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Research paper

DESIGN AND IMPLEMENTATION OF GREEN ROOFS: A CASE STUDY IN NIŠ

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Abstract

Green roof is one of the elements of green infrastructure to compensate for the loss of green areas in urban areas, due to increasingly intensive urbanization and the need to build on existing undeveloped areas. There are different types of green roofs, from extensive to intensive, which differ in the type of vegetation planted on them, access options, functions that can be performed on them, etc. They play an important role in preventing and mitigating the negative impacts of climate change, as well as the occurrence of heat islands in the most populated urban areas. Their implementation was common in the world at the end of the 20th and beginning of the 21st centuries, however, Serbia is only at the beginning of the development of this modern practice. The paper lists the characteristics of green roofs, their types and methods of application. The paper focuses on a case study in the city of Niš, on researching their implementation.

Key words: *Green roof, Extensive green roof, Intensive green roof, Design of green roof, Niš*

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1. INTRODUCTION

We are witnessing the constant various challenges that the world is facing due to climate change and increasing urbanization. According to data, it is predicted that urbanization will reach approximately 83% in 2030 [1]. Also, it is a significant fact that cities occupy only 3% of the Earth's surface, but account for 60-80% of global energy consumption, 75% of global carbon emissions and more than 60% of resource use [2]. Urbanization is recognized to the greatest extent in them - in areas that are the most populated and in which the problem of degradation of natural landscapes, especially open spaces that are used for construction purposes, is recognized [2]. This is automatically reflected in the appearance of urban heat islands. Also, in addition to the fact of excessive energy consumption, the fact that air pollution is at a high level in Serbia is also extremely important. There is a possibility, through an interdisciplinary approach, to respond to the mentioned challenges through new solutions adapted to nature and the space where they are implemented. One of the solutions or answers is the creation of new green areas by introducing various elements of urban green infrastructure (UGI).

Many cities in the world are already striving towards a solution and creating conditions for a better, healthier life by defining plans for creating sustainable cities, eco-cities, precisely by implementing the elements of UGI. It promotes integrated spatial planning by identifying multifunctional zones and incorporating habitat restoration measures and other connectivity elements into various land use plans and policies, such as connecting peri-urban and urban areas. Multifunctionality provides a wide range of environmental, economic and social benefits.

In Serbia, according to the General Regulatory Plan that was valid in the earlier period, it was necessary to maintain or create a minimum of 10% of green areas that are in contact with the ground on the plot. According to the latest version, the percentage of green areas was increased to 25%, of which 10% of the plot area is under green areas in direct contact with the ground [3]. Green areas mean all green areas, including high greenery, green roofs, greenery above underground floors. In this connection, one can see the increasingly frequent appearance of one type of UGI in projects for the construction of new buildings. It is a green roof (GR).

The paper briefly mentions the main characteristics of the GR and presents its main typology. The aim of the work is to research design and implementation of GRs in the city of Niš. Although there are more than 10 examples of GR implementation on top of buildings in the city, the paper selected an analysis of a total of 6 examples of practice, divided into three public buildings and three residential buildings. The main criteria for selection were: year of construction no older than 10 years, location in the city center or wider, an equal number of residential and public buildings and selection of extensive and intensive examples of GRs. The paper, by analyzing a case study of six selected GRs in the city, expects to answer the following questions: 1) Are GRs exclusively planned and implemented on newly constructed buildings or is there a case on old buildings as well?; 2) On which buildings are intensive GRs more often designed, and on which extensive ones?; 3) What is the current state or appearance of the implemented GRs - are they adequately maintained?

2. GREEN ROOF – TERM, STRUCTURE AND CHARACTERISTICS

GR represents one of the effective solutions for the implementation of green spaces when one of the main problems is the lack of free green spaces in the urban core. This is supported by the information that roofs make up almost 20-25% of the total urban area [4], that is, about 32% of the horizontal surface of built-up areas [5]. The application of GR has recognized numerous benefits, most of which relate to the provision of different

categories of ecosystem services, including support services, supply services, regulatory and cultural services (MA, 2005). Therefore, its application advantage is reflected in the positive impacts it has from the ecological, economic and social [6] aspects.

2.1. Structure and typology of green roofs

A GR consists of several components/layers including vegetation (plants), substrate, filter layer, drainage material, waterproofing, root barrier, thermal insulation, vapor barrier and roof structure [7]. Depending on the desired results and financial possibilities, as well as the duration of implementation, the concept and number of components or layers during implementation may vary. However, each component plays an important role in the functioning of GRs and it is not desirable to eliminate it at the same time. The type of each GR component depends primarily on the geographical location where it is implemented [7].

