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Visual protection surface method:

Cityscape values in context of tall buildings

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Abstract

The paper introduces a method of computational analysis of the city landscape called Visual Protection Surface (VPS). The method allows to explore geometrical relations between the scope of visual protection of the city and the maximum heights of new buildings. In contemporary town planning protection of urban landscape is a significant issue, especially for historically composed cities in Europe. Specific panoramic views exposing significant landmarks can be an important element of cultural heritage. On the other hand there are aspirations to modernize the image of a city and highlighting its economic potential. The trend to build tall buildings in Europe is growing and the majority of such facilities were built this century. Strategies for developing a city usually take into consideration the need to protect the historical landscape. Main assumptions of many strategies include selection of so called strategic views foreseen for complete or partial protection (e.g. in London 27 views, in Koln 9 views). The question is: how the city can develop without losing existing valuable views? How to create its contemporary identity in accordance with tradition? How the actual computational techniques can support planning? The VPS method uses the virtual city models as basis for calculations. Input data include: coordinates for a number of strategic views and a 3D city model. Results achieved: the surface above the city defines the maximum height of buildings in such a way that no new facility can be seen in any of the strategic views. On the one hand the VPS method can be used for verification of the potential location of tall building in the city. On the other it can be a verification tool of actual protection strategies, which could be too restrictive. The paper presents the background of VPS, the methodology and sample application: using the computer program developed by authors (dedicated for CityGML data processing) and using other GIS software.

Keywords

Urban landscape protection, tall buildings, 3D city models, computational urban analysis, CityGML.

1. Introduction

Protection of urban landscape is an important factor for contemporary planning process. It particularly applies to those cities where urban structures have been developed as a result of ages of evolution and process of layered historical structures. Specific panoramic views exposing significant landmarks can be precious for identification of city and element of cultural heritage. Strategies for developing a city landscape should take into consideration the need to protect its historical landscape and ambitions of contemporary generations. The new Athens Charter highlights the vision of the connected city as a pillar of urban development in the 21st c., a city which combines the present and future with the past (European Council, 2003). Thus, new facilities in the city should be developed while considering a larger context, which should strengthen the current landscape in a cohesive and harmonious manner. However new tall buildings can be a potential threat to landscape cohesion and integrity of European cities. Due to their broad visual impact range, tall buildings in many instances induce unfavorable and unplanned interaction with historical buildings. For this reason, it is important to provide a reliable and comprehensive diagnosis of the impact exerted by a planned tall building on the city landscape. It is a complex analytical task (necessitates using virtual city models and relevant research and simulation techniques). If simulation of impact of single building on protected view is presently not a problem. Mapping the limits of height in built-up areas in the entire city is a major challenge in itself and demands advanced computational processes (Rubinowicz, 2014; 2013).

2. City landscape protection in Europe

The majority of cities which faced the issue of tall buildings developed modern instruments for monitoring their impact on the landscape. There are a number of planning documents defining procedures for determining height guidelines for new buildings. The majority of procedures requires protecting selected, pre-defined strategic views of a city. Views which highlight the most characteristic and valuable silhouettes, including historical dominant physical structures. These may include panoramas covering a wider city context, as well as views of individual squares or streets. A comprehensive system of assessing and selecting city views was developed in London. It was supported with detailed description of advantages of the existing landscape which needs to be protected (*London View Management Framework, 2012*). *Designated views* are divided into four groups: London Panoramas, River Prospects, Townscape Views and Linear Views (*Seeing the history in the view*, 2011, p. 4). Each view has specific characteristics that contribute to an appreciation of London at the strategic level. Protection guidelines are based on the assumption that any new development should make a positive contribution to the characteristics and composition of the *Designated Views*. Specific principles should cover various constituent parts of a given view, such as foreground, middle ground and background of the views, and the landmark buildings within them. It also seeks to protect and enhance the place from which the view is seen (*Seeing the history in the view*, 2011). Each new construction project, pertaining to developing a tall building in particular, necessitates analyzing the impact of a building facility on the landscape within designated views. A similar procedure is applied in Koln (*Hochhauskonzept Köln*, 2003) and Dusseldorf (*Hochhausentwicklung in Düsseldorf*, 2004).

