APPLICATION OF 3D VIRTUAL CITY MODELS IN URBAN ANALYSES OF TALL BUILDINGS – TODAY PRACTICE AND FUTURE CHALLENGES

Klara Czyńska[1], Paweł Rubinowicz[2]

West Pomeranian University of Technology, Faculty of Civil Engineering and Architecture, 50 Piastów Ave, 70-311 Szczecin, Poland
[1]E-mail: kczynska@zut.edu.pl
[2]E-mail: pawel@rubinowicz.com.pl

Abstract
The complex geometry of the city structure and the increasing speed of ongoing urban transformations in large European cities, requires powerful tools for the analysis, design and management. Virtual 3D city models can be an important tool in urban planning, used to diagnose phenomena produced by tall buildings. In recent years, the issue has become a considerable challenge for the cohesion of the European urban landscape. This paper presents foundations of a research project under Polish-Norwegian financing mechanism called 2TaLL. The project examines possibilities and limitations of using virtual 3D models of cities to provide advanced urban analyses focused on simulating impact tall buildings have on landscapes of European cities. The research is an interdisciplinary combination of geo-information and urban planning and contributes to the development of theory & applications in the two fields of engineering science.

Keywords: 3D virtual city models; 3D analysis; tall buildings; city complexity; urban planning

1. TALL BUILDINGS PHENOMENA IN EUROPE

In contemporary Europe tall building phenomenon creates very up-to-date problem. It appears to be one of the most challenging issues in spatial planning. On our continent, many cities allowed tall buildings to be developed in their centers. The trend of building high is very strong in such historical cities as Milan, Vienna, Paris, Brussels and London, as well as Köln, Frankfurt and Amsterdam. The phenomenon has become quite common not only in the largest capital cities but also smaller towns with population below 500 thousand. This signifies a major ideological impact of tall buildings and global aspirations of those cities. Contrary to other continents, Europe has historically established spatial values which strongly contrast with tall buildings. Therefore, the planned height of buildings is subject of discussions, conflicts and controversies in each city. On the one hand, we attempt to maintain the climate and atmosphere of a city based on historical scale of buildings, habits among inhabitants, and conservation of existing buildings, and on the other, we tend to maximize investment return in valuable and important locations as well as interpretation of tall buildings as symbols contributing for creating a contemporary image of a city and prestige of its owners. However, tall buildings either clustered in one district or scattered within the city structure remain in strong contrast to historical buildings. Moreover, due to their scale and distinguished architectural form, tall buildings have strong visual impact. Therefore, in order to protect valuable urban and architectural development, their location in a city should be determined on the basis of prior in-depth analyses of impact tall buildings have on the urban landscape. In many instances, negative consequences of an inappropriate location of a tall building result from inability to foresee its spatial impact.

2. TALL BUILDINGS ANALYSIS VERSUS ANALOG URBAN PLANNING

Space in a number of European cities reveal planning errors in terms of locating tall buildings. An obvious and clear example of the above is Tour de

