Development of a Simplified Computerized Tool to Measure the Visibility of Open Spaces

Rim Meziani, Mohammed Ghazal, and Hassan Hajjdiab

Abstract

The objective of this research is to create a simple computerized tool to measure the visibility of open spaces by testing different scenarios and building arrangements and comparing their visibility graphs to be created by applying Gaussian theory. Two building arrangements were proposed on a site selected from the Abu Dhabi 2030 master plan. One building arrangement is based on a linear form of buildings (scenario1) and the other one on L-shape (scenario 2). The two scenarios were tested and the visibility of open space was studied according to the horizontal distance, and the angle of view, which is limited by the edges of the window. The simulation results showed that scenario 2 offers more visibility. This confirmed what was already measured by the author in previous research by using a manual approach. This tool will be more developed in the future to include building height, consider recessed windows, etc.

R. Meziani (Corresponding author) • M. Ghazal • H. Hajjdiab
Abu Dhabi University, Abu Dhabi, P. O. Box 59911, UAE
Email: rim.meziani@adu.ac.ae

M. Ghazal
Email: mohammed.ghazal@adu.ac.ae

H. Hajjdiab
Email: hassan.hajjdiab@adu.ac.ae

1. Introduction

The existence of open spaces in our life in general and in cities in particular is very important for the health and wellbeing of the human and the community (Ulrich et al., 1991) and also of the ecosystem. Studies have demonstrated the good effect of windows and good views, especially of nature on people's recovery after surgery (Ulrich, 1984) improvement of their psychological life and mood but also the satisfaction of an area by the residents (Hideotoshi, 1995). In addition to the environmental benefit of open spaces such as providing light, fresh air, balance of ecosystem, etc., open spaces represent a space for social interaction among the community, a place for exercising, playing, gathering and refreshing. So, viewing open spaces would not only positively affect the society and the environment but also the economy. Studies demonstrated that buildings having view on open space would increase their attractiveness in a matter of buyers and renters and would bring more value to the real estate market. Hence our interest to study the relationship between the buildings arrangement and the visibility of open space.

Planning support systems facilitate the understanding of the urban systems and their interaction to store, analyze and view data in order to assess policy choices and future conditions, to identify issues, create visions, formulate goals, and compare scenarios. Hence using technologies such as analytical models, visualization and communication programs, internet and GIS provide the planning and the strategic decision with information support to be more intelligent and community-oriented process. Visual thinking in particular becomes a very important mode of thought that may change people's view of their environment in order to improve it. Furthermore, the planning support systems enable the planners to help the public and decision makers to make better choices and take smarter decisions after visualizing the different scenarios of urban development and forecasting their results and the implication of their interventions by running simulations and building models (Berke et al., 2006); (Riddell, 2003). From here comes our interest in visualization and urban modeling.

This paper aims to develop a simplified user-friendly computerized tool to measure the visibility of open spaces from each building surrounding the open space. In this paper we refer to green area or park as an open space. Two building arrangements will be used as scenarios to be tested by using the proposed tool and a comparison between the visibility graphs produced after simulation by using Gaussian theory will be done allowing us to find out which buildings arrangement offers more visible area of the open space.

This area will be measured in an accurate way leaving not doubt about personal judgement while observing the visibility graphs. The paper will describe the tool then explains its application and presents the simulation results before going to the conclusion.

But before that, it is important to note that visibility has been studies in different ways and been analyzed by using different tools and approaches. Probably the most known visibility studies of outdoor areas at the urban scale are associated with space syntax theory by UCL (Hillier, 2005) in which visibility graphs produced by Depthmap software (Turner, 2004) are represented by different colors to represent values of high or low visibility linked to accessibility by using Isovist, local and global integration values, etc. (Turner, 2001).

Sometime visibility was associated to natural and artificial surveillance of both indoor and outdoor spaces by using of GIS, more precisely the use of Isovist Analyst done by ArcView software. An automated technique called Rank and Overlap Elimination (ROPE) made possible the study of the visibility of open spaces through their visual coverage (Rana, 2005).