Several cities have also developed strategies for locating tall buildings (Brighton, 2003; London 2010; Plymouth, 2005; Swansea 2008). The strategies usually comprise studies of urban morphology, which examine conditions at specific sites for developing tall buildings. They define potential locations while taking into consideration factors related to the overall composition (e.g. shadow effect, accessibility, public transport, land topography, air traffic, etc.). Other studies are of more general nature. A study developed for Warsaw (2008) defines tendencies for developing tall buildings based on the silhouette of the city seen from the side of the river (Oleński, 2012). The study aims at determining principles and trends in planning of tall buildings in the city. Should it be grouped, confined to the smallest area possible, or evenly spread across the city landscape? The study for Milan (2007-2011) focused on analyzing visual experience of tall buildings while moving within the structure of the city. The analysis was supported by a 1:500 mock-up of the city and a special micro-camera used for simulating the reality (Piga et al., 2012).

An inspiration for studies referred to in the title of the article stemmed from authors' professional studies for Lublin, Poland: *Composition study of Lublin, guidelines for protection of historical panorama of the city*, realized on contract with local government and applied in the strategy of development (Czyńska et al., 2011). The study continues previous analysis commissioned by the City of Szczecin (Czyńska et al., 2007), aiming to determine the impact of 10 potential tall buildings. Experiences from preparation of that studies indicate demand for systematization and necessity for development of new computer methods imaging landscape absorption limits for cities in form of objective simulation. It is important for directing spatial development, in aspect of delimitation areas for construction of tall buildings and landscape protection areas. How the city can develop without losing existing valuable views? How to create its contemporary identity in accordance with tradition? How modern computational techniques can support planning?

3. Protection of city landscape versus city development capabilities

Defining of principles for protecting a city landscape and the scale of *absorption* as regards new tall buildings is a complex exercise. It requires precise appraisal of constituent parts of the city silhouette, and determining which of them are worth to be protected. Another element of the process is to select strategic views of the city that highlight spatial and architectural values in its structure. In London, the analysis determined 27 strategic views (*London View Management Framework*, 2012). We should remember, however, that their number translates into significant limitations for city development. The studies carried out by the authors regarding prospects for developing tall buildings in two Polish cities (Lublin and Szczecin) determined strategic views. In Szczecin, the analysis determined 17 views divided into 5 groups depending on their distance from the city center. In Lublin, important views were divided into close (BW) and distant ones (DW). For each view, its scope and range were determined, as well as guidelines developed concerning protection of specific parts of the exposition: viewing point and foreground. Defining such guidelines is simpler since major elements can be seen within an exposition and fits into a scope of tangible issues (between observer's eye and protected facility or set of facilities), whereas determining principles for developing buildings within the view background is much more complex in geometrical terms. It requires analyzing distant areas while taking into consideration land configuration and building development systems.

Those relations can be examined using Dresden as an example (Figure 1). The historical silhouette of the city can be observed from the northern bank of the river on a stretch of two kilometers and from bridges which provide good visibility. The 18th c. panorama of the city, presented in paintings by Canaletto, remains under a strict protection. No new investment should be seen above the roofs of major existing dominant physical structures. Since the panorama can be seen from a river bank, we obtain a sequence of changing frames. In each of the frames, relations and distances between buildings change. Along the pedestrian section, the level of an observer is fairly low and the historical silhouette can be seen against the background of the sky (Figure 1 above). The cohesion of the view is not disturbed in any way. However, if the observer moves several meters upwards, e.g. enters one of bridges, from certain locations contemporary buildings can be seen within the panorama (Figure 1 below), emerging above the historical silhouette. Distance and height of the observer determine the visibility of other facilities within the panorama. Other factors include width of the foreground, level at which a given building is erected and its height, and primarily the height and geometry of facilities comprising the historical silhouette of the city. Mutual relations between those factors determine the visibility of buildings within the exposition.