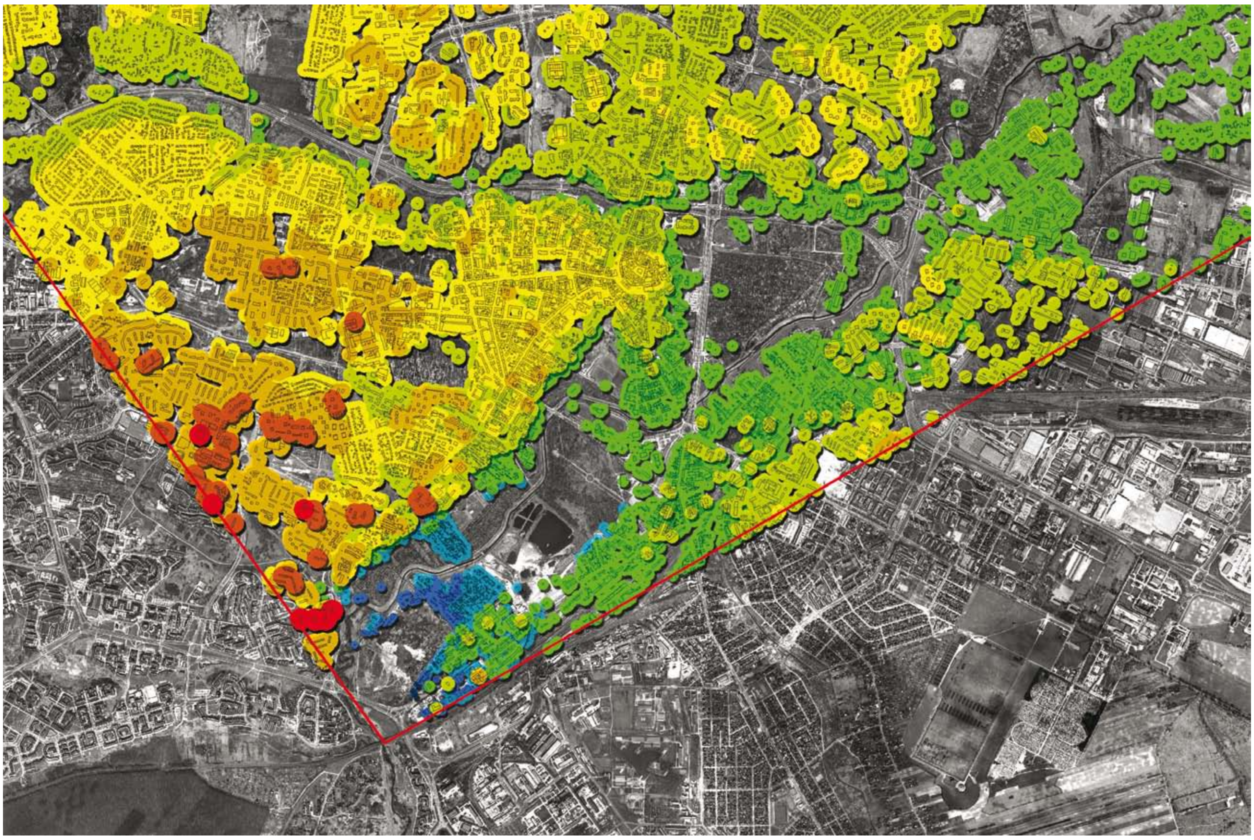

Fig. 1. Analysis of view angles for selected panoramas of Lublin (Poland) – angles characterize relationship between viewpoint and buildings in city (figure by author 2011)

