ANALYSIS OF NUMERICAL INDICATORS OF ECOLOGICAL CONDITIONS OF "BELVIL" COMPLEX USING AERO-PHOTOGRAMMETRY

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Summary: *In the terms of progressive technological advancements, modern planning continuously searches for new innovative methods of qualitative spatial assessments. Green roofs, as one of the measures to ensure conditions for adaptation of urban environments to climate change, are increasingly being implemented. The work aims are to analyze numerical indicators of environ-
mental conditions, such as the Belleville complex in Block 67, to indicate the possibility of green roofs developing to improve environmental and functional performance. Numerical indicators were obtained by measuring potentially green roofs and green surfaces on slant high-resolution digital aero-photogrammetry recordings, based on data from the Urban Plan and the Main Settlement Project.*

Keywords: *green roofs, digital photogrammetry, numerical indicators, ecology*

1. INTRODUCTION

In multidimensional terms, urban areas are key drivers of change. Urban planning is a principal instrument in the sustainable development of cities relying on the protection of the existing environment, improving space, determining positions and content of new structures. The modern planning process carries great responsibility towards future generations expecting to respond to the many challenges of today. Solutions for the problem of uncontrolled urbanization, climate change, and irrational exploitation of resources are needed. The built environment has an impact on the environment, which depends primarily on the principles of planning, urban design, and urban morphology [1]. Two of the world's leading demographic trends that have led to a disruption of natural

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biodiversity and ecosystem are population growth and urbanization. Living standards put ecological comfort at the forefront as one of the most an important indicators of life in urban areas. Housing further stands out as a primary urban function due to the continued expansion of cities. The practice demonstrates that environmental knowledge is not used enough in the absence of green spaces in cities [2] and that today we are witnessing irrational construction of high-density areas where the quality and biodiversity of open spaces is marginalized. Greenery becomes an important element of urban design, it regulates microclimatic conditions, filters-air, reduces noise, and contributes to the ecological values of space. Green spaces, due to a lack of private open spaces, are extremely important in areas intended for multifamily housing. To promote "green growth" and improve the ecological and functional performance of built areas, spatial analysis plays an important role. In terms of significant technological advancements, modern planning continuously searches for new innovative methods of qualitative spatial assessment. In recent years, 3D models and simulations of cities have gained importance and models of modern computers are becoming more detailed in enabling the testing of a wide range of aspects in urban areas. In particular, the method of aero-photogrammetric imaging is explored using the Penta camera system to measure urban parameters. Applying slant air shots gives new possibilities for integrating the texture of objects into a 3D model. These 3D models are applied in the field of engineering design, environmental modeling, real estate, and security systems. The work aims to explore the possibilities of applying slant digital aero-photogrammetry imaging in urban planning, for example, by analyzing numerical parameters of the ecological conditions of the Business and Housing Complex "Belvil" in Block 67 New Belgrade. A special emphasis has been placed on improving environmental performances by increasing the green surface of roofs. "Belvil" is a complex of 14 residential and 2 office buildings in Block 67 in New Belgrade, located between the streets of Yuri Gagarin, Spanish Fighters, Djordje Stanojevic, and Dr. Agostino Neto. Construction of the area began in 2007 and was completed in 2009. Built residential and supporting buildings of gross construction area (GRCA) of about 170000 m2, on an area of 13.7 hectares, is located in the immediate neighborhood of the trade and business center "Delta City" in the function of housing and the need of public services, in the phase of use of this part of the block as a new residential settlement provided by buildings with about 2000 housing units for about 6000 residents.

2. MATERIALS AND METHODS

The aero-photogrammetric recording of the Belleville complex was conducted with the Penta aviation camera system Vexcel UltraCam, from a height of 1000 m by an aircraft with an inertia system that measures the slope of the axis for each shot. Slant aero-photogrammetric images are at a 45° angle over the horizon, with a 90° camera axis position and a spatial resolution of 10 cm. Between recordings, it's 70% overlap, which allows 12 shots from different directions to be provided for each detail in space. Processing of recording data sets parameters for external and internal orientation recordings, while the digital model of the terrain is integrated with the recordings, allowing the measurement of coordinates, lengths, heights, and overhead surfaces of objects and green surfaces to control the parameters of the Main Project built block 67 and complex. The accuracy of digitizing details is the size of an aero-photogrammetric image pixel. In addition to the images for parameter control, the appropriate PHOTOMOD software suitable for the needs of data processing in spatial planning was used [3-6]. Aero-photogrammetric images of Block 67 have been processed covering the space for the construction of housing and commercial activities, as well as free and green areas (GP1-GP6). The parcel-level building index is calculated according to the formula:

