Urban Heat Islands in Skopje

Analysis and Action Plan

December 2018

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1 Urban Heat islands

Urban Heat Islands (UHI) is an effect which occurs in metropolitan or urban areas of the big cities because of the tightly packed buildings and paved surfaces that makeup cities to amplify and trap heat far more effectively than natural ecosystems and rural areas, which are often shaded by trees and vegetation and cooled by evaporating moisture. Cities also generate their own heat, which is released from sources such as furnaces, air conditioners, and vehicles.

Additionally, climate change effect that is happening now days will lead to higher temperatures and longer, more severe, and more frequent heat waves. Urban areas already suffering from the heat island effect will bear the brunt of these harsher heat events. Over the last years, the extreme summer heat has become more frequent across the world. The interaction of rising temperatures, more heat waves, and the heat island effect will be increasingly harmful to people's health and the air and water quality in our communities.

1.1 Methodology

In order to investigate the existence of heat islands in Skopje, team from FINKI organized airborne imaging with thermal and RGB cameras of the Skopje urban area. The flight was performed on 24th of August 2018. The area recorded with the RGB camera is approximately 213 km2. This area is covered with a total of 3951 RGB images, one pixel corresponding to an area of 0.52mx0.52m per pixel. The area covered by the thermal camera is about 150 km2 and is covered with a total of 10596 thermal images, and the resolution of the pictures is 1.5m x 1.5m per pixel. These individual images were processed by Anadolu University [36] team and obtained a geo-located thermal map and a geo-located RGB map of Skopje.

In addition, the the information obtained from the microanalysis made in the summer of 2016 on the move from Vodno to the center of Skopje [38] were used. The data from the global study of heat islands made by the Center for Earth Observation at Yale University [37] was also used for this study

For the analysis of the measures for heat islands mitigation, the recommendations from the US Environmental Protection Agency have been used, as well as the recommendations of the relevant European agencies. In order to gain knowledge of how individual cities deal with this problem, approximately 300 case studies around the world were analyzed.

1.2 Results

Within this study, based on a detailed analysis a number of measures are proposed. The proposed measures are categorized into five groups:

- General strategies/measures for heat islands mitigation (offered six measures)
- Actions/measures for the municipalities and the City of Skopje (14 measures proposed)
- Actions/measures for the citizens of Skopje (proposed four measures)
- Innovative measures (proposed five measures)
- Measures for certain characteristic areas in Skopje (43 measures)

In this action plan, more than 70 actions and measures have been proposed that can be undertaken in order to reduce the effects of the urban heat islands in Skopje.

2 Main causes of the occurrence of the urban heat islands

There are several causes of an urban heat island (UHI) [25]; for example, dark surfaces absorb significantly more solar radiation, which causes urban concentrations of roads and buildings to heat more than suburban and rural areas during the day [26]; materials commonly used in urban areas for pavement and roofs, such as concrete and asphalt, have significantly different thermal bulk properties (including heat capacity and thermal conductivity) and surface radiative properties (albedo and emissivity) than the surrounding rural areas. Another major reason is the lack of evapotranspiration (for example, through lack of vegetation) in urban areas. With a decreased amount of vegetation, cities also lose the shade and cooling effect of trees, and the removal of carbon dioxide [27].

Other causes of a UHI are due to geometric effects. The tall buildings within many urban areas provide multiple surfaces for the reflection and absorption of sunlight, increasing the efficiency with which urban areas are heated. This is called the "urban canyon effect" [28][29]. Another effect of buildings is the blocking of wind, which also inhibits cooling by convection and prevents pollutants from dissipating. Waste heat from automobiles, air conditioning, industry, and other sources also contributes to the UHI [30][31]. High levels of pollution in urban areas can also increase the UHI, as many forms of pollution change the radiative properties of the atmosphere. As UHI raises the temperature of cities, it also increases the concentration of ozone, a greenhouse gas whose production accelerates with an increase in temperature.

Some cities exhibit a heat island effect, largest at night. Seasonally, UHI shows up both in summer and winter. The typical temperature difference is several degrees between the center of the city and surrounding fields.

There are a number of factors which contribute to the formation of Urban Heat Island. The factors which play a significant role in the creation of UHI are [32]:

- Low Albedo Materials: Albedo is evaluated by the ratio of the reflected solar energy to the incident solar energy. It depends on the arrangement of surfaces, materials, pavements, coatings, etc. Albedo has a direct impact on the formation of the microclimate. The albedo of a city varies according to various factors like surface arrangement i.e. orientation, heterogeneity; materials for roofs, pavements etc. If the albedo of the urban surface is low, it will store more solar energy and the effect will be increasing of urban temperature i.e. creation of the urban microclimate.
- Human Gathering: As the human gathering is prominent at the city centers owing to the availability of various facilities, emission of CO2 is also huge in these areas. CO2 stores heat, causing enhanced atmospheric temperature. The ultimate effect is that it assists in the formation of heat island to a great extent.
- Increased Use of Air Conditioner: To provide comfort to the human beings at summertime, air conditioner is massively used with a rising trend. Air conditioners keep a building cool inside, but release the heat absorbing from inside to the atmosphere. As a consequence, the outside environment is warmed leading to the increasing of atmospheric temperature.
- Destruction of Trees: To meet the demand of various urban facilities, forests are wiped out in a massive scale. Lesser trees mean less cooling efficiency. Trees intercept the

solar heat and also absorb CO2 for their own photosynthesis, making the environment cool. With the destruction of plant life, the efficiency of cooling system goes radically down, causing creation of the process.