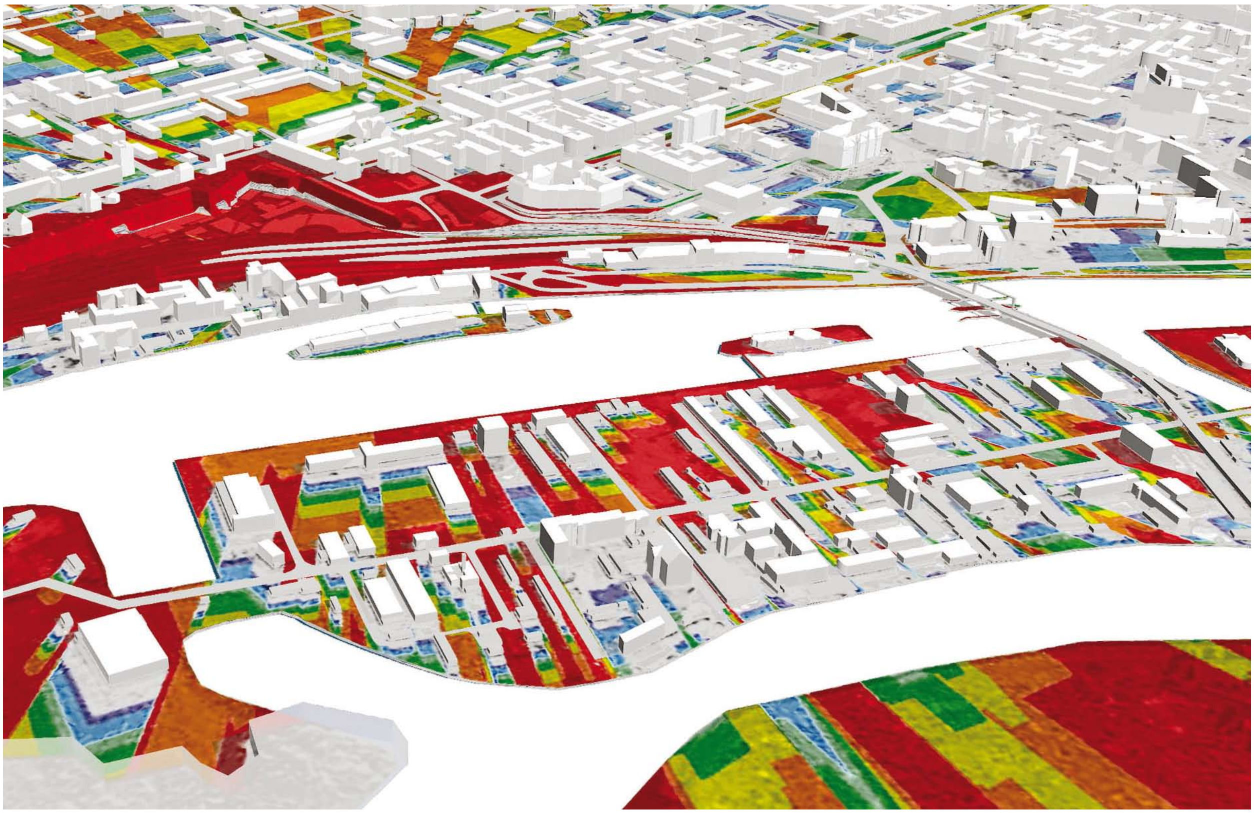

Fig. 2. Analysis of visual impact of tall buildings in Szczecin based of virtual 3D city model. Analysis illustrates in color form which height tall object is visible in space (figure by author 2014)

Montparnasse in Paris, built in the 70s of the 20th c., which distorted the axis of Champ-de-Mars seen from the foot of the Eiffel Tower. Unfortunately, such examples are many all over Europe and the same also applies to buildings erected recently. In the 20th c., when the first tall buildings were built, the tool kit of an urban planner was limited to traditional tools, such as sketches and individual cross sections. Professionals could resort to their experience and intuition only. Thus, a number of design errors were made. Contemporary computer-assisted tools and media provide for objective and thorough analysis and simulation of complex urban conditions. The examination of visual impact of tall buildings is complicated from a geometrical point of view. The use of computer-assisted techniques facilitates and expedites the process of defining guidelines for erecting tall buildings.

Several cities have developed methodologies to provide guidance for selecting locations of tall buildings. The system of supervision developed for the London landscape is in the forefront. A comprehensive system of assessing and selecting city views was developed supported with detailed description of advantages of the existing landscape which needs to be protected[1]. This is accompanied by a system of verifying planned tall buildings by simulating their impact in selected strategic views: London Panoramas, River Prospects, Townscape Views and Linear Views[2]. Computer aided techniques have also been used to develop guidelines for protecting landscapes of such cities as Warsaw[3], Ottawa[4] and Dusseldorf[5]. However, the virtual model of a city was used for simulating and visualizing guidelines rather than a research tool. The model can also become a basis for a very precise and objective analysis, extending far beyond simple drawing/visualizing of a concept. Effects of such a use of the model are frequently surprising and hardly predictable. Figure 1 and 2 are an example of such analysis results. The geometry of the areas of visual impact of a building and calculation of view angles for all buildings in a city could not be achieved by traditional drawing techniques.[6]

3. APPLICATION OF VIRTUAL CITY MODELS

The progress in geo-information research and related development of new techniques of visualization of urban landscape is extremely dynamic. The development of LIDAR techniques, aerial photograph processing techniques, new software solutions and general development of computer technologies enable automation and improvement in modelling of the built-up environment[7]. The majority of large European cities have their 3D virtual models already developed. The key issue for further development in the field was introducing recently of CityGML as an open standard for data recording[8]. The advancement in modelling techniques and visualization is ahead of their application. Virtual models of cities can be viewed on-line. They are used for developing infrastructure and services, commercial sector and marketing, promotion and collecting information about cities (e.g. promotion, tourism, visualizations for investors, etc.). To a certain extent, they are also used for selected specialist analyses (e.g. acoustic analysis, simulation of disasters and traffic management)[9]. To a lesser degree, virtual models are used directly in urban and spatial planning and related to them advanced urban analysis.

In recent years, we have seen the development of computer programs for optimizing and creating maps, obtaining and processing spatial information, etc.[10] Also developed are simple and intuitive applications for obtaining a simple map/visualization of the viewshed for a particular point in space. Google Earth Pro provides a tool to visualize the field in the 3D models available on the platform[11]. There are also a numerous applications that allow to calculate a single 2D isovist[12] (e.g. for AutoCAD). However, the advancement is not followed by theoretical knowledge which could indicate directions of their use by architects and urban planners. Computer simulation like an isovist map itself is not sufficient for the assessment of planning guidelines. The process of reaching a proper solution can be compared to the interpretation of an X-ray image by a medical doctor. It is one of elements helping in diagnosing of the disease.

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[4] Canada's Capital Views Protection…, Ottawa 2007.
[5] Hochhausentwicklung in Düsseldorf Rahmenplan. Düsseldorf 2004.
[6] K. Czyńska, Methods for determining contemporary silhouette of city…, Wrocław 2007, pp. 124-126, 134-138.
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[8] T. H. Kolbe, Representing and Exchanging 3D City Models with CityGML, pp. 15-31.
[9] S. Pal Singh, op.cit. p. 86.
[10] For example: AutoCAD Map 3D (Autodesk), ArcGIS (ESRI), MapInfo (Pitney Bowes).
[11] Option "Show viewshed" is available only in version of Google Earth Pro.
[12] A single isovist is the volume of space visible from a given point in space. M. Batty (2001), Exploring isovist fields..., pp. 123-125.