GIS has been often used to assess the visibility through Viewshed to analyze the visual effect of terrain maps. Viewshed can be defined as the environment points that an observer can see; regardless of its many limitations when it comes to measuring the visibility from a human perspective, since it is linked to the vertical dimension such as the slope of the terrain, its elevation and the distance from the observation point (Nutsford et al., 2015).

Viewshed like other visibility analyses were not originally designed to measure the visibility that is human-centered in landscape planning. Assessing visibility shall be related to aspect of vision and perception, hence by quantifying the effect of slope, aspect, and the distance between the observer to the related area (Chamberley et al., 2013). So, Viweshed analysis is often related to a visibility of “non-flat terrain”.

GIS tools applied to capture the vision field have been used in security, wireless network design, landscape, etc. (Suleiman et al., 2015). For example, in (Eve and Enrico, 2014) Viewshed with traditional topographic variables were used to investigate the visual properties of different parts of landscape both cultural and natural. Furthermore, in (Suleiman et al., 2015), the authors tried to arrange the buildings in a development area to have the best view to the landscape and open space by studying the visibility to these spaces. The paper also tries to answer the question about the best location in a city for a publicity panel or a shop from the visibility viewpoint.

Using Algorithm visibility was also used in (Oren and Yerach, 2012) that studied the structure and disposition of the urban building blocks represented by mass model shops. Furthermore, the visibility analysis of an urban environment by using 3D models was studied using the Spatial Openess Index in (Fisher, 2012); (Fisher-Gewirtzman and Wagner, 2003); (Fisher-Gewirtzman, 2003), which is considered by us as the closest study to our research.

This computerized tool measures the quantity of the open space viewed from different buildings around it considering that the viewer is standing in the center of the building only, which is in our understanding unrealistic, hence in our viewpoint represents the weakness of this study. Because, the measurement of the visible area would be more realistic and accurate if the viewer's location was considered in each window of each building facing the open space, since the building does not have one window only. Here comes the advantage of our tool, its flexibility to give the user the possibility to decide about the windows number, locations and measurements and change the viewer's locations each time the simulation is run. The other flexibility of our tool is represented in the input data. The user can enter any image and not necessarily a drawing file of 3dimensional model. Further explanation is included in the methodology section.

2. Site Selection and Building Arrangement

According to the 2030 vision of Abu Dhabi, the Abu Dhabi Master Plan 2030 is the UAE government's vision to establish Abu Dhabi as an international capital city and is based on sustainable development principles that are related to the wellbeing of the community, the protection of the environment and the development of the economy (Urban Planning Council, 2007). The creation of a sustainable livable urban environment and guarantee a balance between the mixed cultures existing in the cities with the preservation of the cultural character and traditions of Abu Dhabi as an Emirati and Arab city is one of the main objectives of the master plan. Hence, maximizing the use of the open spaces, by increasing walkability and encouraging social interaction, increasing the land use around them, creating a micro-climate, improving the physical as well as psychological health of people, creation of quality urban life, etc. are key factors to achieve a sustainable urban life. So, maximizing the visibility to open spaces would contribute to the execution of these factors, as mentioned in the introduction and literature review section.

To make sure that the research is more realistic, we selected a site located in the south spine precinct of the Capital district in the Abu Dhabi 2030 master plan (Fig1). Since the site has not been built up yet, this makes our proposals for the building arrangements more credible to be applied later on after running the simulation. Our intention is to approach the Urban Planning Council to give recommendations in this regard and to encourage them to use this tool in the phase of urban design and broadcast it to other entities.

Let us note here the actual arrangement of buildings was not proposed in the 2030 master plan of Abu Dhabi and the more detailed design guidelines and orientation were left to be considered in the urban design phase. So, developing such a tool in our research would be of a great help to architects, urban designers and even decision makers. The study area has one open space that is considered green area surrounded by buildings of a maximum 30meters of height (Fig. 2) and a high density residential land use, the setback decided by the master plan was respected and in future research, the building height will be considered as well.

Fig. 1 . *Left*: Building height map of the Capital District, Abu Dhabi 2030 master plan (white circle shows the location of the study). *Right*: Location of the study magnified.

