Klara Czyńska[1] Paweł Rubinowicz[1]
1. West Pomeranian University of Technology, Szczecin

Visual Impact Size Method in Planning Tall Buildings

The article introduces the Visual Impact Size (VIS), a method of computational analysis based on the 3D isovists theory to provide to analyze the impact of tall buildings on the cityscape. In many instances, the negative consequences of an inappropriate location of a tall building especially in European cities resulted from inability to foresee its spatial impact. The VIS method uses the virtual city models as basis for calculations. It allows: a) to identify all locations in the city from which the planned tall building can be seen; b) to show not only real visual impact range but also imaging of the impact power (visual impact size) of the building. The method was applied in author's professional praxis to verify locations and parameters of tall buildings.

I. Tall buildings phenomena in Europe

In recent years, tall buildings have become increasingly popular. The majority of contemporary tall buildings in the world were built 21st century. This phenomenon does not any longer apply to only the largest metropolises, but also medium-sized cities. Especially in Europe, this is an important urban planning challenge. The European cities and their surrounding cultural landscapes have evolved gradually over centuries, if not millennia. Their built heritage, when not ravaged by war, is substantial. (Van der Hoeven and Nijhuis, 2011, p. 279). The development of tall buildings involves major threats to landscape cohesion and integrity of those cities. Specific architectural and urban arrangements reflected in the silhouette of a city are an important part of the protected cultural heritage (Rubinowicz and Czyńska, 2015). Due to their broad visual impact range, tall buildings frequently induce unfavorable and unplanned interaction with historical buildings. They diminish the influence of primary architectural dominants (e.g. towers of churches and town halls) as regards to their role in the overall composition. For this reason, plans to develop tall buildings trigger conflicts and controversies (Fig. 1a). In order to proceed with an objective discussion on the role of tall buildings as such, we need to develop a methodology for assessing and planning such buildings in a city landscape. We need to fully document the future, planned visual impact to formulate reliable and competent planning guidelines and strategies for landscape protection and development.

The current planning mechanisms do not fully utilize the advancement of modern technologies and analytical tools. The development of computer aided techniques, increase in computing power, as well as growing accessibility of virtual city models significantly boosts and expedites the verification of specific planning decisions, in particular those regarding tall buildings. However, we still are missing a clearly defined methodology for diagnosing the phenomenon and dedicated analytical support. The planning of new tall buildings necessitates analyzing the urban structure of a city at various scales: from global, including the impact of a building on the space of the entire city, partial external exposition within skylines, to internal views of public space (squares and streets) (Zwoliński and Jarzemski, 2015). For planning purposes, a relevant synthesis is necessary – determining the sum of visibility fields for a planned tall building. The use of scientific theories concerning determining of isovists 3D in analyzing visual aspects of tall buildings is particularly valuable. The Visual Impact Size (VIS) method presented in the article enables determining all locations in a city from which a planned facility can be seen. This helps define whether a new vertically dominating architectural structure may appear in areas of strong spatial values. This helps foresee potential changes in the skyline of a city.

II. Application of isovist for urban study

II.1 Isovist theory

Visibility analysis allow us to apply mathematical certainty to the experience of urban and building environments (Turner, 2003, p. 657). Many attempts to use isovist in architectural and urban analysis have taken place. Since Benedikt (1979), isovists have been an active field of research. A number of authors have suggested techniques to calculate isovists, describe their shape, thus gaining insights into urban morphology. Isovist is usually defined as the field of view, available from a specific point of view. An isovist can also be understood as the area not in shadow cast from a point light source. In general, the isovist is a closed 2D polygon (Morello and Ratti, 2009, p. 839). In Space Syntax theory, isovist is the sum of the infinite number of lines-of-sight (or axial lines) that pass through a single point in space (usually at eye height) and that occupy the same plane (usually parallel to the ground plane) (Conroy Dalton and Bafna, 2003).