Figure 1: Panoramic view from Elbe River in Dresden. Above: the wide boulevard on the river bank well exposes values of city skyline. Below: view from one of the bridges reveals contemporary building visible in the background of panorama (photos by authors).

The example of Dresden shows that the protection of panoramas may significantly reduce possibility of implementing new investment in the city. Examining the relations between a protected view and the height of planned facilities, especially the possibility of erecting tall buildings is a geometrical exercise. The size of a city, number of views and number of prospective locations for new facilities are decisive regarding the complexity of the exercise. In the case of Dresden, instead of several strategic views we consider a sequence of such views along boulevards on the Elbe River. Additionally, defining guidelines regarding the height for the entire city rather than selected locations (multiple locations) is important in spatial planning. Similar observations are also relevant for many other European cities. This justifies the need for developing new analytical methods which enable more precise analysis of relations between protecting city landscape values and possibilities for developing new facilities. The article examines new applications of contemporary computational and digital techniques involving 3D city models. The presented method helps determining the area limiting the height of buildings for a given strategic view. For the purpose of the article, the area is referred to as the Visual Protection Surface.

4. Computation of the visual protection surface

Summarizing the above, determining strategic views, which are recognized by citizens and important for the history and identity of the city is an important tool for contemporary protection of a city landscape. Depending on planning studies and local legal conditions, such views are subject to partial of complete protection (i.e. when interference of new investment require consultations, e.g. BWSCA system in London, 2012). The relationship between historical values and the development of a new image of a city is in principle a multifaceted and debatable task. Therefore, defining those areas where mutual relations can be analyzed in an objective manner is crucial.

The VPS method involves determining geometrical relations between the scope of protecting strategic views, and maximum heights of buildings in a city. Input data include: coordinates for a number of strategic views and a 3D city model. Results achieved: the plane above the city defines the maximum height of buildings in such a way that no new facility can be seen in any of the strategic views. The studies presented in the article were implemented in parallel while using two environments: a) software developed by the authors (C++) and b) using ArcGIS program with 3D Analyst by ESRI.

Assumptions and results achieved by using VPS are presented in the chart attached (Figure 2). The initial model representing a 'city' consisted of an E shaped block of two heights. VPS surfaces generated for views from points O1 and O2 are presented in the chart (Figures 2b1, c1) in an axonometric projection. Figures below (Figures 2b2, c2) include visualizations for the two points examined. The surfaces cannot be seen since they merge into one line comprising an individual skyline for O1 and O2. The same applies to all facilities (subsets of space) which remain under the VPS surfaces. While observing the generation of those surfaces from the outside we may notice that for each viewing point a new block is developed in the process of simulation. The new block is a geometrical 'echo' of the initial shape (see Figures 2d1-d5). The diversity of thus achieved 3D forms is significant.

As regards geometry, for an individual point, the VPS is a boundary surface of isovist 3D (determined for that point) (Suleiman 2013; Chang and Park, 2011). In a key area, when the VPS is not adjacent to terrain or existing buildings, it is a simple ruled surface. However, when we combine results for many viewing points (several strategic views) significantly increases the complexity of the surface. The program developed by the authors examines visibility of any number of viewing points for each XY in the space of a city. The result, which is the highest coordinate Z, for which each observation point O1-On remains unseen, is set with the precision of about 5.0cm. The real measure of accuracy of the simulation is the precision of the city model. The program interprets only city models developed in CityGML. The semantics of the standard (Kolbe, 2009), assuming hierarchical grouping of building geometry, is used in the program to optimize algorithms. Examples of determining VPS for several viewing points are presented in the simulation sequence (Figures 2e1, e5).