- Urban Canopy: In urban areas, there are multilayer buildings. The heat reflected by a building is trapped by the nearby taller buildings which is known as the urban canopy. UHI is exacerbated with the formation of urban canopy.
- Wind Blocking: Due to the presence of densely situated buildings, wind velocity is reduced. As a result, the cooling effect by convection lessens. So, the heat trapped, cannot be blown out, resulting intensification of the effect.
- Air Pollutants: In the urban areas, especially in the city centers, air pollution is eminent. Exhaust gases from vehicles and industrial pollutants released in the environment, trap solar radiation. Thus, the temperature rises, and the microclimate effect becomes stronger.

3 Heat islands maps for the City of Skopje

3.1 Thermal map of the City of Skopje

One of the inputs for the analysis of the heat islands in Skopje is the thermal map created using the data collected from the aerial flight performed on 24th August, 2018.

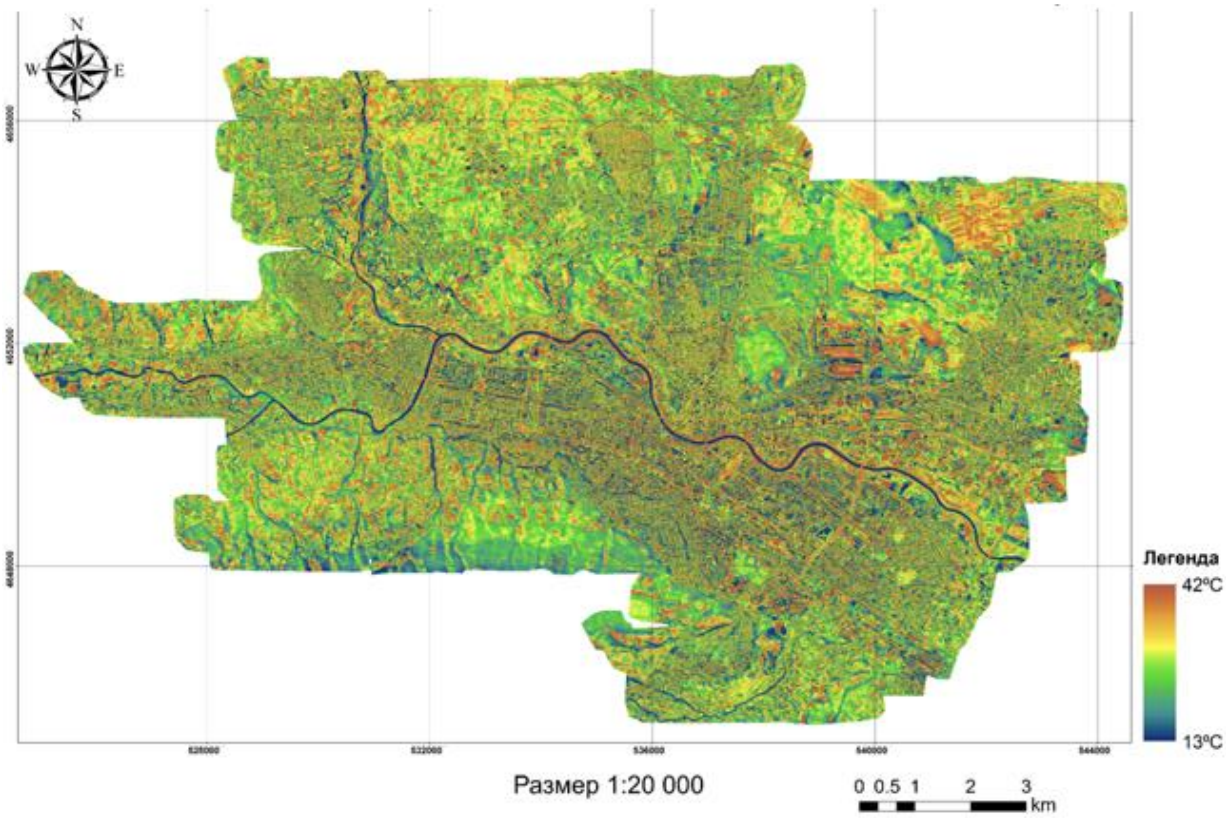

Figure 1 The thermal map of City of Skopje [36]

3.2 Identified hot and cold spots using GIS tools

Using statistical GIS tools, both hot and cold spots, or the areas that the average temperature was significantly higher or lower than the other areas have been extracted as a point cluster. The results are presented in the next Figure.