The possibility of applying the isovist software can be broad and cover a number of research areas. For the majority of potential applications, reducing the simulation to two dimensions only is sufficient. However, visual analyses of tall buildings requires introducing an isovist in its full form of a 3D space. A 3D isovist defines the 3D field of view, which can be seen from a vantage point with a circular rotation of 360 degrees and from the ground to the sky. Adding the vertical dimension helps to better simulate the physical environment observed from the vantage point (Morello and Ratti, 2009). Yin (2013) in his doctoral thesis summarized the limitations of 2D and 3D visibility calculations. Suleiman et al. (2013) explored ways of calculation 3D visibility and introduce a new algorithm based on vector GIS data. At the 3D level, the structure of a city is more complex. Therefore, 3D isovist in a given point of a city opens a wider space for potential analyses. It includes for example visible parts of the area (depending on topography), visible sections of facades and roofs.

II.2 Isovist 3D and tall building impact

The literature includes a number of examples of practical isovist application (Łubczonek, 2008; Moser et al. 2010;Pal Singh et al. 2013). However, there fewer examples referring to visual aspect of high development. Van der Hoeven and Nijhuis (2012a,b; 2011) describe analysis of the visual impact of Rotterdam's and Hague's buildings on the open landscape by means of GIS. They describe two aspects of visual information: visual coverage and cumulative visibility, which represents the intensity, or amount of high buildings in the skyline of the city. Yamano and Yoshikawa (2005) refer to studying visibility and visual size of a tall building. Another example is the study of tall buildings performerance for Helsinki (*Korkea Rakentaminen*, 2011). Isovist was used to examine the visual impact of tall buildings, with particular emphasis on the exposition above the Gulf of Finland. The professional experience of the authors also confirms applicability of the isovist for analyzing tall buildings. The method was used several times for studies on city landscape. Major observations refer to increase of the impact area of a building with the increase in its height. The observations enabled formulating objectives of the method described in the article as the Visual Impact Size (VIS).

III. Visual Impact Size (VIS) method

III.1 VIS assumptions and computation rules

The method aims at showing a total impact of a tall building in a city. This leads to developing a single visual impact map (VIS) which facilitates the interpretation of results and their application in planning. A novelty of the method is imaging of not only real visual impact range but also imaging of the impact power (expressed in intensity of color used). Relevant number and height of thresholds, depending on a specific nature of a city, are crucial for the quality of results. If the number of thresholds is too large, the result is not legible. Usually seven thresholds are assumed (20, 40, 50, 60, 80, 100, 150 and 200 m) for which the analysis are performed. Computer simulation produces a map with all locations from which the planned building can be seen. Colors used in the map reflect the strength of exposition of a planned building in space. It is the most visible from areas marked red according to the chart (Fig. 1b). The impact area can be presented in a projection and in two axonometric or perspective views (Fig. 1c, d). The VIS simulation reflects a real impact of the building in a city landscape.

The sequence below (fig. 1d) enables examining how particular 3D isovists change depending on the location of a tall building against the analyzed urban structure. Based on examples of the urban fabric we may draw general conclusions concerning the exposition of tall buildings in a city. It is possible to examine the change of the visibility area depending on different heights and locations of a building. We can also observe relations between the location and shape of the visibility area. Relations with the urban composition become clear. As a result, terms such as street axes, shapes and size of squares, visibility foreground gain new meanings in relation to the exposition of a tall building.

III.2 Application of the VIS method in planning

The application of the VIS method can be observed using the example of a real city space – e.g. part of Frankfurt center. The city has its individual landscape where tall buildings prevail (Fig. 1e, f). The study examines a location situated at one of squares in the middle of dense structure of streets based on a historical grid in the immediate neighborhood of a tall buildings cluster. The analysis indicates location of strong exposition (Fig. 1e). Usually, the result is limited to the examination of public space, understood as all undeveloped sites in a city. Simulation, however, may include examining of tall building visibility from other buildings and all predefined geometrical elements of the 3D city model. In this particular case of the Frankfurt old town, these include adjacent axes of streets lead towards the building. Along the river of Main, visibility of the building is excellent, since the building is exposed from 40 m in height. Provided there are limitations to the development of the city skyline from the side of the river, the above analysis could help determining the maximum permitted height of buildings at the square. The major advantage of this method is that it determines all locations of visual exposition of a building in a city, which is crucial for determining planning guidelines.