There are two basic types of GRs, depending on the future purpose, type, number and size of greenery, i.e. the thickness of the substrate in the layers of the roof: intensive and extensive GR. Depending on the desired results and financial possibilities, the concept and number of components or layers during implementation may vary, however, each component plays an important role in the functioning of GRs and it is not desirable to cancel it during the same. The type of each GR component depends primarily on the geographical location where it is implemented. The basic division of GRs is into intensive and extensive GR.

- **Extensive green roofs**

Extensive GRs, depending on the roof structure on which they are installed, can be flat or sloping. They are characterized by a thin substrate layer (less than 15 cm), lower costs, light weight and minimal maintenance [7]. Therefore, the advantage of extensive GRs is reflected, among other things, in that they can be installed on almost all roof structures of any building because they have a low specific weight. Also, they do not require an irrigation system. This type of GR supports plant species that have a small root system and can easily withstand high temperatures and drought.

- **Intensive green roofs**

Intensive GRs are almost identical to the natural habitat of plants on the ground, that is, they represent a landscape-architecturally designed garden on the roof of the building [8]. They are characterized by a thick layer of substrate (20-200 cm), a wide selection of plants, a high degree of maintenance and greater weight [7]. A wider selection of plants refers to shrubs and taller plants from 50cm to 4m. The thickness of the substrate layer depends on the desired vegetation that will be planted on the roof. The cost of construction as well as the cost of maintenance is very high compared to other types of GRs. This type of GR requires the most maintenance, constant fertilizing and watering is necessary. For watering, i.e. irrigation, it is recommended to collect rainwater, which is later, after collection, absorbed in the soil. Intensive GRs can contain all the same elements as classic green areas - paths, furniture, lighting, various garden-architectural elements such as pergolas, walls and the like. Judging by the mentioned facts, it can be said that such GRs provide a complete possibility of relaxation, recreation and at the same time socialization in addition to the visual-aesthetic impact on the environment.

2.2. Advantages of applying green roofs

The application of GRs enables regulatory services: 1) rainwater collection and its infiltration - control of the quantity of rainwater runoff [7]; 2) improving the quality of rain runoff; 3) reducing the temperature [9]; 4) mitigation of the heat island effect; 5) reducing

the negative impact of noise [10]; 6) improvement of air quality [11]; 7) improvement of microclimatic conditions, support services: improvement of biodiversity [12], supply services: 9) application of urban agriculture and cultural services 10) recreation and education [13].

In addition to the greening of facades, the greening of roofs is, in the context of structural improvement, the only sustainable measure that also has visual significance. The visual impression itself is directly related to the increase in the market value of the real estate within the facility where it was implemented, which represents a significant value from an economic point of view. The most significant economic benefits at the building level refer to savings in energy consumption to achieve thermal comfort, extended life of the roof structure [2] and the use of GRs for the development of agriculture.

Social benefits are primarily observed with intensive GRs, which, among other things, are designed as passable and accessible to people for various types of activities. Their existence and use affects the improvement of people's physical activities and healthy lifestyle. GRs can be used for the study of flora and fauna, and therefore it can be concluded that it has a role in the mentioned sphere of education. Also, they can be rearranged by introducing adequate furniture in the park areas on the tops of the buildings with the possibility of use throughout the day. Therefore, GR serves to create additional usable area on top of a building.

3. APPLICATION OF THE GREEN ROOF - A CASE STUDY IN NIŠ

The city of Niš, which is the third largest city in Serbia in terms of size and number of inhabitants, was selected for the case study. In the continuation of the work, a total of six residential and public buildings where GRs have been implemented so far are presented.

3.1. Business building, Vizantijski Boulevard

As part of the wider city center, a GR has been installed on top of a public building on Vizantijski Boulevard in Niš (Figure 1). It is a P+3 storey building that is the center of three companies - Dualsoft, UFC Holding and KAPAPROJEKT. The last, third floor, as well as the roof of the building, belongs to the company KAPAPROJEKT.