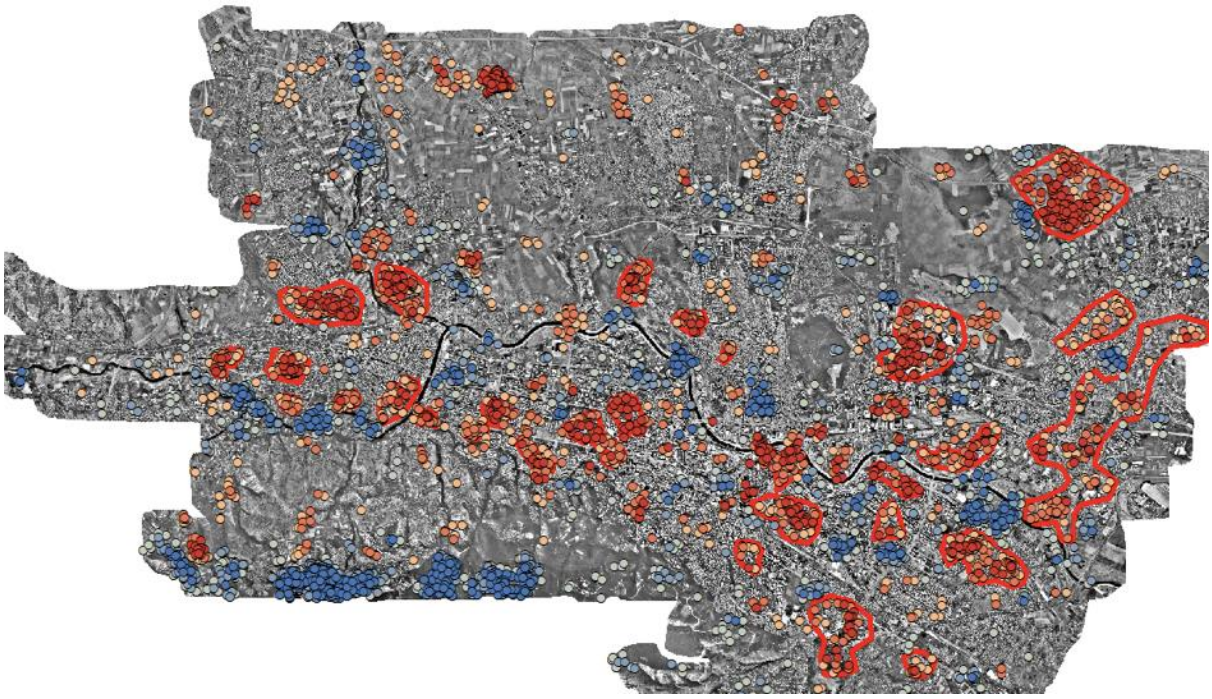

Figure 2 Identified hot and cold areas using statistical GIS tools

3.3 Urban Heat Islands (global analysis)

For a long-term analysis of the existence of urban heat islands in Skopje, we used the data from a global study of heat islands made by the Center for Earth Observation at Yale University [37]. The data obtained for the average summer day, summer night, winter day and winter night are given in Figure 3, Figure 4, Figure 5 and Figure 6 respectively.

From these data, it can be seen that in the night hours this effect is much more noticeable, especially during the winter nights.