Another picture show some example of how the methods concerned can be applied in a real city space. The area examined is a 1km^2 part of Charlottenburg, a district of Berlin. The analysis is based on the CityGML model of LoD2 (including geometry of roofs). An average height within the area is about 25-30m, whereas the tallest building has 73m in height. The analysis is performed for 1, 2 and 3 viewing points. The first simulation (Figures 3a1, a2) protects an individual viewing point set in the middle of one of squares (Viktoria-Luise-Platz). The resulting VPS is presented as an axonometric projection – in the form of a 3D mesh (Figure 3a1) and in regular projection – in the form of a map with height levels marked from 0.0 to 250.0m above ground level (Figure 3a2). According to assumptions, every new facility, which does not extend beyond the mesh will not be seen from the middle of the square. In further simulations (Figures 3b, c), other points for protection of the view are added. This increases the complexity of surface geometry and more importantly possibility of developing new tall buildings significantly reduced.

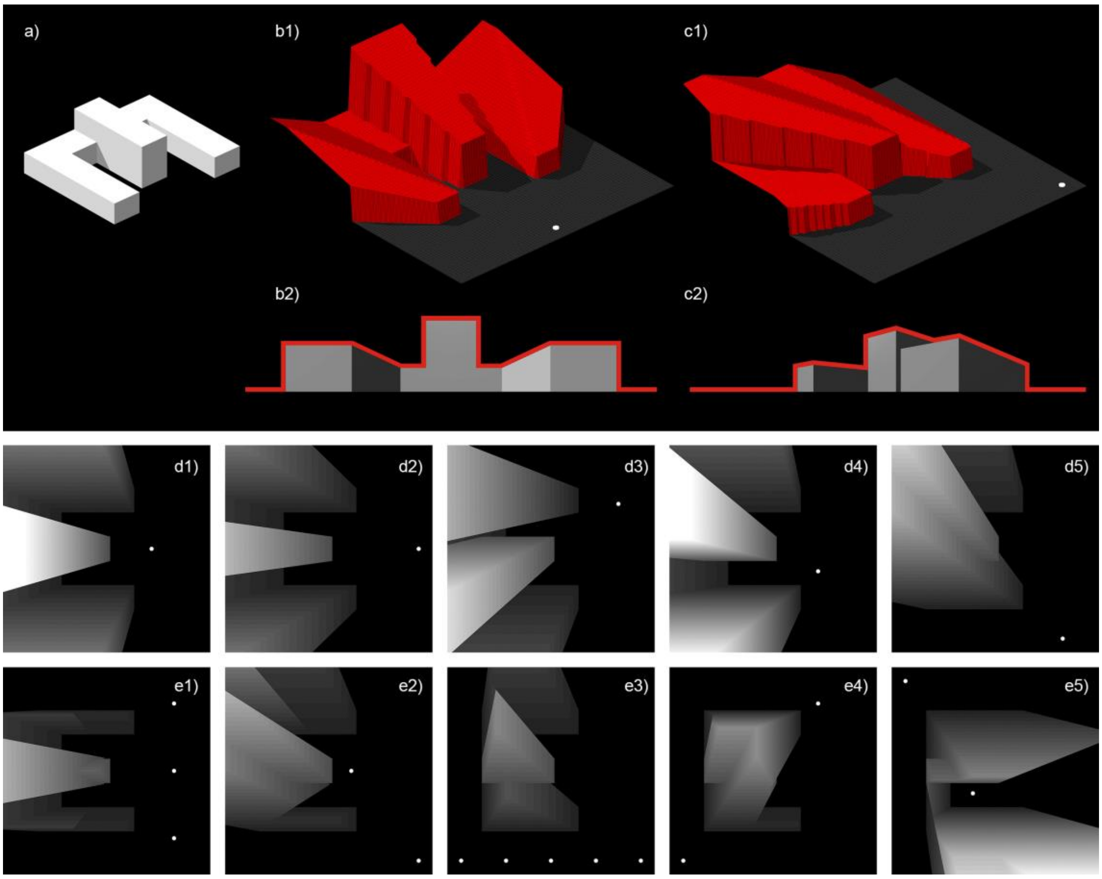

Figure 2: Example of application of VPS method: a) model for performed analyses; b1), c1) VPS simulations for viewing points O1, O2; b2), c2) perspective view from points O1 and O2 with marked VPS surface visible as skyline; d1-5) VPS for different viewing points; e1-5) VPS for several viewing points simultaneously (Figures by authors).