Figure 1. Marked location and view of the object, Google maps, Author's archive

The facility was built and officially opened in March 2023, when the GR on top was implemented. Considering the location where it was built, from the top there is an impressive view of the surrounding greenery and the river Nišava. In the initial phase of the project, there was no greenery on the roof but, In one of the following phases, it was decided to implement an extensive GR on the top of the building. Of the total roof area of 471.25m^2, 86.38m^2 was selected for green space (Figure 2a). The urbanscape greening system produced by KnaufInsolation was chosen (Figure 2b). Its features are numerous and it is distinguished by its innovation, light weight, simple installation, high water retention capacity, etc. In particular, the choice was a modular roof in cubes, which is recommended for smaller square footage and all elements of which, except for the

anti-root membrane, are delivered in cubes measuring 50x50cm. The layers of the selected GR consist of: 1) basic roof structure; 2) waterproofing; 3) urbanscape anti-root membrane; 4) urbanscape drainage system; 5) urbanscape green roll substrate and 6) urbanscape cover with sedum mix (Figure 2c).

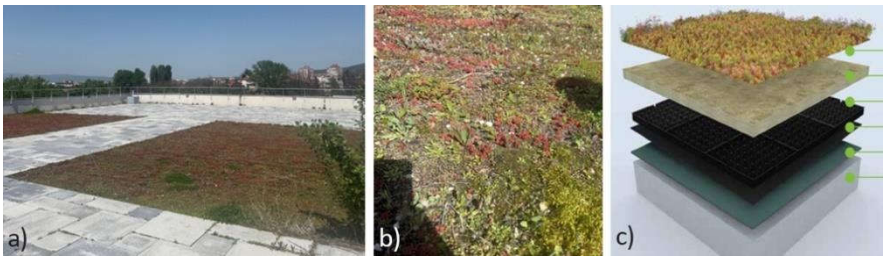

Figure 2. (a), (b) Current appearance of the GR (April 2025), (c) KnaufInsolation system - view of the roof layers, (a), (b) Author's archive, (c) https://knauf.com/sr-RS/

The original idea was to place planters on the roof with planted thuja trees that will be irrigated with a drip system. However, it was not an ideal solution. Most of the thuja trees dried up, and the rest were transplanted in the garden that belongs to the parterre landscaping around the building (Figure 3a). Also, the greenery on the roof is not maintained in the best way, it has also sprouted along the perimeter of the roof, along the linear gutter that extends to the other end of the roof (Figure 3b) and among the succulents (Figure 3c).

Figure 3. (a) Dried thuja in planters; (b) Weeds along a linear drain; (c) Weeds among succulents, (a), (b), (c) Author's archive

3.2. Science and Technology Park, Aleksandra Medvedeva Street

The Science and Technology park in Niš was built and opened in 2020. It is located in the immediate vicinity of the technical faculties, at the location Gradsko polje, on Aleksandra Medvedeva Street (Figure 4). The facility consists of a basement, ground floor and three floors intended for young researchers and innovative companies. The premises in the building are mainly offices, multifunctional halls and amphitheatres for holding larger gatherings such as various conferences and scientific meetings.

Figure 4. Marked location and view of the object, Google maps

On the third floor of the building, on the edge of the terrace, as well as on the roof, an attempt to implement GR is visible, which is designed in terms of the selection of layers, as an extensive roof, and in terms of purpose and use, as an intensive GR (urban

furniture has also been installed). Including the terrace and roof, the greenery covers an area of 930 m^2. Figure 5 shows the condition of the roof during the implementation of greenery (Figure 5a) and the current condition (Figure 5b). It can be seen that the maintenance is not at an enviable level, that there is no greenery except in the planters, where thujas are planted. One of the main mistakes that resulted in the current look is choosing and placing silt instead of substrate. In these situations, the material can pass through the textile and flood the accumulation drainage panels. The plan is to transform this surface soon, but this time with the selection and placement of appropriate layers.

Figure 5. Current appearance of the GR (April 2025), Author's archive

3.3. Annex of the Faculty of Electonic Engineering, Aleksandra Medvedeva Street

The last selected example of the implementation of a GR on a public building is located next to the previous one, within the complex of technical faculties. It is a multi-purpose slat built as an annex of the Faculty of Electronics in 2020 (Figure 6).

Figure 6. Marked location and view of the object, Google maps, https://www.gradnja.rs/visenamenska-lamela-elektronskog-fakulteta-nis-teking/

In order to achieve greater sustainability and the life cycle of the building as well as the impact of the building on the environment, the flat roof was designed as an extensive GR on its impassable part. The greenery was designed on two surfaces, in a total area of 400 m^2.The flat terrace is made of the following layers - green layer of soil with plants, drainage layer Sarnavert Aquardrain 550, FPO membrane Sarnafil TG 66 thermal insulation HPS 20cm, vapor barrier Sarnavap 5000E, concrete layer for fall, reinforced concrete slab, extension mortar [14]. Similar to the previous example, after analyzing the current state, it is concluded that the maintenance is not at an enviable level (Figure 7).