The analysis of Frankfurt was developed using the computer program developed by the authors (C++). Input material included a CityGML model of a city with precision of LoD2 imaging (with geometry of roofs

– Fig. 1f). VIS simulations can be performed using conventional GIS software and available tools. Differences apply to the precision of simulations. The algorithm used in the program developed by the authors emulated VIS maps using a vector model of a city as a basis. GIS tools such as ArcGIS (with 3D Analyst application) by ESRI use the Digital Surface Model, which reflects the geometry of a city in a simplified manner. The precision of imaging of the model is important in the case of analyzing a complex geometry of buildings comprising historical skylines of European cities. They contain a number of tower like elements. Neglecting them may distort results of the analyses and impede their interpretation in urban planning. However, analyses based on DSM models are frequently the only solution possible (in case CityGML model is not available). In such a case, results of the VIS analyses depend on the precision of the model. The larger the number of measured points per meter in DSM model, the better simulation results achieved. The advantage of DSM, however, is the possibility of examining large sections of a city and reduced cost of data acquisition. This has been described more extensively in other publications (Czyńska, 2015).

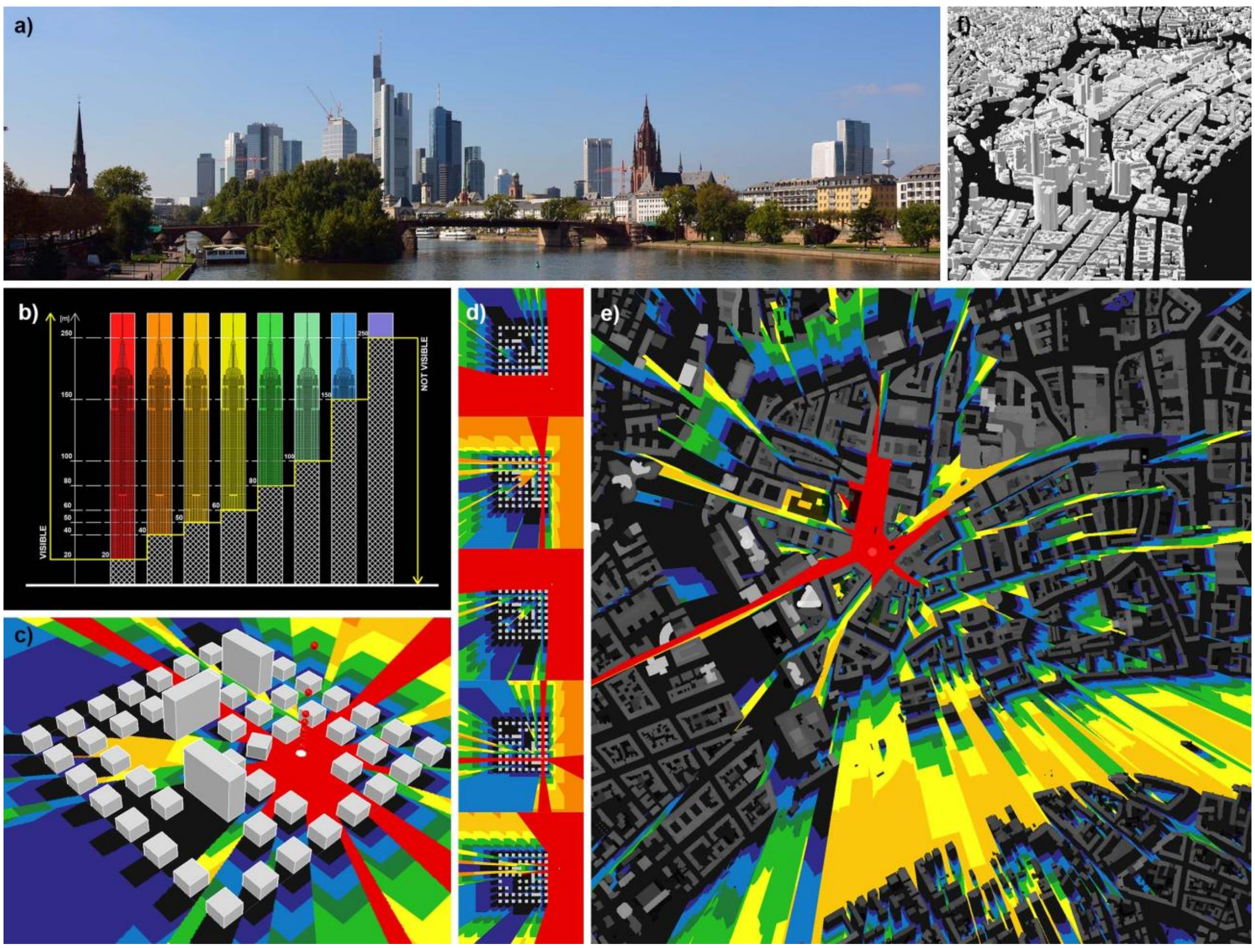

Fig. 1. a) Panoramic view of Frankfurt from the river side; b) interpretation of colors used in VIS method; c) VIS analysis for a schematic build-up development model; d) simulation for 5 different locations of building; e) VIS analysis for location of tall building in old town area of Frankfurt; f) CityGML model of Frankfurt

Source: All figures by authors

In the professional practice of the authors, the VIS method proved to be particularly useful (Czyńska, 2009). It was used in 2007 to verify potential locations of tall buildings in Szczecin, Poland. The studies were implemented under a contract with the local government (Czyńska et al., 2007). The studies analyzed in total 10 potential investment projects. The aim was to determine the impact of planned facilities on the city landscape while taking into consideration cultural values and also define detailed guidelines concerning their height and form. Yet another example of the application of methods is the "Impact study of the new library in seminar gardens" developed in 2015 (Marzęcki et al., 2015). It aimed at determining rules for new buildings height in historical skyline of Warsaw.