Two building arrangements were studied based on basic building form, a linear one (Fig.3) and an L-shape one (Fig.4). The distances between buildings, the privacy, the size of the plots, and the exposure of the buildings to the open spaces by maximizing the length of the building facades were considered. More building arrangements and complex building forms will be tested in the future.

The proposals were drawn to scale, respecting the real dimensions by using AutoCAd, and then imported as a picture to the tool. Since the land use proposed in the 2030 master plan is a high density residential, the L-shape based arrangement will create more indoor areas that would emphasize the social interaction among the community, and proposed to face as much as possible the open space in order to maximum its visibility.

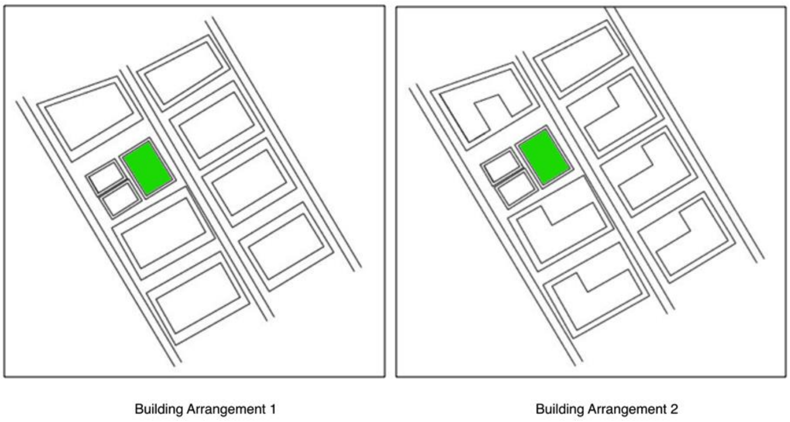

Fig. 2 Linear and L-shaped building arrangements studied.

3. Methodology

3.1 Description of the Proposed Tool

The tool is user-friendly somehow like any CAD tool (Fig.5) that can be used easily by students or professionals. Any building arrangements were drawn in CAD then converted to a picture format and inserted into the tool with an identification of the center points of the windows. Let us note that the developed tool accepts any picture format even not previously drawn by CAD packages. The number of buildings or open spaces is not limited, as well as the number of windows from which the visibility is to be assessed, hence the importance of this tool.

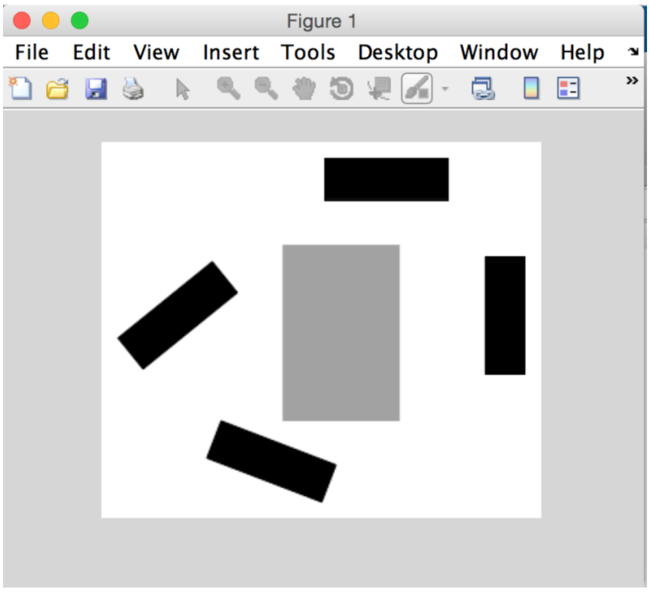

Fig. Configuration of the tool.

The number of windows and their dimensions shall be decided prior to the location of their center points. The buildings and the open spaces have to be drawn in a single line border and two colors are to be used to distinguish the open space by grey and the building by black. The drawing has to be kept simple and supports only the borders of the building form and the open space, without road, etc.

The user then clicks on these points by using the tool (Fig.6), the visibility graph (Fig.7) is calculated based on a Gaussian distribution model (Simon, 2007).

