

Viewshed Analyses as Support for Objective Landscape Assessment

Agnieszka Ozimek¹, Paweł Ozimek²

¹Institute of Landscape Architecture, Cracow University of Technology/Poland · aozimek@pk.edu.pl

²Institute of Computer Science, Cracow University of Technology/Poland

Abstract: Capacities of digital technologies, concerning support for decision making by providing experts with numerical, objective measures, are still not fully utilized in landscape assessment and planning. The paper presents a method that enables landscape factors modelling by applying viewshed and landform studies. The results of the research in the form of maps may be easily applied in spatial analyses, decisions on new investments, land management or monitoring changes over time.

Keywords: Geodesign, visibility analyses, landscape phenomena modelling, landscape assessment, landscape planning

1 Introduction

Since the 1960s and 1970s, scientists have been articulating the need for precise indicators that would characterize the landscape, reducing the subjectivity of experts' opinions (UNWIN 1975; BUHYOFF & RIESENMAN 1979). They have recognized that the exact evaluation of landscape resources should be the starting point for all kinds of planning works (SMARDON et al. 1986).

Together with an increase in computing capacity, the development of algorithms and GIS applications, new opportunities have appeared, especially in the creation of numerical indicators, that would be useful in landscape assessment (COOPER & MURRAY 1992). Landscape architects, whose profession is largely related to the aesthetic aspects of the environment, focus their attention on the issues concerning landscape perception. Due to the fact that sight is the most important human sense, they undertake research concerning visibility. At the beginning of the 1990s such terms as: "viewshed", "isovist", "zone of visual influence" were introduced (FLORIANI et al. 1994, DAVIS & BENEDIKT 1979). In the course of time, functions for their determination have become standard tools in GIS programs. At the same time, research on the landscape perception was conducted, mostly on the basis of surveys, the results of which could be meaningful only if a large group of landscape users was involved (NAS-SAUER 2012). In the case of this type of research, parametrization was much more difficult because of individual characteristics of the observer's experience (KEARNEY et al. 2008).

Implementation of the results of these studies has not proceeded uniformly in all countries. Definitely, the leaders were the US (SMARDON 2016) and the UK (TUDOR 2014). Procedures done there, like the Visual Impact Assessment used in the United States, combine the parametrized landscape aspects (e. g. the landform or distance zone) with those which may be classified as subjective ones (user experience) (PALMER 2016). The methods applied are becoming increasingly precise; however, there is still place for implementation of exact parameters that can characterise landscape or its alterations.

2 Materials and Application Example

Studies were conducted on a terrain which is characterised by outstanding aesthetic values, including diverse landforms, mountain ranges, forests, a lake and arable land combined with two castles, a traditional development, as well as with absence of large-scale infrastructure (Fig. 1). Four National Parks are located in the vicinity: the Tatra, Gorce, Pieniny Mountains and the Babia Góra Range, which are under the most restrictive protection. Ethnic aspects of this area, which is situated on the borderline between two cultures (Spisz – Podhale), are still evident in the plans of settlements. Some problems, however, appear with regard to protection against dispersed new development or floods caused by overflowing rivers.



Fig. 1: A view from the Wdżar Mountain showing the terrain (the Tatra Mountains in the background)

During the research, different types of data were collected:

- DEM (Digital Elevation Model) of the lake basin, from geodesic measurement of the terrain and its cover, supplemented with road infrastructure, dams and levees;
- STRM terrain model (Shuttle Radar Topography Mission) for the adjacent and distant (but visible) landscape fragments;
- Data concerning development, historical monuments, churches or shrines, as well as forests or areas under natural protection (national parks, landscape parks and reserves) collected and digitalised;
- Photographs and panoramas from vantage points and hiking trails.

3 Methods

In the first step of investigation, an expert (landscape architect) determined the elements that characterized landscape, basing on his professional knowledge, the literature research, maps (tourist, relief, ecological, infra-structural), GIS data and field studies. This evaluation, which is susceptible to accusations of arbitrariness, can be verified in subsequent steps.