$$FSI = \frac{\sum P_i}{P_p} \quad (1)$$

∑ Pi is the sum of useful surfaces of the building (ground floor + floors),
Pp - the surface of the building plot.
Po- surface under object.
The degree of utilization at the parcel level is calculated as:

$$SI = \frac{P_0}{P_p} \cdot 100[\%] \quad (2)$$

UP- Urban project
GP- Building plot

Illustration of aero-photogrammetry and subject area recording is in Figure 1:

Figure 1 – Aero-photogrammetry and images of the subject area

2.1. ECOLOGICAL PARAMETERS OF THE AREA

At the specified location, urban parameters of green areas of the General Plan of Belgrade 2021 have been applied, adjusted based on changes to the General Plan of Belgrade 2021. Urban parameters of green surfaces for construction areas and buildings in the city blocks are: green and non-residential areas relative to the surface of the block are 20%, green areas on the building plot (GP) 30% to 40%, and maximal density of housing is 250 – 450 res/ha. Within the UP phase of use block 67 are planned: roads 27779 m^2, free and green area 24121 m^2 for public building complexes 15097 m^2, space for housing and commercial activity, and pedestrian communication for public use 67690 m^2. That is a total of about 137064 m^2 [7-10]. The work measured green spaces on digital slant aero-photogrammetric images of Block 67 covering green areas and potentially green spaces on construction parcels (GP1-GP6) (Figure 2). The total area of Block 67 obtained by measuring, digital processing on the slant aero-photogrammetric images is 190800 m^2. The area of construction parcels covered by the Urban Project is 137064 m^2 and consists of 9 building plots. Given the possibility of greening roof surfaces and the importance of greening, the research aims to indicate the possibility of improving the environmental performance of the subject area.

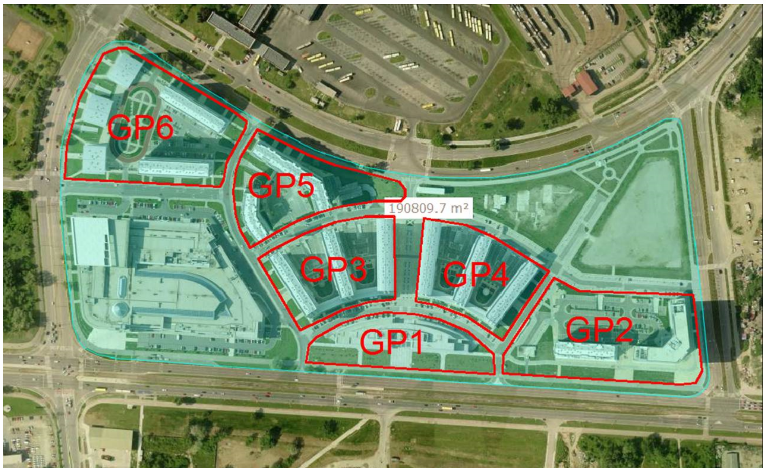

Figure 2 – Construction parcells (GP1-GP6) of the "Belvil" complex

2.2. GREEN ROOFS

Green roofs known as roof gardens date back to the time of Babylon, and today they are of great importance for contemporary architecture and contemporary man, both because of their aesthetic and functional purposes and because of the impact they have on the development of biodiversity in urban environments, and on raising environmental performance. In urban areas, green roofs gain importance especially in the context of climate change, contributing to the increase in the overall area under vegetation. The construction of green roofs is increasingly being implemented, as a measure, to ensure conditions for adaptation of environments to climate change by increasing the green area that is missing the most in major cities. Given the fact that rooftop areas occupy almost one-quarter of the total area of urban space in the central parts of the city, green roofs are increasingly becoming an integral part of urban spaces and green infrastructure as one of the increasingly important "passive techniques" for regulating the need for cooling and heating of buildings. Green roofs have many positive impacts such as:

- They affect the quality and quantity of atmospheric waters.
- They are increasing the effects of heat islands.They are affecting air quality improvements.
- They improve the biodiversity of urban environments.
- They are making noise reductions.