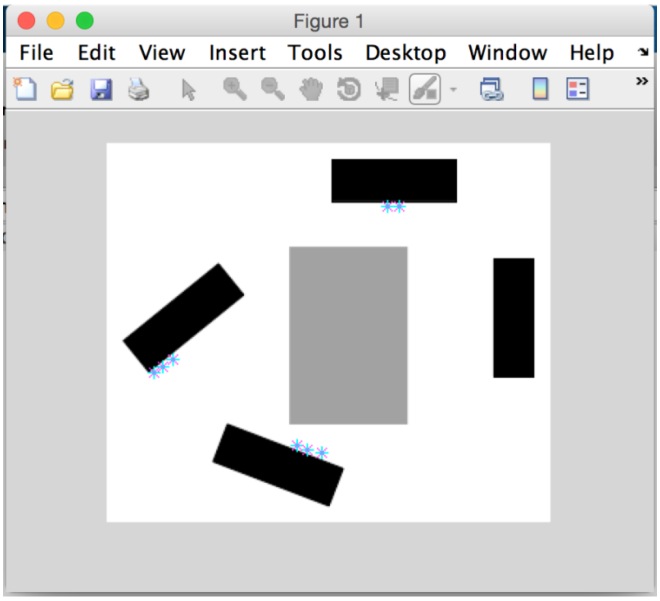

Fig. Location of the windows (represented by X) by using the tool.

Fig.7 shows the visibility graph of the input configuration defined in Figure 2. A degree of one color is shown to express the degrees of visibility from high to low. The brighter the color the higher is the visibility.

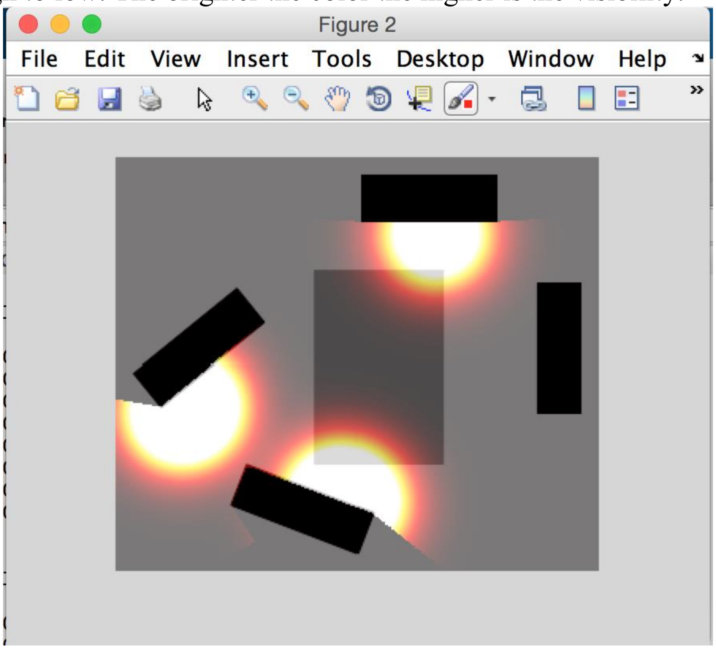

Fig. Visibility Graph.

Where x and y represent the spatial dimensions, and σ represent the standard deviation of the distribution.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

The Gaussian distribution is widely used in the area of signal processing (Gonzalez, 2009) to model and filter random noise. Gaussian distribution is also used to model human physical properties (such as height and weight) and financial and social behavior (Shiryaev and Kruzhilin, 1999); (Shen et al., 2012) In this paper we model the visibility preference of human observers using a Gaussian model. In this paper our observer-space model is demonstrated in Fig.8. The parameters that influence the model are the distance (d) from the observer to the center of the Gaussian, the angle of view (α) of the observe in addition to the standard deviation (σ) of the Gaussian distribution. All of the parameters d, α and σ are defined based on the user preference. Our proposed algorithm starts by shooting rays from the observer to the viewed space. Each point in the space is given a score based on the Gaussian model defined by parameters d, α and σ.