IV. Conclusions

Developing tall buildings in European cities is controversial and generates strong emotions. There are probably as many supporters as there are those who are skeptical to such a development. To bring the discussion to the level of objective and measureable arguments it is necessary to develop tools that enable analyzing the phenomenon at its geometrical level. In other words, analyzing it in an objective manner to the extent possible so the result achieved is not debatable. In many instances the negative impact of tall buildings on the city landscape is the result of mistakes in the planning process, disregarding of important views in analyses, etc. Although a realistic visualization of a new investment project has become a standard element of the architectural design process, a reverse action which involves determining all locations in a city from which a building can be seen is a larger challenge. The use of the isovist theory enables examining such relations.

The VIS method, outlined in the article, is a proposal for imaging of the tall building impact on the landscape of a city. On the one hand, the objectives of the method resulted from research by the authors, and on the other, they are the result of their professional experience from developing guidelines for potential tall buildings (where the method was applied). An important part of VIS is to visualize the impact of a tall building. With the increase in accessibility and precision of digital 3D city models, the possibilities for using the method in real urban planning increase as well. The simulations presented in the article were developed using a special computer program developed by the authors, dedicated to analyzing CityGML models. However, it is possible to generate approximate VIS using DSM models and LiDAR data (LAS). It is also possible to simulate approximate VIS results by using different GIS programs. The main limitation and challenge is the size of data to be processed, which is applicable mainly to large cities. The VIS analysis should cover the entire space of a city and sometimes also its wider landscape context.