5. Application of the VPS method in planning

How can the above considerations be translated into planning provisions? How can we define the maximum height of new buildings to keep it unseen within protected panoramas? How can we balance those parameters for several or several dozen of viewing points not to block the development of a city? VPS simulations, presented in the previous part of the article, for the district of Berlin aimed at providing an overview of the situation. Observation points analyzed do not reflect real strategic views that should be protected. The study does not take into account a major impact of trees, so much present in that part of Berlin.

In real urban planning, usually external views of a city and broad or partially open urban interiors are subject of protection (Zwoliński, 2014). It is considerably rare that small squares need to be protected. While referring to the above example of Dresden, the use of the VPS method could potentially involve planning a series of protection points along the 2km stretch of the boulevard on the Elbe River, on the north part of the city. Distance between the observation point and build-up area line and the height of buildings determine the shape of the VPS. The view angle which depends on proportions is an important piece of information in itself for the analysis of the spatial structure of a city (Czyńska, 2011). It also has an important influence on the expected shape of the VPS. This can be seen in the chart discussed before (see Figures 2d1 and 2d2), where the change of the location influenced changes in the shape of the VP-Surface. In the case of Dresden, the distance between the boulevard and the line of historical buildings is significant, on average about 350m. Therefore, the VPS is flatter than the corresponding simulation for the interior of Viktoria-Luise-Platz in Berlin (Figure 3). In Dresden, it translates into larger limitations to planning the height of new buildings and greater susceptibility of the historical skyline to changes.