Simultaneously, a digital terrain elevation model was structured, represented as a triangulated irregular network, which was optimal for the tiny details of the surface (FLORIANI et al. 1985). Both the terrain model and its cover may be obtained using the point clouds captured by the LIDAR devices (CISŁO-LESICKA et al. 2014). This data, which can be described as “the static models” make it possible to generate certain “functional models”. Basing on the assumption that visual and aesthetic aspects of scenery should be an important focal point for landscape architects, the phenomena related to visibility were the main subject of the research. Therefore, maps were generated that showed the passive exposition (visibility) of the elements which defined the landscape identity. Nowadays, GIS programmes provide tools that serve this purpose; however, the exact viewsheds may be produced using the raytracing algorithm (WHITTED 1980). In this case, light is located in a place of the landscape object. Fragments of the lit terrain surface are, at the same time, visible from this object and simultaneously the object is visible from these parts of the terrain, basing on the assumption that the rays are straight, as well as sightlines (CALDWELL et al. 2003). This step can be realised in any modelling program which implements raytracing algorithm. Because of the large research area, the studies included only major elements of terrain cover, such as wooded areas. Single trees and buildings were not taken into account, since their impact on the visibility is much smaller.

Black-and-white viewsheds are obtained in the image precision; therefore, the results may be easily combined with the GIS data. The adequate rendering resolution is chosen in order to cover a certain part of the terrain by one pixel (for example 100 m²).

With regard to the visual impact of large objects (like the Tatra Mountains or other hill ranges visible from the research terrain) we used cumulative visibility diagrams. The final figure (in grayscale) is formed as the result of systematic sampling. In regular grid covering the surface of the objects, point lights are placed and individual viewsheds are produced, which are afterwards summarized according to matrix calculations and normalized to the accessible data limits (Fig. 2). These operations were performed in MATLAB environment with Image Processing Toolbox.

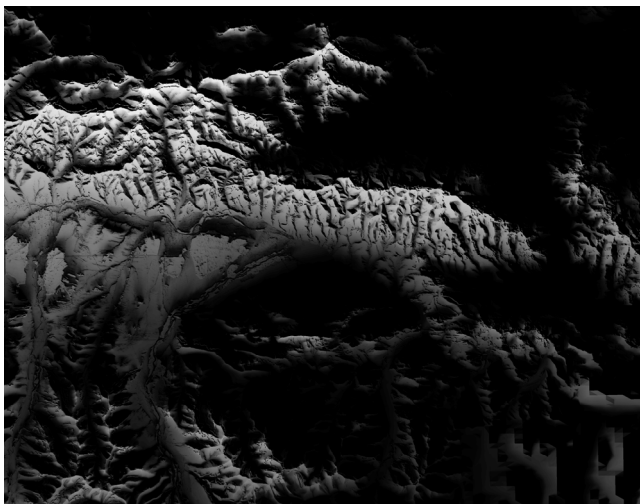


Fig. 2:
Cumulative visibility of the Tatra Mountains. Pixel brightness corresponds to the number of objects visible from a given place

Subsequently, the attained diagrams were juxtaposed with tourist maps in order to determine crucial viewpoints, important for the visibility of objects in interest. The analyses of the abovementioned views should be carried out in order to confirm the initial expert's assessment. Field study conducted at this stage is necessary, because of the widespread incompleteness or inexactness of available data (MALLOY & DEAN 2001).

Basing on the former steps, a list of factors that affect the aesthetic aspects of landscape was formulated. These factors were divided into two groups: the positive and the negative ones. For the test area, the following may be regarded as the positive ones: remarkability, sublimity, the durability of motifs, the richness of plans and wings, the diversity and changeability of colours and textures, the harmony of composition, vastness of accessible areas of untouched nature, outstanding monuments or motifs calling up (historical, literary) associations. On the other hand, the negative features included: industry and technical infrastructure, mining zones, objects of large-scale agriculture, illegal landfill sites, sprawl, primitive engineering constructions, advertising, disharmonious building forms, trashy street furniture, artificial pseudo-regional and pseudo-historical "set designs", primitive temporary elements or off-season devastations (OZIMEK et al. 2013). It should be kept in mind that these factors are specific for a given region and they may cover some phenomena that have no visual aspects.

A group of experts representing different disciplines (e. g. landscape architects, psychologists, sociologists, architects, urban planners) called "the team of competent judges" was involved to evaluate the level of perception of the factors (BABBIE 2004). This method, drawn from social psychology, allowed weighing the opinions by calculating the average of several personal judgements; therefore, the level of subjectivism is limited. Attractiveness of the landscape factors was rated according to their: uniqueness, authenticity, scale in the view field, structure and level of perception (sensory-motor, semantic-functional, semantic-symbolic) (OZIMEK et al. 2013). Every category was divided into three levels. This evaluation resulted in the ranking of the factors, increasing or decreasing the view quality.