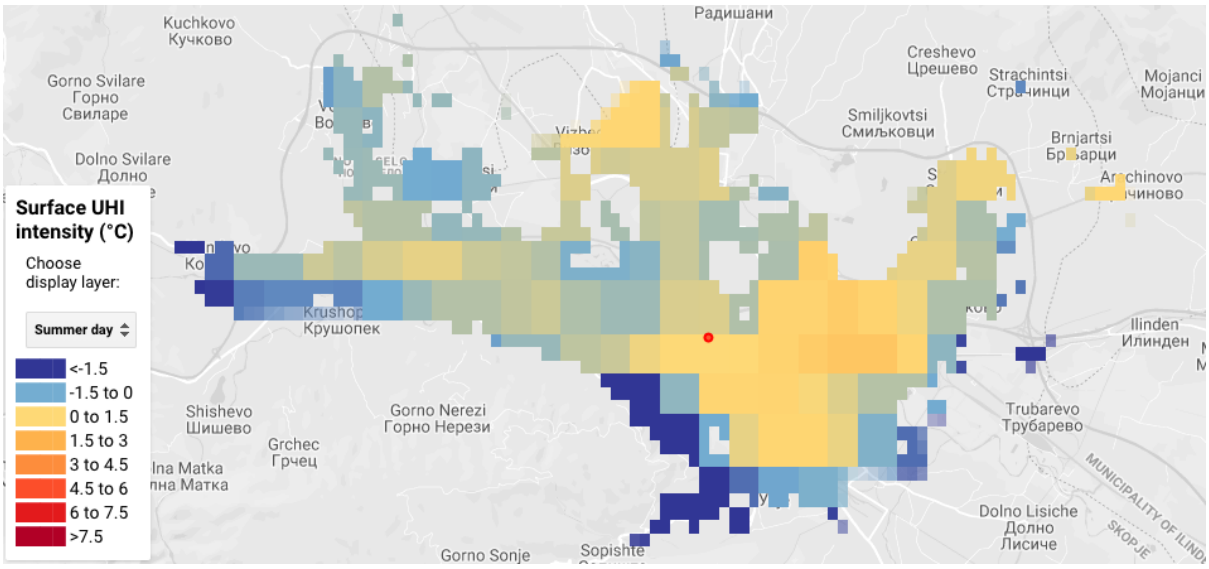

Figure 3 Urban heat islands intensity during the summer day

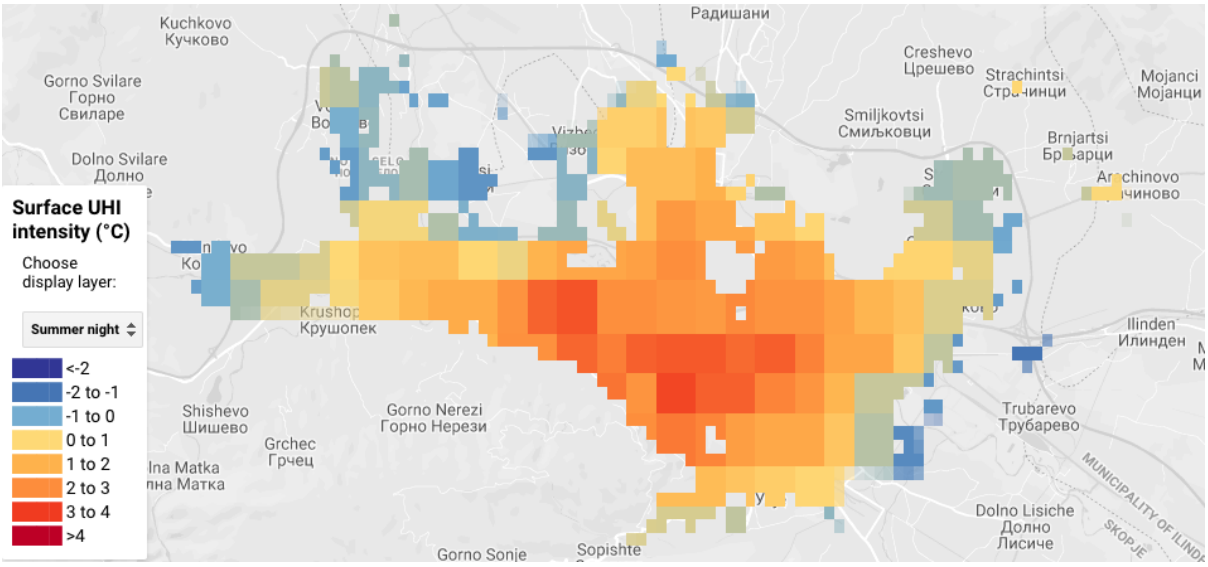

Figure 4 Urban heat islands intensity during the summer night

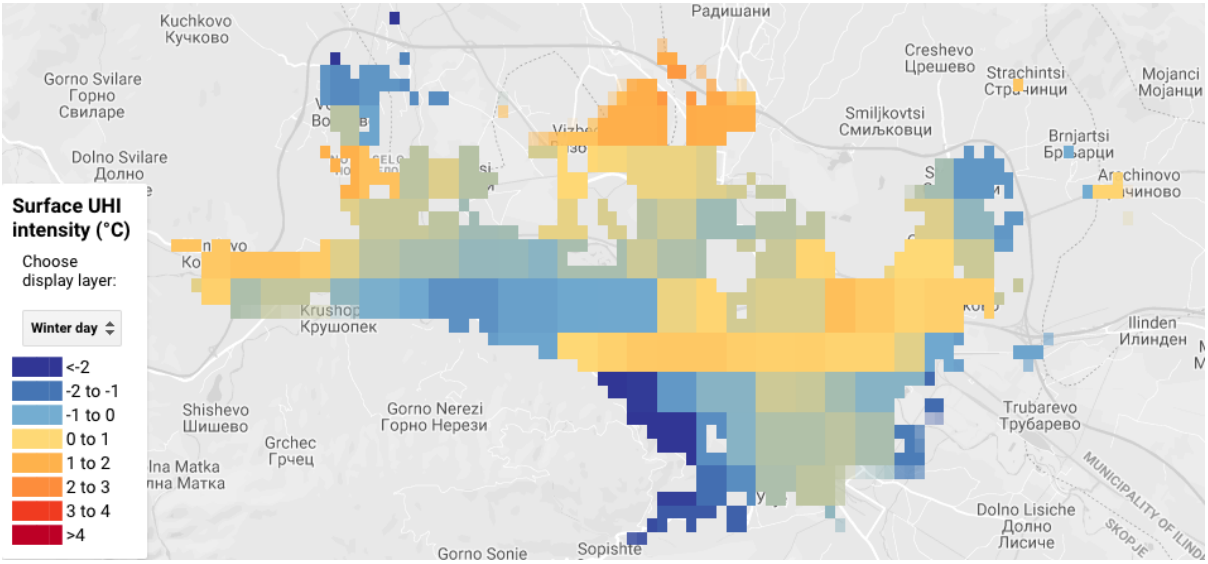

Figure 5 Urban heat islands intensity during the winter day

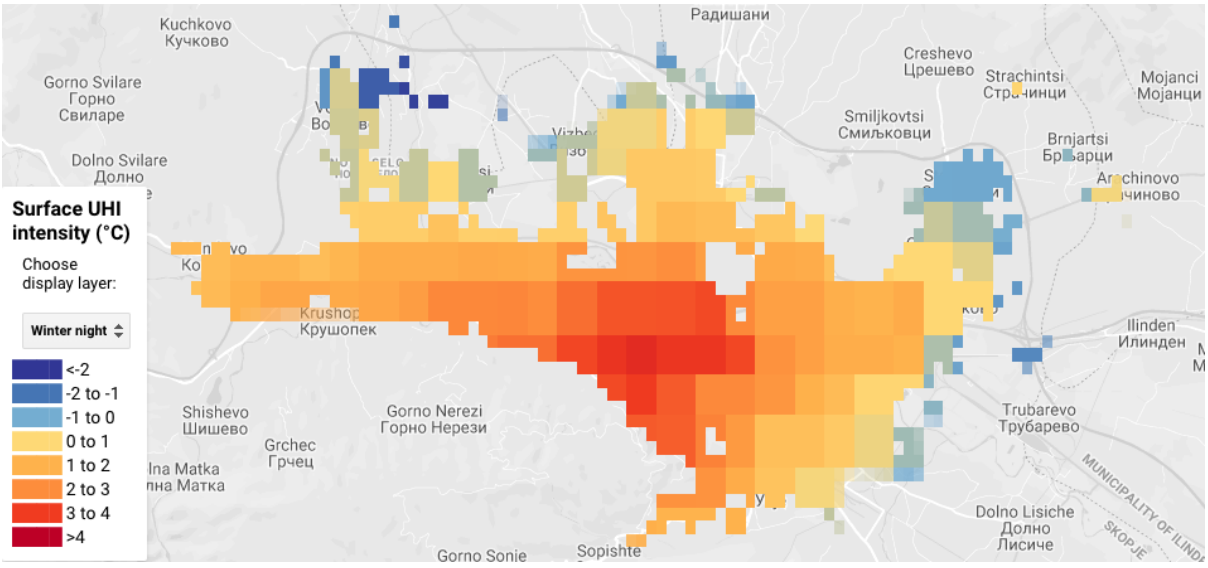

Figure 6 Urban heat islands intensity during the winter night

3.4 Temperature profile-based analysis

3.4.1 Temperature profile of Partizanska Boulevard

On Figure 7 the temperature profile along the Partizanska boulevard is shown. From the profile, it can be noticed that the temperature is higher in the region of the center of Skopje, compared to the temperature in the Gjorce Petrov settlement.

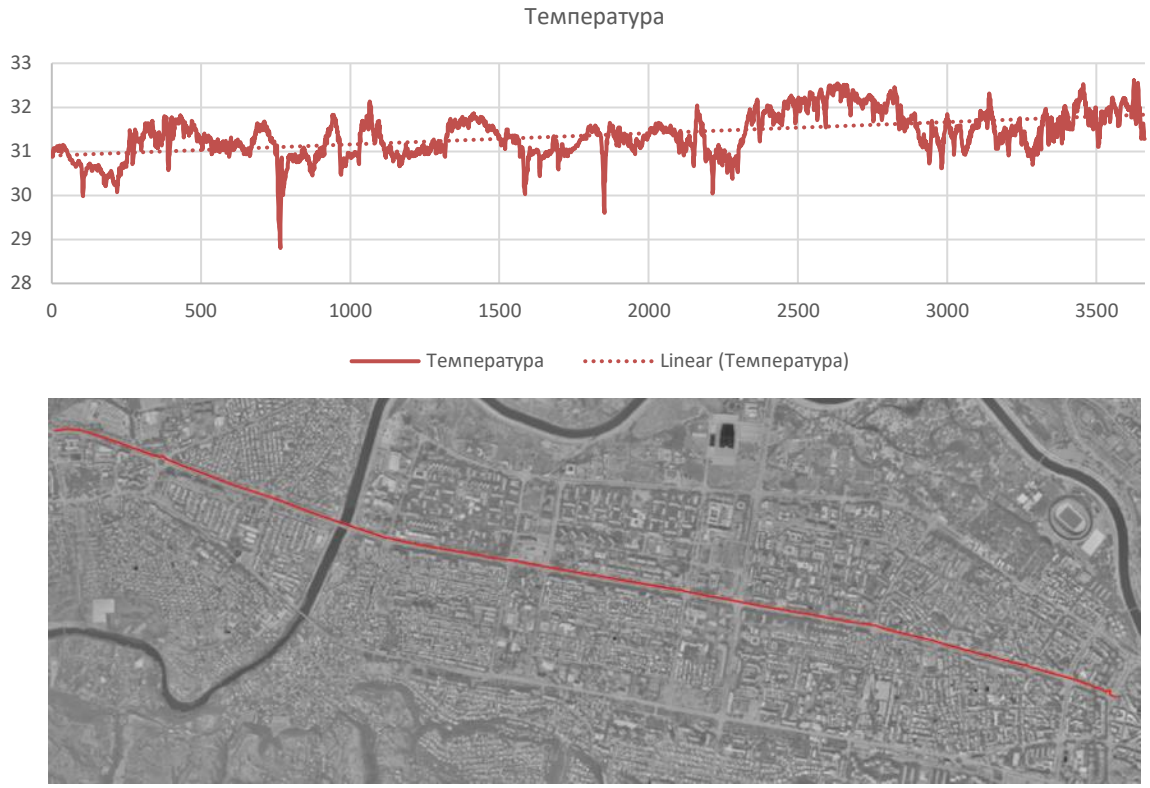

Figure 7 Temperature profile of the Partizanska Boulevard

3.5 Micro analysis of the central area

This analysis covers the central city area around Macedonia Square and the streets of Maxim Gorki and Nikola Vaptsarov. Based on the thermal images shown on Figure 8, the following conclusions can be made:

- The white color on Macedonia Square has a direct positive impact on the temperature, and it is lower than the surrounding asphalt surfaces, so the central square is cooler than the street Maxim Gorky
- The dark colored roofs are much warmer than the light-colored ones and they affect the increase in temperature
- Parked cars that are exposed to direct sunlight are also significantly hotter, and that is directly affecting the temperature increase on Maxim Gorky Street.
- Due to shade, the presence of trees, as well as the lack of cars, the Street Nikola Vaptsarov is significant cooler from the Street Maxim Gorky

Surface heating is highly dependent on direct exposure to the sun. So, at some other time of the day, we can get a slightly different result.

