists, the total length of uncollided isovists is created from multiplying the number of uncollided isovists with a specified distance is added to collided isovists' lengths. The specified distance is given by user demand. The number slider node that gives the number of isovists cut point is the specified distance given by user.

“The total number of isovists” information is created from the lines which starts from the observer point and ends with the point output of the “spherical coordinates node”.

**Visual Openness 2:** This coefficient gives a value that is obtained from the viewpoint that determines what percentage of view distances are uninterrupted within the specified length radius. This value gives idea for users to understand at a specified distance from the observer location what percentage of the rays created from the observer location do not hit the objects. When a higher number of specified distances is given, more isovists hit an object. Thus, keeping the specified distance minimum also gives the idea of built environment density within the specified distance.

The number of isovists which collided on object can be pulled from the list count of the node “Line.ByStartPointEnd Point” which is connected to “RayBounce.ByOriginDirection”. The number of isovists is created from the vantage point and can be pulled from the list count of the “Line.ByPoints” node.

The equation is shown below (2).

$$VO2 = 100 - \frac{x}{n} 100, \quad (2)$$

where

$\Sigma$  = Sum

x = the number of isovists collided on built environment in a specified distance

n = the number of isovists created from vantage point

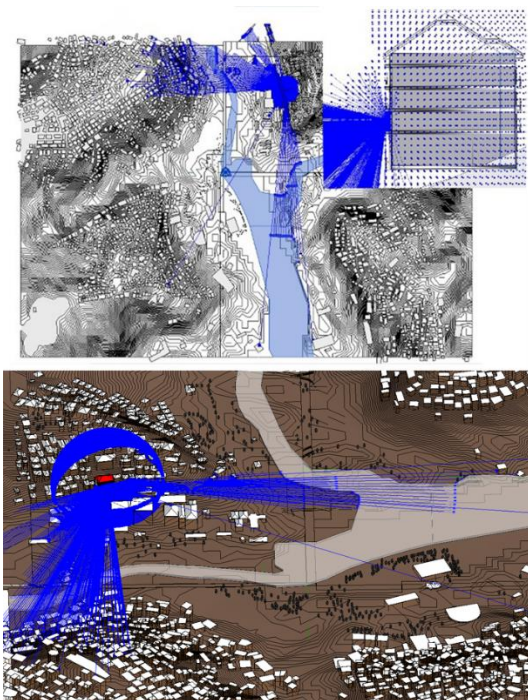


Figure 7. 3D Visibility analysis

### 3. RESULTS

The study area was chosen as Eyüp, Istanbul, Turkey, where four intervisible hills around the Golden Horn are located. There, in a densely populated area, some buildings have fewer views, and some have wider views. In a densely populated area, some buildings are located on sloping topography and their front facades have a view of a larger area, while their rear facades are oriented towards the sloping topography and have a view of a smaller area. The lower floors of the buildings have less view because of the surrounding buildings, while the buildings on the upper floors have more views. Thus, the analysis area enables to reveal the differences between the visibility values for the openness index.

In the study, a dormitory located behind Bilgi University was chosen. The visibility analyses were done for the building rooms. The front facade has more view and the room located at the highest level has a wider view. The first room is chosen which is in the front facade on the left of the second floor, the second room is in the front facade on the left of the fourth floor. The third room is in the rear facade in the middle of the second floor. The fourth room is in rear facade in the middle of the fourth floor. The specified distance is chosen as 50 m, and 150 m in the study. That way, the relationship between the building and the built environment is shown, and how dense the built environment is investigated by measuring the sum of the length of uninterrupted isovists created from vantage point within a distance. It is calculated how much the building users cognitively perceive the openness of the view, and it was provided a mathematical comparison of the different views' openness indexes (Figure 7).

The results are seen in the table below (Table 1). The results show the higher number of visual openness index 1, the longer visible area is achieved from the vantage point. Since, the length of the isovists are increased, the higher value means that more open area is visible from a vantage point. The visual openness index 2 shows, how many percentages of isovists hits an object in a limitless vision. This object might be topography, water, trees, buildings, and building-related elements, such as roofs, and windows in the environment. That result also shows the elements located surrounding observer, stating in other words, the density of the visible area. That result shows uninterrupted isovists are reaching further and hitting objects.