Figure 7. Current appearance of the GR (May 2025), Author's archive

3.4. Residential and business building, Nemanjića Boulevard

The newly built building at the end of Nemanjića Bulevard in Niš is a residential and business building with Po1+Po2+8 floors (Figure 8). On the roof of the building, on the 9th floor, a GR was designed and built on a gross area of 0.12 ha.

Figure 8. Marked location and view of the object, Google maps

The idea for the implementation of the GR was to provide tenants with an oasis of peace and greenery within the roof garden, from where an impressive view of the entire city is offered. One of the wishes of the investor of the building was that by greening the top floor, the building would be further tucked away and isolated from negative influences. By greening and planting numerous species of plants, the GR also provides a new place for the creation and development of biodiversity, a new place for birds and insects. Of course, primarily a space was created for the building's residents to meet and relax.

Of the total roof area of 1200 m^2, 800-900 m^2 is covered with sedums, while the rest is made up of paths. The BioPixel system was selected and more than 30,000 different plant species were planted (Figure 9). The growth of plants, ie the formation of a green cover, is ongoing. Extensive vegetation as well as ornamental grasses and ferns were selected for planting.

Figure 9. Presentation of the GR implementation, https://www.zelenikrov.rs/

At the moment, a more intensive development of vegetation on the surface of the roof has begun, as shown in the following photos (Figure 10).

Figure 10. Current appearance of the GR (April 2025), Author's archive

3.5. Residential and business complex Planet Residence, Blagoja Parovića Street

Planet Residence represents a newly built residential and business complex in Niš, located in Blagoja Parovića street (Figure 11). The complex is made up of 13 floors that make up the residential part of the building, the mezzanine, ground floor and

underground garage, which include public spaces and a parking space. The structure of the apartments ranges from studios to penthouses. On the first floor, above the mezzanine, as part of the residential part, there is a courtyard intended exclusively for tenants. The yard is designed as an intensive GR and covers an area of 2800 m^2.

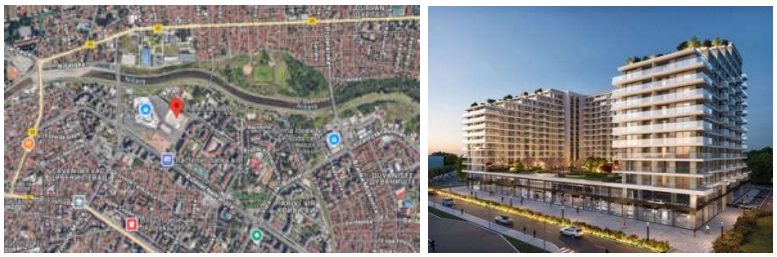

Figure 11. Marked location and view of the object, Google maps

The implementation of the GR took about half a year, which included all the steps from the pictures below (Figure 12). The first step was to mark the exact positions where the paths will be and where the greens will be. Accordingly, a drainage layer was installed in the form of drainage-accumulation panels filled with natural gravel. A geotextile was placed over it, on which a layer of crushed stone was later sprinkled. Behaton was intended for the trails. Large planters were placed in positions where high greenery was planned. The tall greens are carefully raised with a sizer. Also, in addition to tall greenery, low and medium-high greenery was also raised in the form of various types of plants that were planted around the planters and along the perimeter of the yard, next to private gardens. Due to the deadline for the implementation of the project, but also according to the recommendation of the landscape architects who participated in the implementation, instead of the traditional planting of grass, grass in the form of sod was installed. With a sufficient number of people participating in the trimming and laying of sod, the area was completely greened after one day. The green areas are irrigated using a drip irrigation system and using jet grass sprinklers.