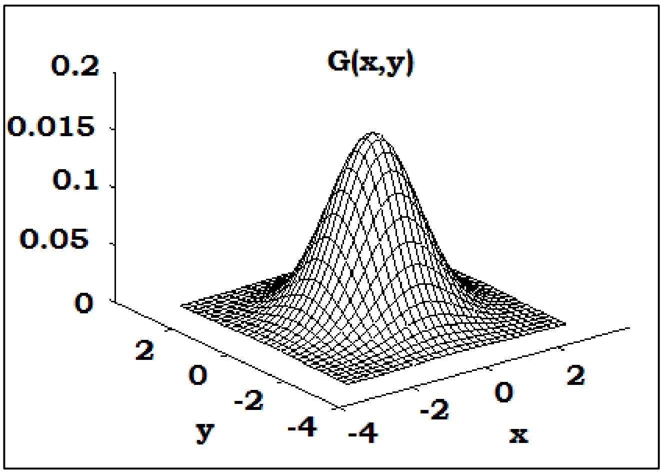

Fig. The Gaussian distribution of mean=0 and standard deviation of 1.

The process is repeated for all observers. Finally the accumulated score for the space points are displayed (Fig.9).

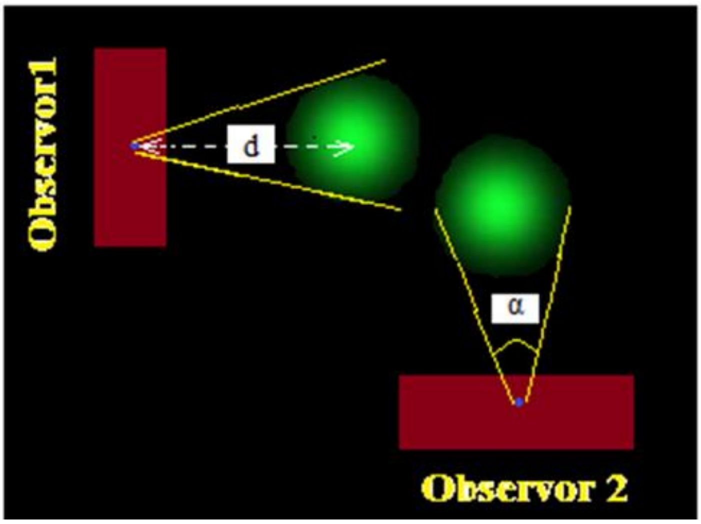

Fig. Our observer space model.

3.2 Application of the Proposed Tool

The tool was applied to run two simulations to assess the visibility of building arrangement 1 (simulation 1) and building arrangement 2 (simulation 2) explained in section4 (Fig.10 and Fig.11) taking into consideration: 1-the viewer's location is the center of each window located on the building floor, 2- all the floors have a similar windows layout decided by the program's user before running the simulation.

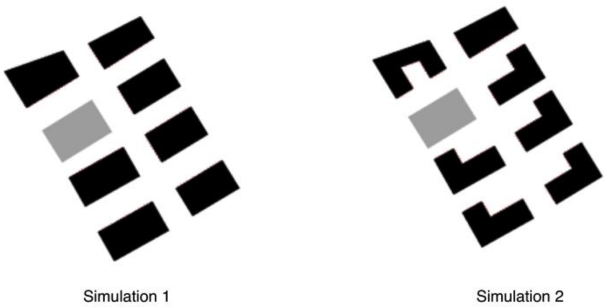

Fig. Simulations.

The resulting graphs (Fig.12 and Fig.13) show the visibility of all the outdoor areas including the open space. It is seen that the open space is more visible in the arrangement 2.

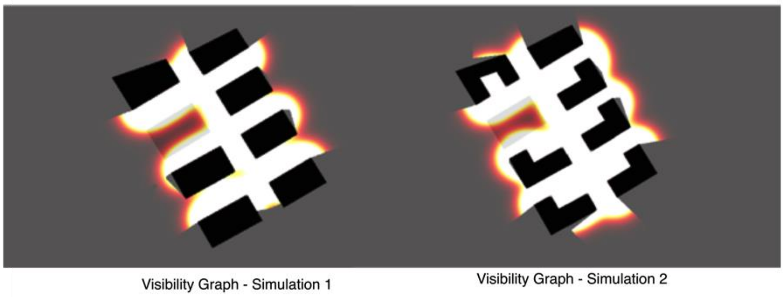

Fig. Simulation Results.