- They prevent the degradation of the roof membrane and more than double its lifespan.
- They reduce overall energy consumption for heating and cooling.
- They contribute to the aesthetic and ambient values of urban environments.
- They protect against ultraviolet radiation.
- They increase the overall area under vegetation in urban areas.

3. RESULTS AND DISCUSSION

By digitizing the surface on Penta with aero-photogrammetric scans and processing of measurement results with adequate software, results of measuring the green surfaces of "Belvil" settlements have compared to the results of the Main Project (GP) and the results of the Urban Settlement Project (UP), where P is the surface of the plot, ZK is potentially green surfaces (roofs), and ZP is existing green surfaces according to measurements of slant aero-photogrammetric imaging.

Table 1 – Construction parcells (GP1-GP6), green areas and potentially green roofs in m^2

Parcel	P	UP	GP	ZP	ZK
GP1	4387	4485	2945.2	2953.1	3690.8
GP2	11744	4957	1351,2	3799.9	2876.8
GP3	12666	773	1978.77	1315.1	3664.1
GP4	12666	3353	1632.85	1315.1	3864.0
GP5	9897	3981	4557.23	4141.8	2098.2
GP6	18623	2167	6172.4	4859.2	4557.7
ΣGP	69983	19216	18646.65	18391.2	20751.6

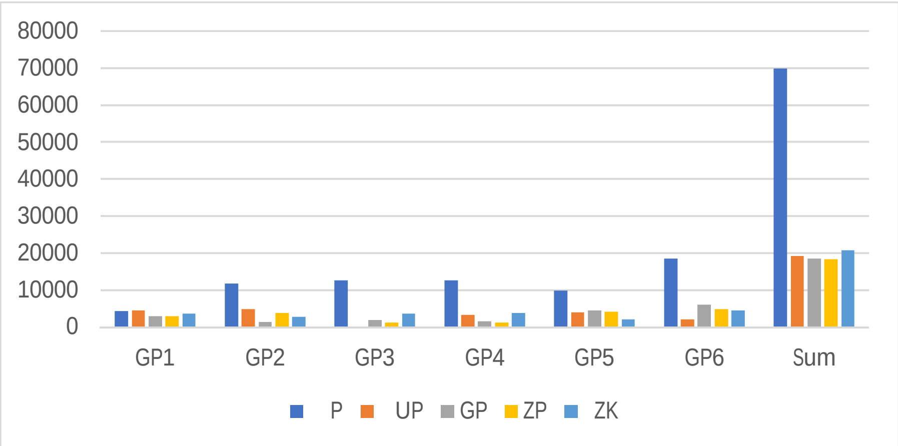

Figure 3 – Graphical representing of the surface of building plots based on Table 1

The total green area and potential green roofs represent 39142.8 m^2. The current state of derivative green areas obtained by digital processing of Penta aero-photogrammetric images within the case parcels (GP1-GP6) of the settlement shows that it is less than the planned surfaces per project documentation by 255.45 m^2, i.e., 0.36% for the "Belvil" settlement. Green spaces given to the Main Settlement Project are lower by 569.35 m^2 than the green spaces of urban projects, representing 0.81% for "Belvil" settlement (see Table 2). According to the measurements, the total area of green space and future green roofs is 55.93%. Table 3 is given a view of green areas relative to the population according to UP, GP, and based on measurements of green surfaces by digital processing of Penta aero-photogrametric images.

Table 2 – View of green areas based on UP and GP

	UP	GP	ZP	ZK
% ZP	27.46%	26.64%	26.27%	29.66%

Table 3 – View of green areas (level of settlement greenery) relative to the population of settlements

	UP	GP	ZP	ZK
m^2 ZP	3.20 m^2 ZP per resident	3.10 m^2ZP per resident	3.07 m^2 ZP per resident	6.52 m^2 ZP per resident

The results of measuring green areas based on digital processing of recordings show that they are highly compliant with green area data from the Main and Urban Project. The accuracy of comparative analyses of the green surfaces of the subject area with digital processing depends on the quality of aerophotogrammetric images, software, quality of recording resolution, quality of digitization of line elements of green surfaces, meteorological conditions of aerophotogrammetric imaging, and experiences of operators processing spatial data of green surfaces.