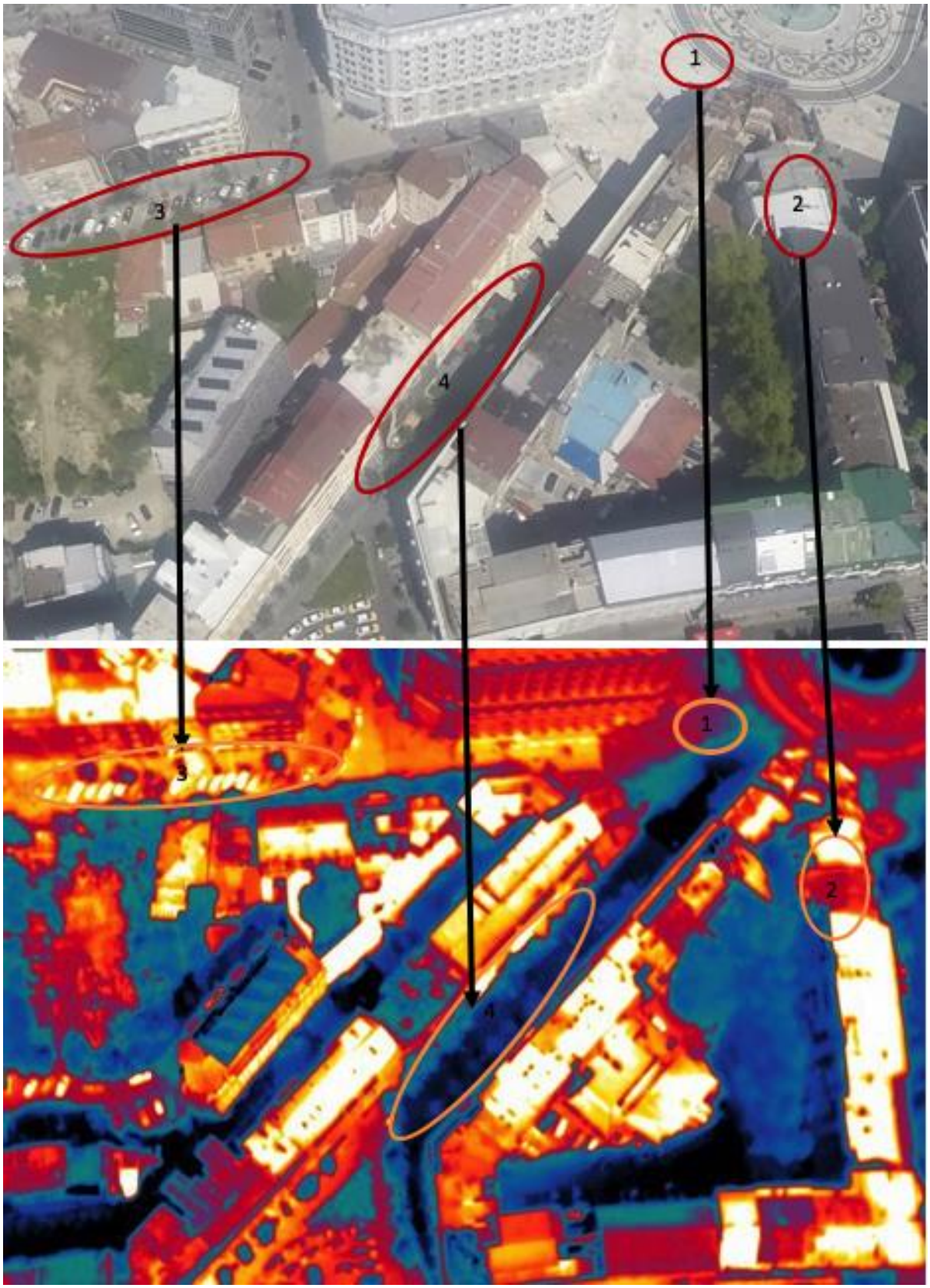

Figure 8 Micro analysis of central area

4 City of Skopje' Urban Heat Islands Action Plan

Based on the number of analyzed cases and literature review, in the following text are given strategies, measures and actions whose application would lead to reduction of the effects of urban thermal islands in Skopje.

4.1 General Heat Island Cooling Strategies

EPA, the United States Environmental Protection Agency is responsible for UHI mitigation in the US. The agency publishes and maintains a repository of UHI mitigation strategies [1]. According to EPA there are five main strategies how communities can take action to reduce urban heat islands: 1) increasing tree and vegetative cover, 2) installing green roofs, 3) installing cool—mainly reflective—roofs, 4) using cool pavements (either reflective or permeable), and 5) utilizing smart growth practices. In addition to these five measures, in this context, the strategy for creating Green Parks has been added.

4.1.1 Trees and Vegetation

Trees and other plants help cool the environment, making vegetation a simple and effective way to reduce urban heat islands. Trees and vegetation lower surface and air temperatures by providing shade and through evapotranspiration. Shaded surfaces, for example, may be 11–25°C cooler than the peak temperatures of unshaded materials. Evapotranspiration, alone or in combination with shading, can help reduce peak summer temperatures by 1–5°C. Trees and vegetation are most useful as a mitigation strategy when planted in strategic locations around buildings or to shade pavement in parking lots and on streets. Researchers have found that planting deciduous trees or vines to the west is typically most effective for cooling a building, especially if they shade windows and part of the building's roof [12].

4.1.2 Green Roof

Green roofs have been proven to help reduce heat islands. A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs provide shade, remove heat from the air, and reduce temperatures of the roof surface and surrounding air. Using green roofs in cities or other built environments with limited vegetation can moderate the heat island effect, particularly during the day. Green roof temperatures can be 16–22°C lower than those of conventional roofs and can reduce city-wide ambient temperatures by up to 3°C [2][3]. In addition, green roofs can reduce building energy use by 0.7% compared to conventional roofs, reducing peak electricity demand. These temperature reduction and energy efficiency benefits are a key contributor to the growing popularity of green roofs in the United States [13].

4.1.2.1 Types of Green Roofs

Green roofs can be installed on a wide range of buildings, from industrial facilities to private residences. There are two types of green roofs: extensive and intensive.