There is a need for developing a scientific approach, knowledge of the spatial structure of the city and adequate supply of expertise that enables a proper evaluation and interpretation of the resulting viewshed. It is necessary to develop theoretical knowledge in this field dedicated for urban planners.

3.1. Objectives of 2TaLL project.

Relevant research is carried out by the 2TaLL project (Application of 3D virtual city models in urban analyses of tall buildings) funded from Norway Grants. The project is implemented by a team of researchers called the Cyber Urban Center at the Department of Civil Engineering and Architecture at the West Pomeranian University of Technology.[13] The research is based on previous scientific and practical experience of the author. Some theoretical work was developed during preparing studies implemented by the author in Szczecin and Lublin and commissioned by the two cities. The studies focused on city space and tall buildings[14], and finding suitable locations for such buildings from the point of view of the city composition and defining specific parameters of tall buildings in Szczecin[15]. The study for Lublin focused on examining and defining principles for protecting city landscape values.[16] Each of the two studies involved using computer assisted techniques and a virtual city model. Each time, the set of tools was adjusted to specific research needs. The experience was described in the doctoral thesis of the author[17] and other publications[18]. A typical basis consisted of five analytical techniques: height structure analysis, view angle analysis, view range analysis, panorama simulation using height lines as well as analyzing the visual impact of a building[19]. The methods enable precise and objective analysis of the city structure, defining parameters of new buildings and determining zones were tall buildings should be excluded.

The 2TaLL project aims at developing both theoretical and practical knowledge to optimize diagnosing of tall buildings impact. The project combines several research areas. The use of virtual city models as an analytical tool creates possibilities of improved forecasts regarding the spatial impact of tall buildings on the city landscape, including impact on panoramic views and sequences of urban interiors and important public spaces (perception of tall buildings). The research is going to be based on four virtual city models for Szczecin, Lublin, Berlin and Frankfurt. The models will be adjusted to provide for complex analyses of the urban space. For this reason, special applications will be developed. The applications will be used to implement specific research tasks related to typology of public space and impact of tall buildings.

The research is divided into two theme blocks: a theoretical part aimed at expanding knowledge about the status of research and background of the issue. Other planning studies related to the topic will also be developed. The research additionally includes studies documenting the actual location and visual impact of tall buildings in the largest European cities. The project is expected to develop a methodology for new research techniques. The practical part will include an analytical basis for spatial analyses: optimizing 3D models of new cities, preparing new computer applications and testing available GIS and CAD software (e.g. ArcGIS 3D Analyst). The research is designed to produce a comprehensive methodology facilitating diagnosis and simulation of tall buildings impact (3D Urban Analysis Systems of tall buildings) to protect valuable city landscapes.

CONCLUSIONS

For architects and urban planners, the use of a digital picture of 3D urban space creates completely new analyzing and designing opportunities. It provides unique results that are not available in the case of classical research techniques. The visualization of design and planning concepts in the broader 3D context provides for more suitable solutions. However, the virtual modelling of cities is still in its fledgling stage and possibilities for applying it in urban planning have started

[13] Zespół w składzie: Professor W. Marzęcki and Doctors K. Czyńska, P. Rubinowicz, A. Zwoliński. Głównym celem jest rozpoznawanie na gruncie naukowym potencjału aplikacyjnego „cyfrowego obrazu miasta" w procesie planowania i w kreacji urbanistycznej. More in: P. Rubinowicz, Cyber Urban Design, Archivolta 3(59)2013, pp. 58-65.
[14] Composition study of Szczecin with respect to high buildings, implemented under contract with local government and applied in the strategy of development, Szczecin 2005 / W. Marzęcki, K. Czyńska, P. Rubinowicz.
[15] Analyses of visual impact and definition of spatial guidelines for tall buildings in Szczecin, implemented for 10 buildings in total, Szczecin 2007 / K. Czyńska, W. Marzęcki, P. Rubinowicz.
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[17] K. Czyńska, 2007, *op. cit.*
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[19] K. Czyńska, Using a model of virtual city for research on visibility…, *Space and Form* no 12, 2009, p. 91.
[20] J. Moser, F. Albrecht, & B. Kosar, Berlin 2010, p. 143-147.

to be examined. The community of professionals and researchers in the field of architecture and urban planning should be more involved in the development of the specialist knowledge. In the future, virtual city models can be an important tool in urban planning[20]. One of possible uses is the planning of locations for tall buildings and protecting historical city landscapes. The models can form a platform coordinating interdisciplinary research leading to better management of city spatial development.

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