The features that can be digitally modelled were chosen in the next step of the method. They depended on the accessibility of data, as well as on the choice of the modelling method. In general, modelling of factors is based on the estimation of their impact maps. The precise borders of all these impacts were defined. As a result, a collective map was created, in which all the factors (both positive and negative) were weighed, taking into consideration the level of their visual perception. On this basis, the area was divided into zones that should be fully protected, partially protected or those that do not require protection.

4 Results and Discussion

The results of this method were presented on the maps that graphically show spatial distribution of various factors. They were analysed regarding the characteristics that are crucial to perceive them. For example, the "remarkability" depends on the visibility of unusual objects that cannot be seen elsewhere. The impression is enhanced by synergy that occurs in the case of the possibility of observing a number of unique objects simultaneously. Cumulative visibility maps of mountain ranges, lakes and two castles were added together and averaged with weights in accordance with their level of perception, evaluated by "a team of competent judges". Notwithstanding, wooded parts of the terrain were excluded. The brightest fragments of the map indicate the location of the most remarkable views (Fig. 3).

Another factor which was modelled, was richness of plans and wings. This can be assessed on the basis of viewsheds executed from every point located on the terrain. Such a viewshed shows the surface area visible from a given point, where white patches correspond to the visible areas and black ones to the invisible ones. Therefore, if there are more hidden areas and they are more scattered, it means that from this point more we can perceive plans and wings. The greater the terrain relief and the higher the viewpoint location, the darker the patches appear in the diagram. For every viewshed, a difference between the number of objects (white patches) and holes in them (black patches) was calculated and the absolute value of this number was assigned to a given pixel (Fig. 4).

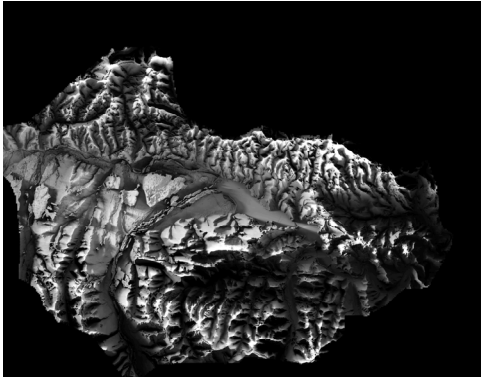


Fig. 3: Remarkability map

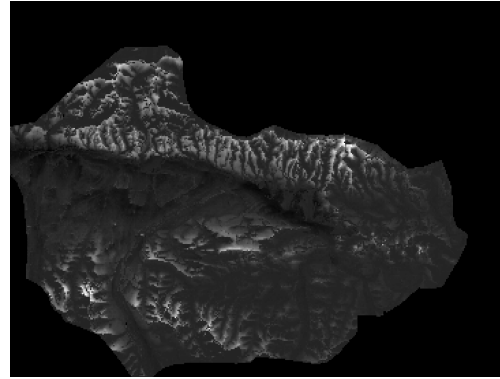


Fig. 4: Richness of plans and wings

Sublimity was another factor that was modelled. The most well-known definition was formulated by Kant, who described it as the sensation of the immediate contact with Nature, possibility to admire It, without a feeling of fear (KANT 1914). A slightly different definition is given by Nohl, who sees in Nature a kind of disorder, which seems to contradict the principles of beauty, and despite this, seems to fascinate as a force which at least temporarily breaks away from the rule of man (NOHL 2001). Therefore, in the equation the visibility of mighty elements of wild Nature (mountain ranges, the lake, forests) is taken as a positive aspect, and the visibility of sprawl (chaotic new development) is considered negative (Fig. 5, left).

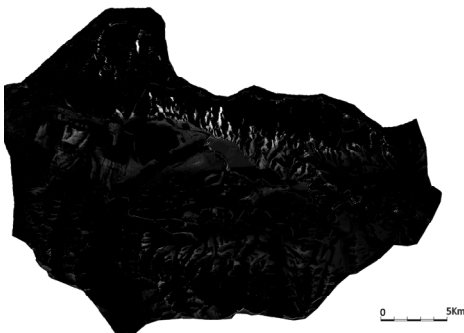


Fig. 5: Left: A map of sublime views. Right: A map of prospective sublime views in case of realisation of spatial development plan.