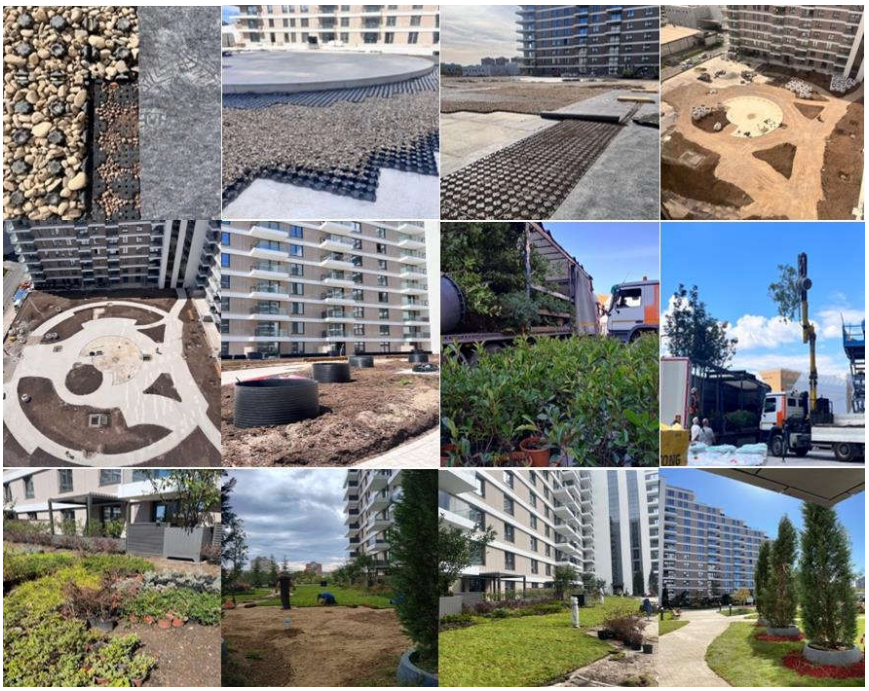

Figure 12. GR Implementation Steps (March 2024 - Sept. 2024), Author's archive

The following species were selected for the greenery planted as part of the GR: Lavender, Liriope muscari, Tiarella, Pennisetum little bunny, Spiraea golden carpet, Evonimus beucom, Verbena bonariensis, etc. Finally, the appropriate furniture was selected and installed. Benches and bins for small waste have been placed in the area intended for the building's tenants to gather, strengthen their relationships and relax. In the central part, there is a children's play area that includes swings and a large slide. Lighting is installed in the form of small reflectors positioned in planters that illuminate the treetops and in the form of columnar elements arranged around the perimeter of the paths. White quartz sand was placed along the entire length of the paths, and mulch was sprinkled around the planters (Figure 13)..

Figure 13. Current appearance of the GR (March 2025), Author's archive

3.6. Residential and business building, Vojvode Tankosića Street

The residential and commercial building in Vojvode Tankosića Street, located in a residential block with a high density of housing in Niš, is another example of a building with a GR on top. The construction of the building was completed in 2015 (Figure 14).

Figure 14. Marked location and view of the object, Google maps, Author's archive

Forty-four residential units, two business units and an underground garage are provided for in the project terms of reference. It was designed without bay window overhangs towards the street, with a composition of a dominant white cube with window openings in the living rooms. The structure of the apartments ranges from one- and two-bedroom apartments. The roof of the building intended for intensive use by the tenants, for relaxation and their gathering, is enriched with greenery on an area of about 100m2. The focus was primarily on the selection of low and medium height greenery in the form of turf and bushy plants. The project also provides for the arrangement of the main path and the fence on the roof (Figure 15). It is adequately maintained.

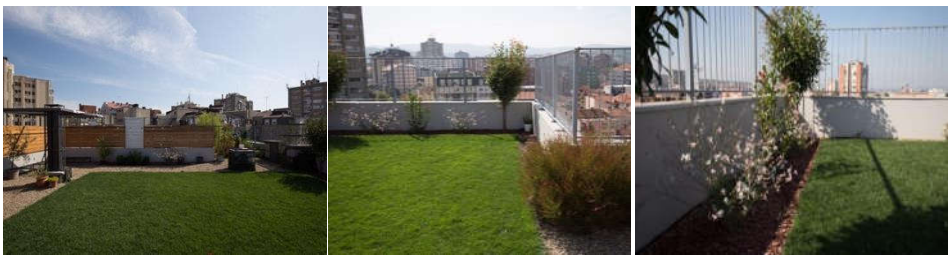

Figure 15. Appearance of the GR after implementation, Author's archive

4. DISCUSSION

During the analysis of the case study in the city of Niš, it is primarily noted that GRs are slowly becoming a practice during the design. The question arises whether awareness of the benefits of green areas on buildings has increased or whether the progress is solely a consequence of the introduction of new regulations, i.e. an increase in the percentage of required greenery on the plot where the building is being built. It was also determined that the planting of greenery was carried out immediately after the construction of the buildings, so that examples exist exclusively in new construction. Most of the GRs presented in the paper are designed as extensive in terms of layer selection, and intensive in terms of purpose and use. Tall greenery is planted in planters that are later placed on the roof.