Furthermore, this tool allows us to assess the visible area by multiplying the % of pixels by the original area of the open space. For building arrangement 1: Fig.14 represents a number of white pixels of 9477 out of a possible 17066 in the open area, making a percentage of 55.53, approximately 55.5%. The original area of the open space is: 1703 square meters

The visible area represents = 55.5%x 1703 square meters = 945.165 square meters, approximately 945 square meters. For building arrangement 2: Fig.15 represents a number of white pixels of 9655 out of a possible 17066 in the open area, making a percentage of 56.57 approximately 56.6%.The original area of the open space is: 1703 square meters. The visible area represents = 56.6%x 1703 square meters = 963.896 square meters, approximately 963.9 square meters.

Fig. The visible area of the open space Simulation 1.

As a conclusion we confirm that the building arrangement 2 based on the L-shape provides more visibility of the open space. This verifies also the research study done before when the assessment was done manually without using the digital tool. In addition to this, L-shape based arrangement provides more outdoor areas that enhance the social life in particular in the residential land use.

4. Conclusion and future work

This research aimed to develop a user- friendly tool to allow students and professional to assess the visibility of open space while proposing a certain building arrangement. By using simulation, visibility graph is produced and measurement of the visible area of outdoor spaces can be done. Our interest is the visibility of open space in order to compare accurately between different scenarios of building arrangements. Using this tool in the urban design and urban planning is very much helpful and useful especially when it comes to provide a quality of urban life to the community.

Although our research methodology could be applied to any site in different situations, it remains simple and interesting. It can be applied in general, with a change of the building form by professionals, architecture and urban design students and even non-professionals, who are not necessarily familiar with Computer Aided Design programs (CAD), hence the importance of this research.

Further research would consider the building height and number of floors, and would study the effect of the recessed windows on the visibility. A variety of building forms and building arrangements will be considered in the study.

References

Archea, John. 'The Place Of Architectural Factors In Behavioral Theories Of Privacy'. *Journal of Social Issues* 33.3 (1977): 116--137. Print

Chamberlain, Brent C., and Michael J. Meitner. 'A Route-Based Visibility Analysis For Landscape Management'. *Landscape and Urban Planning* 111 (2013): 13-24. Web. 19 May 2015.

Council, Abu Dhabi Urban Planning. 'Plan Abu Dhabi 2030: Urban Structure Framework Plan'. *Abu Dhabi, UAE* (2007).

Eve, Stuart J., and Enrico R. Crema. 'A House With A View? Multi-Model Inference, Visibility Fields, And Point Process Analysis Of A Bronze Age Settlement On Leskernick Hill (Cornwall, UK)'. *Journal of Archaeological Science* 43 (2014): 267-277. Web. 19 May 2015.

Farr, D. (2012). *Sustainable urbanism: urban design with nature*. John Wiley & Sons.

Fisher-Gewirtzman, D. '3D Models As A Platform For Urban Analysis And Studies On Human Perception Of Space'. *Usage, Usability, and Utility of 3D City Models " European COST Action TU0801* (2012): n. pag. Web. 19 May 2015.

Fisher-Gewirtzman, D., and A. Natapov. 'Different Approaches Of Visibility Analyses Applied On Hilly Urban Environment'. *Surv. Rev.* 46.338 (2014): 366-382. Web. 19 May 2015.

Fisher-Gewirtzman, Dafna, and Israel A Wagner. 'Spatial Openness As A Practical Metric For Evaluating Built-Up Environments'. *Environment and Planning B* 30.1 (2003): 37--50. Print.

Fisher-Gewirtzman, Dafna, and Israel A Wagner. 'Spatial Openness As A Practical Metric For Evaluating Built-Up Environments'. *Environment and Planning B* 30.1 (2003): 37--50. Print.

Gibson, J. J. (2013). *The ecological approach to visual perception*. Psychology Press.

Gibson, J. J. (1950). The perception of the visual world.

Gonzalez, R. C. (2009). *Digital image processing*. Pearson Education India.