On the example of this factor, some simulations were conducted in order to present visually to officials the effects of their decisions. Nowadays, spatial development plans allow erecting detached buildings, which generates sprawl. Bearing in mind that sublimity is dependent on the visibility of mighty natural objects and dispersed development has a negative effect on it, should this law be implemented, the majority of sublime views would disappear (Fig. 5, right).

All maps of factors modelled were added together with weights corresponding to their perception level. Based on this, the maps that depict all the factors which increase and reduce the aesthetic value of the study area were obtained (Fig. 6). Visible predominance of the positive ones over the negatives tallies with an intuitive landscape assessment.

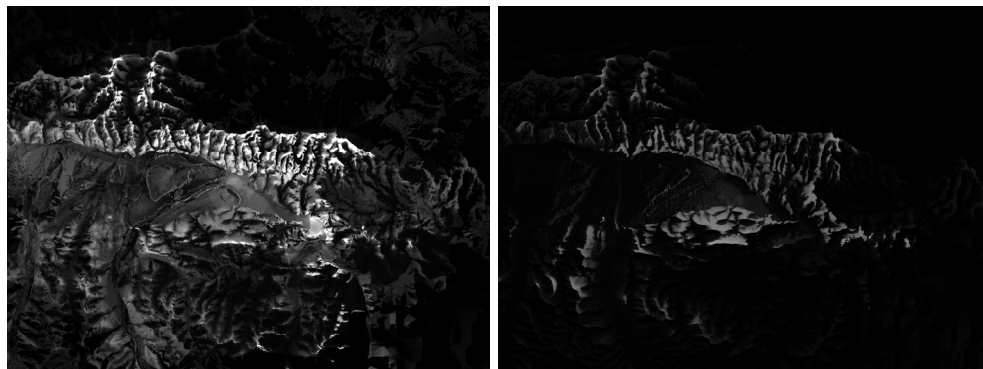


Fig. 6: Left: A map of positive factors. Right: A map of negative factors.

Taking into account all the factors that have effect on the aesthetic aspects of the area, three zones were distinguished. The parts of the terrain marked in white should be subject to full protection, because of the outstanding scenic values. The non-protected areas (black) are in the visual shade from the important vantage points and the most attractive elements of landscape cannot be perceived from these fragments of the terrain; therefore, they are mostly predestined for alternations. The remaining parts of the region should be partially-protected (Fig. 7).

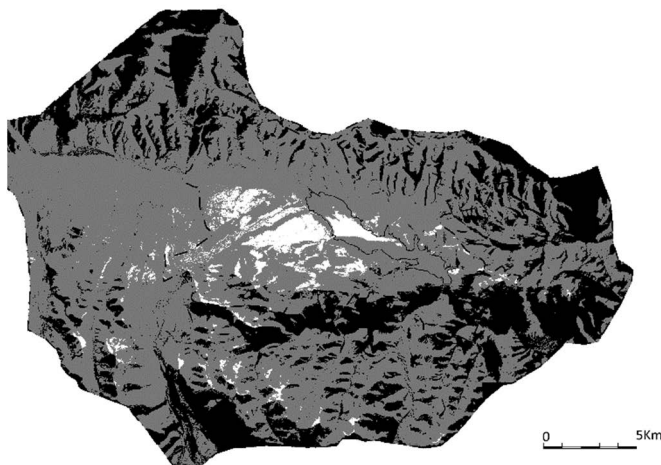


Fig. 7:
Landscape protection
regarding visual quality
of the terrain
white – full protection
grey – partial protection
black – beyond protection

5 Conclusions and Outlook

The core of the study was an attempt to model the landscape factors, distinguished by the expert (the landscape architect) and assessed, in terms of the perception, by “the team of competent judges”. The study involved the area of a specific nature, therefore it still requires confirmation in a number of other examples.

The models, which are by definition an approximation of reality, were an effort to show the factors in a graphical form, basing on their definitions. In the future, these models should be evaluated or verified by comparing the intensity of factors in the map with its actual perception in the field.

The choice of factors made by the expert, which is based on studies and knowledge resulting from his professional training, was objectified to some extent by “the team of competent judges”; nonetheless, it should be supplemented by surveys of onlookers.

The study of this type is still accompanied by the problem of workload and computational complexity, which requires the possibility of using advanced equipment. Because of the area vastness, availability of data and labour intensity of analyses, some simplifications were introduced, both about landform and its coverage. They may have some effect on the results, especially in terms of visibility from urban areas.

Results in the form of maps can be easily implemented in the work of planning, but the idea is so complex that its implementation to the practice of officials will probably take some time.

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