Table 1 Green roof types

Extensive Green Roofs	Intensive Green Roofs
• Tend to be simpler, with hardy plants and a growing medium depth of two to four inches • Require the least amount of added structural support since they are lightweight • Need little maintenance once established	• Tend to be more complex, such as a fully accessible park complete with trees • Resemble conventional gardens or parks • Require more structural support since they are heavier • Require a higher initial investment • Require more intensive maintenance

Both types of green roofs consist of the same basic layering components with a number of barriers to prevent water or root damage to the structure, a drainage layer to aid in water drainage, as well as a growing medium and vegetative layer. The Common Green Roof Layers figure (below) represents the most common design of a green roof, although not all the layers shown are found on every green roof.

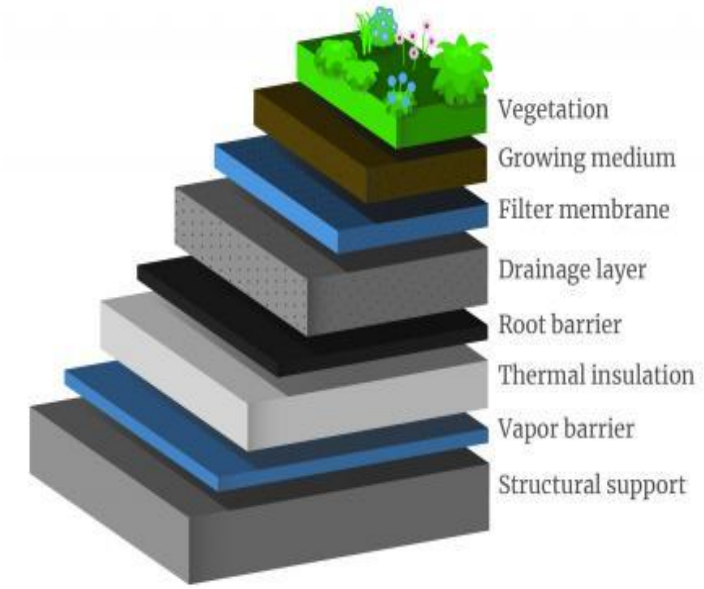

Figure 9 Green roof structure

On the following picture some examples of green roof are shown.

Figure 10 Green roof examples

4.1.3 Cool Roofs

A high solar reflectance—or albedo—is the most important characteristic of a cool roof as it helps to reflect sunlight and heat away from a building, reducing roof temperatures. A high thermal emittance also plays a role, particularly in climates that are warm and sunny. Together, these properties help roofs to absorb less heat and stay cooler than conventional materials during peak summer weather [14].

Building owners and roofing contractors have used cool roofing products for more than 20 years on commercial, industrial, and residential buildings. They may be installed on low-slope roofs (such as the flat or gently sloping roofs typically found on commercial, industrial, and office buildings) or the steep-sloped roofs used in many residences and retail buildings.

Through the ENERGY STAR program, EPA and the Department of Energy (DOE) help consumers and other purchasers identify the most energy-efficient roofing products. Roofing materials with the ENERGY STAR label have met minimum solar reflectance and reliability criteria.

Cool roofs deflect some desired heat gain during the winter. In general, though, cool roofs result in net energy savings, especially in areas where electricity prices are high.

4.1.4 Cool Pavements

Cool pavements include a range of established and emerging technologies that communities are exploring as part of their heat island reduction efforts. The term currently refers to paving materials that reflect more solar energy, enhance water evaporation, or have been otherwise modified to remain cooler than conventional pavements [15][23][24].

Conventional paving materials can reach peak summertime temperatures of 48–67°C, transferring excess heat to the air above them and heating stormwater as it runs off the pavement into local waterways. Due to the large area covered by pavements in urban areas (nearly 30–45% of land cover based on an analysis of four geographically diverse cities [9][10]), they are an important element to consider in heat island mitigation.

Cool pavements can be created with existing paving technologies (such as asphalt and concrete) as well as newer approaches such as the use of coatings or grass paving. Cool

pavement technologies are not as advanced as other heat island mitigation strategies, and there is no official standard or labeling program to designate cool paving materials.