Visibility Analysis	Visual Openness 1		Visual Openness 2
	50m	150m	Limitless view
Research area			
Rooms			
Front Facade Level 2	16.9851 739589	38.4718 8612162	19.7654320988
Front Facade Level 4	18.3212 8589643 36	40.5939 2567696 14	20.038580246913 6
Rear Facade Level 2	13.7073 0061609 97	29.3414 6694379 61	15.186728395061 7
Rear Facade Level 4	15.6576 8777154 83	31.8949 2602121 59	15.685185185185 2

Table 1. Visibility Values

#### 4. DISCUSSION & CONCLUSION

Measuring space with evolving technology has opened the way up for quantifying the visibility of urban design elements. With the data-driven from urban design elements, the perception of humans for the environment can also be defined. In this study, visibility was examined regarding spatial openness, and mathematically calculated “visual openness indices” were developed for building valuation. Spatial openness is investigated through BIM and GIS data integration with line-of-sight analysis.

The study supported that 3D isovists can be used to obtain the desired information in BIM and can be created in line with the desired analysis. The study also supported 3D isovists' usage for defining the openness of space. This way, creating isovists in BIM provides AEC users to create visibility analysis for different scenarios. Also, it allows users to make detailed analyses and offers the opportunity to examine different qualities. The visual output of line-of-sights can also be achieved. Reliance on visibility analyses performed for different purposes in different software is reduced.

The numerical data obtained with the analysis proposed in the study can be used for building valuation purposes because it is objective and comparable. Obtaining a higher number of visual openness index values indicating that the building user comfort is higher. Thus, achieving a higher number of visual index values can be counted as a desired feature for buildings in building appraisal. For this reason, AEC sector professionals and building users can make decision from this value.

This study differs from other research by calculating the spatial openness by length of isovists and total number of isovists in an urban area. Also calculating the indexes in BIM is another point of differentiation from other research.

To create a sufficient analysis result, defining the isovists' number is critical. For quick analysis, the isovists number can be decreased but this leads to less accurate results. As the number of isovists increases, the analysis process also increases. Model units also need to be checked. With the software upgrades and in different versions, visual programming may become unusable. This can be overcome by writing scripts or using other nodes. Creating the environment and building accurately is a critical phase because providing access to usable data and being able to use and process the data within BIM is challenging. Since data sources are consistent and have ongoing efforts to update data, the analysis method can be used in future research. Unfortunately, the higher environment info given in BIM, BIM software spent more time creating and analysing the model. In this study, for vector data, OSM is used, and for DEM, USGS raster data is used which both include data for every location in the world. Although achieving 100% accuracy is hardly possible, due to heterogeneous data of the OSM resulting from VGI-based spatial data infrastructure and due to the low resolution of DEM, the workflow enables a quick way to create an urban model. Adding and editing the information manually in OSM would enable the creation of a precise 3D model. Also, USGS has data that have more resolution for some areas in the world. Additionally, the OSM has an infrastructure that allows the data to be processed worldwide. In this way, the workflow creates a method valid for every location in the world.

To sum up, this study differs from the other research in creating a visibility analysis in BIM software. It plays a significant role in the visibility evaluation, in terms of proposing a quantitative

method by evaluating the context of the visible area using only 3D isovists.

The study makes contributions to architectural and urban computational analysis by applying the following methods:

This study creates a workflow for modelling a 3D urban model with the integration of BIM and GIS data; the required urban information and built data has downloaded from open-source resources. The architectural and urban data are combined on BIM software; the line-of-sight analysis method using 3D isovists is created in BIM; the visibility evaluation method is proposed using BIM software; the limited possibilities for visibility analysis provided from other GIS software are overcome by using BIM software; digitalization in real estate evaluation is increased; view factor can be analysed in the early design stage of BIM. Therefore, BIM uses are increased in the construction industry.

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## APPENDIX

The files have been shared in GitHub repository via link below.  
<https://github.com/ececorlu/GeoAdvances2024>