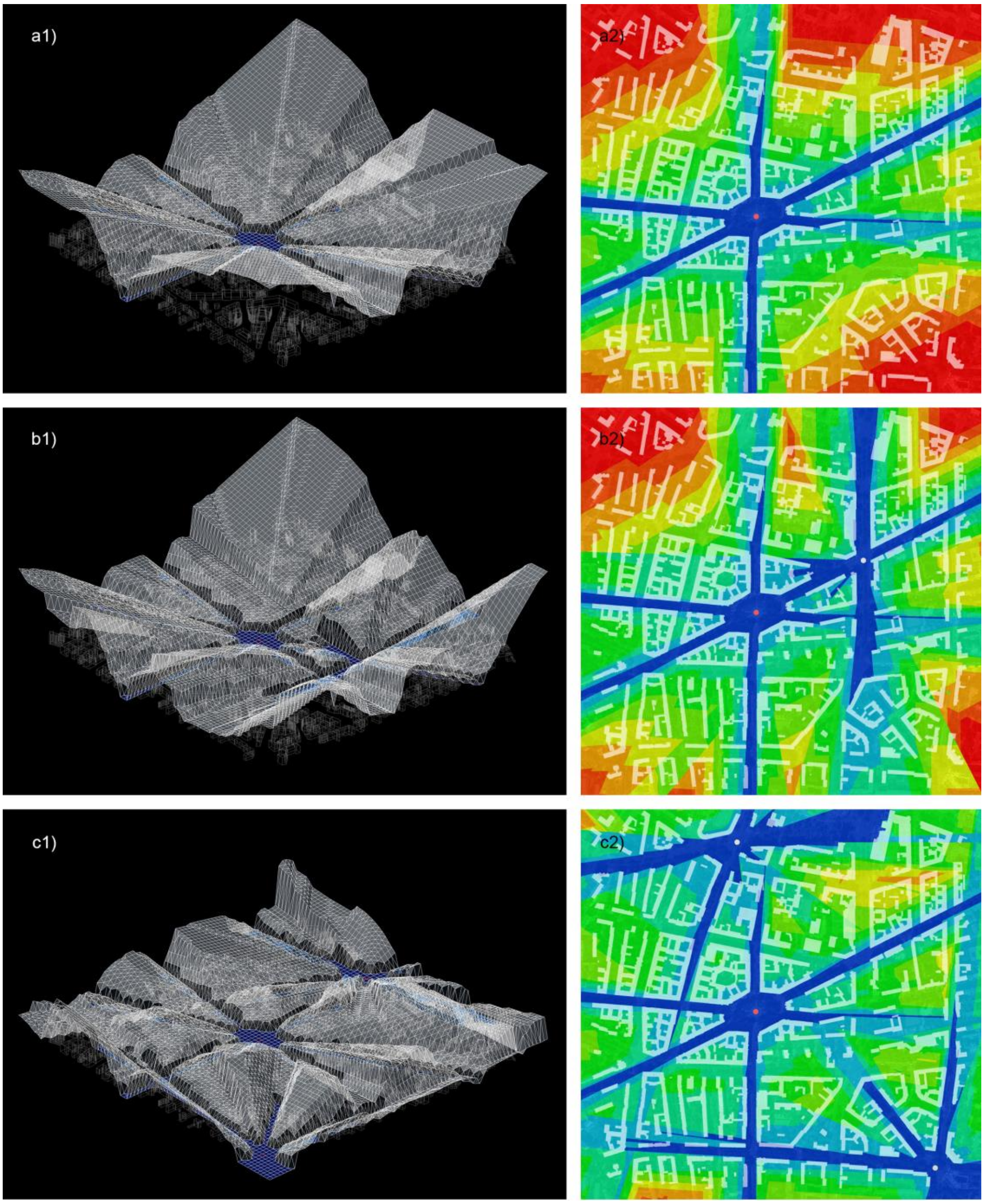

Figure 3: VPS simulations for Berlin performed for 1, 2 and 3 viewing points (a, b, c). VPS is presented as an axonometric projection – in the form of a 3D mesh (a1, b1, c1) and in regular projection – in the form of a map (a2, b2, c2) with height levels marked from 0.0 to 250.0m above ground level (Figures by authors).

A certain approximation of the shape of the VPS can be achieved using the height rulers method (Czyńska, 2010). The method was used by the authors in 2005-2007, under a study of building height and analysis of potential locations of tall buildings in Szczecin (Czyńska et al., 2007) commissioned by the local government. The method enables analyzing of the impact of limited number of potential locations for tall buildings in the city on a single strategic view. The effect is the panoramic visualization (perspective) of a view from a specific viewing point. The CAD application enabled adding examined facilities to the model and visualization. Height rulers for planned buildings helped determining numbers and limit heights above which specific buildings can be seen in a panorama concerned (Figure 4). Findings were analyzed manually. On the one hand, distribution of markers gives an approximated shape of the VPS. On the other, the advantage of the method is the intuitive interpretation of results, a possibility of metrical analyses of panoramic views and examining proportions of new landmarks (analysis takes into consideration not only examining of heights but also widths of facilities).

Figure 4: Simulations of Szczecin's (Poland) panoramas with height rulers placed in locations of planned tall buildings. The method helped determining numbers and limit heights above which specific buildings can be seen above skyline (Czyńska et al, 2007 – above; Marzęcki et al, 2005 – below).

Another figure (Figures 5, 6), also pertaining to Szczecin, Poland, presents an analysis of generating the VPS for pre-determined external strategic views of the city. In this particular case, protection applies to views of the architectural urban arrangement of the Wały Chrobrego embankment (Figure 5 above). Edifices of the National Museum, Governor's Office and the maritime University enjoy strong exposition in panoramas seen from the Oder River. The skyline created by the facilities is a major cultural value of the city and a recognizable landmark in the country. The studies of 2005-2007, performer by a team involving the authors of the article, aimed at preserving this particular section of the skyline unchanged, including Wały Chrobrego. The protection covered strategic panoramic views seen from the river and the overpass of Trasa Zamkowa, the main city inbound route.