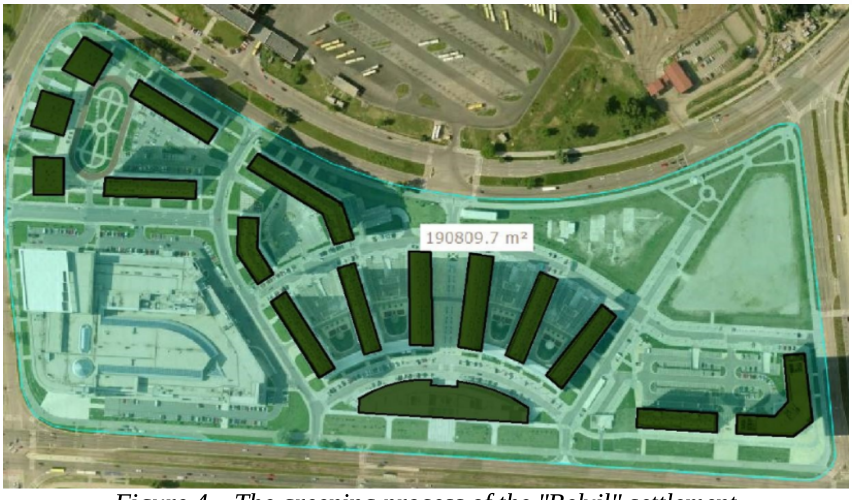

Figure 4 – The greening process of the "Belvil" settlement

To improve environmental performance, the results of the study point to the possibility of greening roofs, as in Figure 4. The current state of derivative green surfaces and surfaces of green roofs obtained by digital processing of Penta aero-photogrammetric images within the subject parcels of the GP1-GP6 complex shows that they are larger than the planned green areas per Main Project for 20496.15 m^2, and according to the Urban Project for 19926.8 m^2. Compared to the projected population (6000), Table 3, the level of settlement greenness according to UP is 3.20 m^2 ZP/ per resident and GP 3.10 m2 ZP/ per resident. According to aero-photogrammetric measurements of green surfaces, based on the processing of recordings 3.07 m2 ZP/ per resident. Derived green areas and green roofs (for 14 residential and 2 office buildings) measured by digital processing of "Belvil" complex provide 6.52 m2 ZP / per resident. The possibilities of applying different images used to improve environmental performance are numerous [11-13].

4. CONCLUSION

Digital aerophotogrammetry recordings, using the appropriate software, open up new possibilities for quality spatial analysis. In addition to application in the field of urban planning, they could be used for engineering design purposes, in the reconstruction and rehabilitation of buildings, in the process of legalization of illegally erected buildings, in the real estate market, processing facilities and fees for the use of construction land, in managing risk situations for the needs of fire departments and emergency services, tourism, etc. The paper analyzed numerical indicators of the environmental performance of "Belvil" settlements. The results obtained by the mowed aero-photogrammetry images show that if the roof surfaces are greened, greenery in square meters per resident could be significantly increased. Space planning can be significantly affected by high-resolution aero-photogrammetry images in a 3D model of the terrain. The results obtained for this case area show that the accuracy of the measurement meets the needs of landscaping.

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АНАЛИЗА НУМЕРИЧКИХ ИНДИКАТОРА ЕКОЛОШКИХ УСЛОВА КОМПЛЕКСА "BELVIL" ПРИМЕНОМ АЕРОФОТОГРАМЕТРИЈЕ

Резиме: *У условима прогресивних технолошких достигнућа, савремено планирање непрекидно трага за но-вим иновативним методама квалита- тивних просторних процена. Као једна од мера за обезбеђивање услова за адаптацију урбаних средина на кли- матске промене, све више се приме-њује изградња зелених кровова. Циљ рада јесте да анализом нумеричких индикатора еколошких услова на примеру комплекса „Белвил“ у Блоку 67 укаже на могућност развоја зеле-них кровова у циљу унапређења еколошких и функционалних перфор-манси. Нумерички индикатори добије-ни су мерењем потенцијално зелених кровова и зелених површина на косим дигиталним аерофотограметријским снимцима високих резолуција, и на основу података из Урбанистичког плана и Главног пројекта насеља.*

Кључне речи: *зелени кровови, дигитална фотограметрија, нумери- чки индикатори, екологија*