Hideotoshi, W, K Akio, and N Takashi. 'A Study On The Relation Of Resident Evaluation Of Waterfront Area And Living Environment'. *Journal of Architecture Planning and Environmental Engineering* (1995): n. pag. Print.

Hillier, Bill. 'The Art Of Place And The Science Of Space'. *World Architecture* 185 (2005): 96--102. Print.

Meziani, Rim, and N Saif. 'Visibility And Climatic Analysis Of The Capital District In Abu Dhabi Master Plan 2030'. *New Urban Configurations: International Seminar On Urban Form (ISUF)*. Amsterdam, Netherlands: N.p., 2012. 603-609. Print.

MEZIANI, RIM, and Toshiyuki Kaneda. 'Toward Further Application Of Visibility Analysis In The Case Of Ghardaia'. 2007. Print.

Meziani, Rim. ', The Study Of The Relationships Between Building Arrangements And Climatic Comfort'. *International Journal of Chemical, Environmental & Biological Sciences* 2.2 (2014): 98-104. Print.

Meziani, R. *Visibility Analysis of the Capital District in the 2030 Master Plan of Abu Dhabi*. Cavallo, R., Komossa, S., & Marzot, N. (Eds.). (2014). *New Urban Configurations*. IOS Press. 1071--1079. Print.

Newell, Patricia Brierley. 'Perspectives On Privacy'. *Journal of environmental psychology* 15.2 (1995): 87--104. Print.

Nijhuis, Steffen. 'GIS-Based Landscape Design Research: Exploring Aspects Of Visibility In Landscape Architectonic Compositions'. *GeoJournal Library* (2014): 193-217. Web. 19 May 2015.

Nutsford, Daniel et al. 'Personalising The Viewshed: Visibility Analysis From The Human Perspective'. *Applied Geography* 62 (2015): 1-7. Web. 19 May 2015.

Rana, Sanjay. 'Use Of GIS For Planning Visual Surveillance Installations'.

ESRI (on CD-ROM) (2005): n. pag. Print.

Ruzickova, Katerina. 'THE INFLUENCE OF OBSERVER LINE GEOMETRY ON RESULTS OF VISIBILITY ANALYSIS'. *SGEM2012 12th International Multidisciplinary Scientific GeoConference* (2012): n. pag. Web. 19 May 2015.

Shach-Pinsly, Dalit, Dafna Fisher-Gewirtzman, and Michael Burt. 'Visual Exposure And Visual Openness: An Integrated Approach And Comparative Evaluation'. *Journal of Urban Design* 16.02 (2011): 233--256. Print.

Shen, Yelong et al. 'Socialized Gaussian Process Model For Human Behavior Prediction In A Health Social Network.'. 2012. 1110--1115. Print.

Shiryaev, AN. 'Essentials Of Stochastic Finance. Facts. Models'. *Ðœ.: Phasis* (1998): n. pag. Print.

Simon, Marvin K. *Probability Distributions Involving Gaussian Random Variables: A Handbook For Engineers And Scientists*. 2007. Print.

Suleiman, Wassim, Thierry Joliveau, and Eric Favier. 'A New Algorithm For 3D Isovists'. *Advances in Geographic Information Science* (2012): 157-173. Web. 19 May 2015.

Turner, Alasdair. 'Angular Analysis'. 2001. 30--1. Print.

Turner, Alasdair. 'Depthmap 4: A Researcher's Handbook'. *Bartlett School of Graduate Studies, University College London* (2004): n. pag. Print.

Ulrich, Roger S et al. 'Stress Recovery During Exposure To Natural And Urban Environments'. *Journal of environmental psychology* 11.3 (1991): 201--230. Print.

Ulrich, Roger. 'View Through A Window May Influence Recovery'. *Science* 224.4647 (1984): 224--225. Print.

Weitkamp, Gerd et al. 'Three Sampling Methods For Visibility Measures Of Landscape Perception'. *Springer* (2007): 268--284. Print.

Berke, P., & Kaiser, E. J. (2006). *Urban land use planning*. University of Illinois Press.

Riddell, R. (2008). *Sustainable urban planning: tipping the balance*. John Wiley & Sons.