VPS simulations of Szczecin presented in the article were developed using ArcGIS. It aimed at generating the VPS in various software environments (simulations presented in previous figures were developed using software developed by authors of article). The simulations used a 3D digital model of the city center of Szczecin made by the authors in 2005 and extended in 2007. The analysis covered 3 potential strategic views: two from the Trasa Zamkowa overpass (see Figure 5 above) and one from a distance of about 5.5 km (from a railway overpass Dziewoklicz, see Figure 5 below). An additional assumption was to limit the angular range of the protection to sections of the skyline covering the direct context of the Wały Chrobrego skyline. Results were recorded in the form of independent raster maps which underwent consolidation. The resulting map showed the VPS for 3 strategic views (Figure 6c). The simulation points at potential areas for locating tall buildings that could not be seen within the Wały Chrobrego skyline (Figures 6a, b). The simulation provided a general overview. The simulation verified technical capacity of generating the VPS. A limitation of the program is that it cannot provide analysis for a large number of strategic viewpoints and the size of the city. In case of a model covering areas of larger cities (e.g. Berlin) simulation posed major difficulties.

Figure 5: Panoramic views of Szczecin (Poland) for which VPS was calculated. Wały Chrobrego embankment under protection (photos by authors).

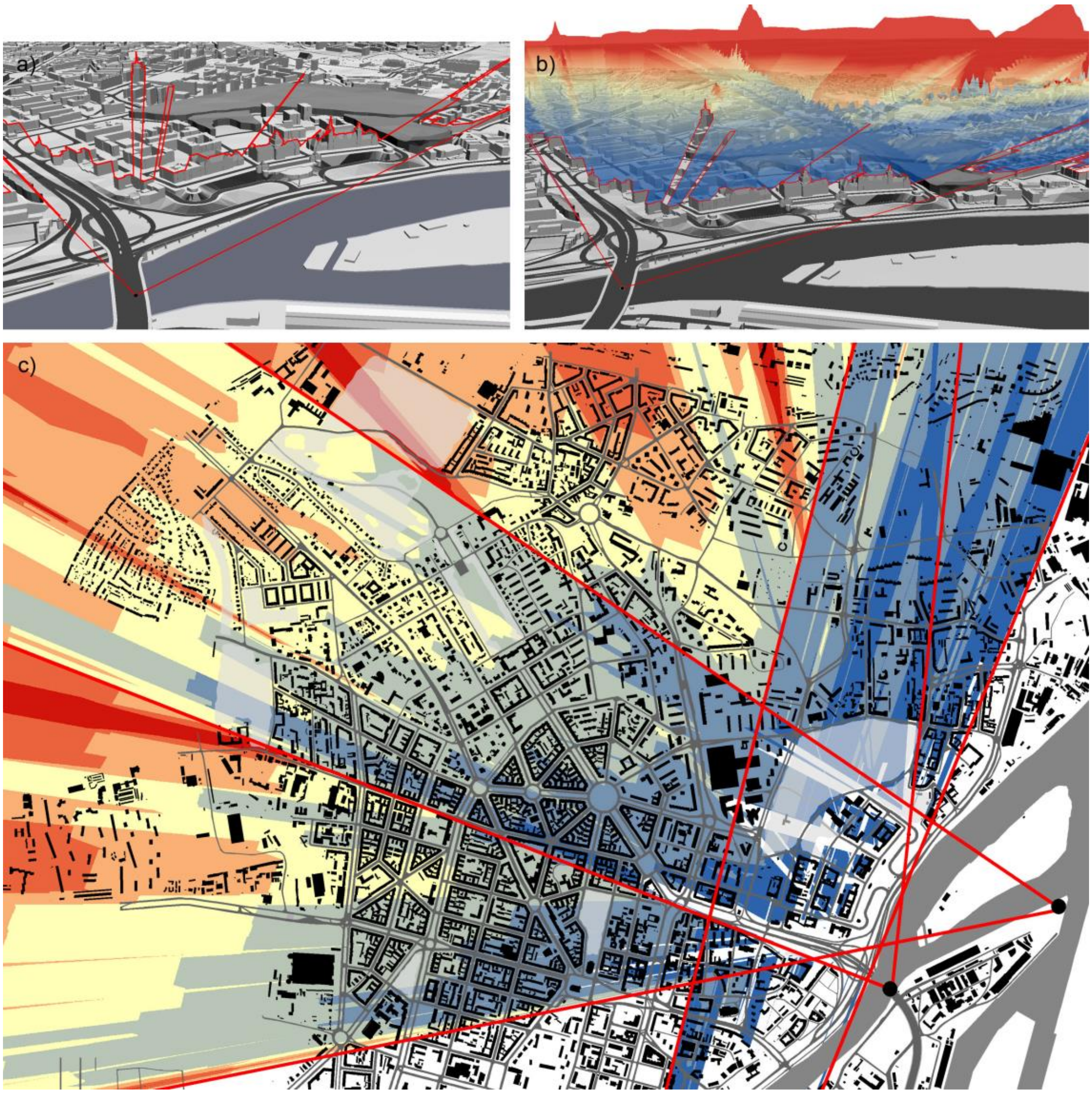

Figure 6: VPS for Szczecin developed in ArcGIS software. The analysis covered 3 potential strategic views exposing the direct context of the Wały Chrobrego skyline (a). VPS is presented as a perspective view (b) and in the form of a map (c) (Figure by authors).

6. Conclusions

In many European cities, planned locations for tall buildings are subject to numerous conflicts and controversies. One the one hand, we observe trends to preserve historical urban structures and skyline values well recognized among citizens. On the other hand, there are aspirations to modernize the image of a city and highlighting its economic potential. It is true that the trend to build tall buildings in Europe is growing and the majority of such facilities were built this century. The same applies to those cities that for centuries had well regulated building height structure and were not much destroyed during the war, e.g. Amsterdam, Helsinki and Cracow, Poland.