By analyzing the buildings given in the paper, it is clearly observed that green covers are installed on both residential and public buildings The paper lists three public buildings with green covers - the Science and Technology Park on Aleksandra Medvedeva Street, the Annex of the Faculty of Electronics at the same location and the building where Kapa Projekt is located, on Vizantijski Boulevard. Other three objects are residential&business buildings in the city core. The use of various systems was observed for the implementation of GRs on the analyzed buildings. The choise depends on the completion date of the works, the cost of the system, and the plants that need to be installed.

Although most of the analyzed green areas date back no more than a decade, it is noted that some of them have not been adequately preserved and treated. These examples are observed exclusively on the roofs of buildings that are for public purposes, which is interesting given that in terms of layers they are designed as extensive GRs that are simpler and less frequently maintained. The Table 1 also provides insight into the fact that intensive roofs are more often designed on residential buildings in order to create additional space for residents to gather and relax.

Table 1 - Analysis of all objects with GR selected in the work

No.	Location In Niš	Use (public / residental)	Year (construction)	GR Type (intensive / extensive)	Current state (green-good / red-not good)
1	Vizantijski Boulevard	Public	2023	Extensive	
2	Aleksandra Medvedeva Street	Public	2020	Extensive / Intensive	
3	Aleksandra Medvedeva Street	Public	2020	Extensive	
4	Nemanjića Boulevard	Residential	2024	Intensive	
5	Blagoja Parovića Street	Residential	2024	Intensive	
6	Vojvode Tankosića Street	Residential	2015	Intensive	

5. CONCLUSION

The application of GRs in city centers is considered a sustainable measure to improve the condition, microclimate and living conditions, especially in areas where there is a constant appearance of construction and occupation of free open areas. Also, the advantages that GRs provide at the level of the facility, from the economic and aesthetic side, have been observed, and are reflected in saving and energy consumption,

increasing the market value of facilities, visually more attractive appearance of the facility, as well as extending the life of the existing structure.

More frequent design of GRs has been observed since the previous decade. The first conclusion is that the application of GRs has so far been recorded only on newly built buildings. The reason for this data is primarily the fulfillment of the minimum % of greenery on the plot. It is necessary to raise citizens' awareness of all the aforementioned advantages that vegetation on flat roofs provides and to open the issue of greening existing, built buildings in Niš. If the owners and tenants of existing buildings decide to take this step, it would be necessary first of all to examine the load-bearing capacity and condition of the current existing structure and materials on the roof, as well as the selection of an appropriate GR system and possible strengthening of the existing structure. For future projects that would relate to already existing buildings, a better option would be the implementation of extensive GRs due to the ease of installation.

Another conclusion after analyzing the case studies in Niš is that residential buildings are more often designed with intensive GRs intended for the activities of tenants of the buildings on whose roofs they are located, while public buildings are designed, in this case, exclusively with extensive GRs. However, it is necessary to note that some roofs, due to the selection of layers and types of plants planted during implementation, are considered extensive, but their very purpose and the existence of other elements such as paths and furniture make them intensive. One such example is the GR on the Science and Technology Park in Niš

The conclusion and also the answer to the third question in the paper, based on the analysis of the case study in the city, is that the current state of GRs on residential buildings is much better than the condition on public buildings. One of the possible reasons for the current unenviable appearance of GRs is the need to save money when installing greenery and the choice of lower-quality materials. Such decisions lead to long-term damage to buildings.

Analyzing the previous examples, it is important to note that after the implementation of GRs on a building, adequate maintenance is necessary. Greenery on roofs does not require daily maintenance and watering. It only needs to be watered a few times a year to prevent it from falling into winter hibernation.

Observing other buildings in the city of Niš, which according to the design have a GR on top and realizing that it has not been implemented, it is concluded that there is insufficient control and verification of completed works in the city during the technical acceptance of the building. During the inspection of the performed state, it is necessary to take a detailed look at all segments of the project. Therefore, a special appeal has been made to strengthen controls during the technical acceptance of the building as a main measure for the well-being of all.

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