Acknowledgments

The article was prepared within the research project 2TaLL: *Application of 3D Virtual City Models in Urban Analyses of Tall Buildings*, funded by a Norwegian Financing Mechanism. Digital model of Frankfurt provided by Stadtvermessungsamt Frankfurt am Main. We gratefully acknowledge this support.

References

[1] Benedikt, M. L. (1979). To take hold of space: isovist fields, In Environment and Planning B: Planning and Design 6: 47-65.

[2] Conroy Dalton, R., Bafna, S. (2003). The syntactical image of the city: a reciprocal definition of spatial syntaxes, In Hanson, J. (ed.), Proceedings of the Fourth International Space Syntax Symposium. London: University College London, 59.1-59.22.

[3] Czyńska, K. (2015). Application of Lidar Data and 3D-City Models in Visual Impact Simulations of Tall Buildings. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XL-7/W3. Berlin: 36th International Symposium on Remote Sensing of Environment, 1359-1366. doi:10.5194/isprsarchives-XL-7-W3-1359-2015.

[4] Czyńska, K. (2009). Can tall buildings enrich the beauty of the city? Proceedings of international conference Urban Landscape Renewal. Gliwice, 401-409.

[5] Czyńska, K., Marzęcki, W., Rubinowicz, P. (2007). Analyses of visual impact and definition of spatial guidelines for high buildings in Szczecin. Urban Study commissioned by Department of Spatial Planning, City of Szczecin.

[6] Korkea Rakentaminen Helsingissä (2011). Kaupunkimittausosasto. Helsinki, ISSN 1235-4104

[7] Marzęcki, W., Czyńska, K., Rubinowicz, P., Zwoliński A. (2015). Impact study of the new library in seminar gardens in Warsaw. Urban study commissioned by Warsaw Archbishop.

[8] Morello, E., Ratti, C. (2009). A digital image of the city: 3D isovists in Lynch's urban analysis. Environment and Planning B: Planning and Design 36(5), 837-853.

[9] Rubinowicz, P., Czyńska, K. (2015). Study of City Landscape Heritage Using Lidar Data and 3D-City Models. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XL-7/W3. Berlin: 36th International Symposium on Remote Sensing of Environment, 1395-1402. doi:10.5194/isprsarchives-XL-7-W3-1395-2015.

[10] Suleiman, W., Joliveau, T., Favier, E. (2013). A New Algorithm for 3D Isovist. Proceedings of 15th International Symposium on Spatial Data Handling Geospatial dynamics, geosimulation and exploratory visualization, Bonn, 157-173.

[11] Van der Hoeven, F., Nijhuis, S. (2012a). Developing Rotterdam's Skyline. CTBUH Journal Issue II, 32-36.

[12] Van der Hoeven, F., Nijhuis, S. (2012b). Planning and Visibility Assessment of High Building Development in The Hague. In Meyer, H., and Zandbelt D. (eds.), High-Rise and the Sustainable City, Techne Press, 102-119.

[13] Van der Hoeven, F., Nijhuis, S. (2011). Hi Rise, I can see you! Planning and visibility assessment of high building development in Rotterdam. Research in Urbanism Series. Vol. 2, 277-301.

[14] Yamano, T., Yoshikawa, S. (2005). Cityscape analysis and simulation with three-dimensional urban model. Proceedings of the 9th International Conference on Computers in Urban Planning and Urban Management (CUPUM2005). London: University College of London, 1-14.

[15] Yin, J. (2013). Mobile 2D and 3D Spatial Query Techniques for the Geospatial Web. Doctoral Thesis, Dublin Institute of Technology.

[16] Zwolinski, A., Jarzemski, M. (2015). Computing and monitoring potential of public spaces by shading analysis using 3D LiDAR data and advanced image analysis. International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XL-7/W3. Berlin: 36th International Symposium on Remote Sensing of Environment, 743-750. doi:10.5194/isprsarchives-XL-7-W3-743-2015.