The article does not aim at presenting a position for or against tall buildings. Dilemmas related to tall buildings cannot be solved at the scientific level and finally boil down to arbitrary planning decisions. Developing analytical methods that enable better understanding of relations and examining consequences of investment and possibly objective conservation principles are equally important for researchers. The use of computer techniques and 3D city models create new possibilities. There are various methods for analyzing the impact of tall buildings on the landscape. While referring to other studies by the same authors, we should list for instance the visual impact rage or visual angles analyses (Czyńska, 2011).
The VPS method, presented in the article, is yet another interpretation of city space. It enables analyzing relations between protection of city landscape values and possibilities of developing new tall buildings. Protection should cover properly selected strategic views of the city so they can remain unchanged. Therefore, in result of a single calculation process, based on any number of strategic views, we can generate a surface determining maximum height of buildings. Each building which fits under the surface will not be seen from any of pre-determined viewing points.

An advantage of the method is the possibility of simultaneous analysis of the entire city, including virtually any landscape context. This helps verifying possibility for erecting tall buildings in a given city, as well as applicable protection principles. A limitation is the calculation capacity, which is related not only to the capacity of a computer, but also imperfection of algorithms. At the current stage, the program developed by the authors enables efficient examination of areas of about 20km^2. In the case of ESRI, the problem is automation of the process for a large number of points and size of a 3D model. The VPS emulated by the computer may facilitate the process of spatial planning in a city. It does not generate, however, specific solutions but information that needs to undergo professional interpretation from the urban planning point of view.

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