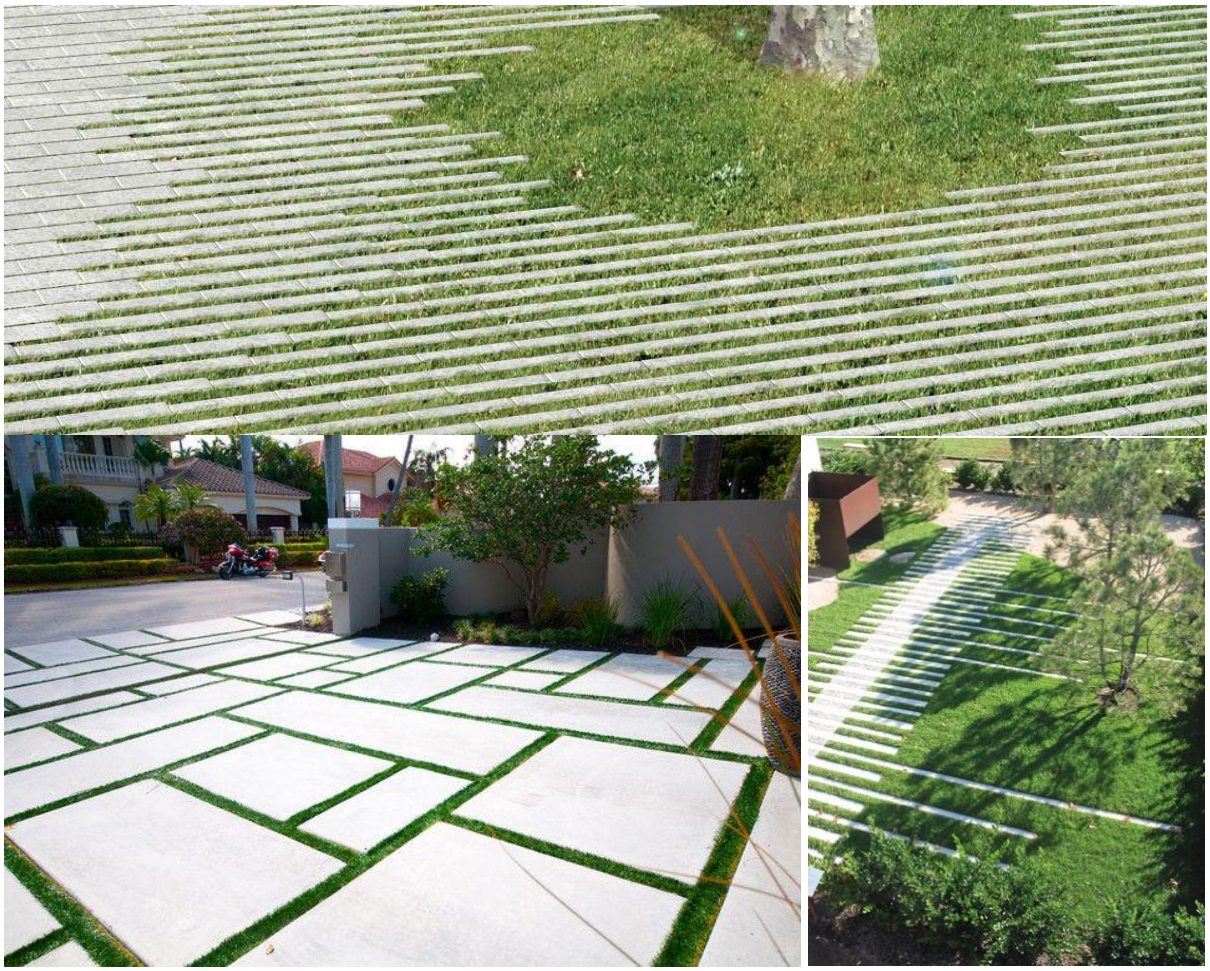

Figure 11 Cool pavements examples

4.1.4.1 Materials

There are two main ways that paving surfaces in alleys can help to reduce the heat island effect: by using high albedo paving surfaces (surfaces that will reflect heat as opposed to absorbing it, see Image 12), and through using porous paving which allows for more air circulation and consequently less absorption and re-radiation of heat. “The Solar Reflectance Index (SRI)---Combines albedo and emittance (a material’s ability to release absorbed heat).” LEED standards [22] require at least a 29 SRI on 50% of the paved areas.

Table 2 Solar Reflectance Index SRI

Material surface	Solar Reflectance*	Emittance	SRI*
Black acrylic paint	0.05	0.9	0
New asphalt	0.05	0.9	0
Aged asphalt	0.1	0.9	6
"White" asphalt shingle	0.21	0.91	21
Aged concrete	0.2 to 0.3	0.9	19 to 32
New concrete (ordinary)	0.35 to 0.45	0.9	38 to 52
New white portland cement concrete	0.7 to 0.8	0.9	86 to 100
White acrylic paint	0.8	0.9	100

4.1.5 Smart Growth

While many factors contribute to heat island formation, several characteristics typical of urban areas significantly influence the existence of a heat island. Urban areas commonly have few trees and green spaces and are predominantly made up surfaces that are impervious or covered with buildings, thus leading to extreme temperatures. Roads, parking lots, and buildings are often constructed of materials that reflect less and absorb more of the sun's energy. In addition, cities are typically designed to be dense and compact, which prevents adequate release of heat. Therefore, because urban design plays a large role in the creation of heat islands, smart growth development strategies provide an opportunity to reduce the heat island effect. When communities also incorporate cooling strategies into smart growth initiatives, they can realize multiple benefits more efficiently than pursuing these issues separately [16].

Figure 12 Smart growth examples

Based on the experience of communities around the nation that have used smart growth approaches to create and maintain great neighborhoods, the Smart Growth Network developed a set of ten basic Smart Growth principles, as follows:

- Mix land uses, such as residential, commercial, and recreational uses
- Take advantage of compact building design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Strengthen and direct development towards existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair, and cost effective
- Encourage community and stakeholder collaboration in development decisions

Heat island cooling strategies can incorporate these smart growth principles. For example, planting trees and vegetation and promoting parks and open space throughout developed areas can simultaneously result in mixed land uses, more attractive communities, and preserved natural beauty. Local heat island initiatives can incorporate community and stakeholder collaboration in decisions on appropriate strategies, which helps to foster a stronger community as a whole.

Conversely, smart growth initiatives can incorporate any or all of the main heat island cooling strategies – trees and vegetation, green roofs, cool roofs, and cool pavements, as illustrated in the following examples. When developing new smart growth areas, local officials and developers can incorporate green and cool roofs into the design of residential and commercial buildings. These roof designs help to lower energy costs and allow continued use of existing buildings. Planting trees and adding green spaces not only reduces temperatures inside and outside buildings, but can also enhance the attractiveness and distinctiveness of a community. Streets, alleys, parking lots, sidewalks, and other surfaces can be constructed using permeable/pervious paving materials, helping to cool a community while also reducing stormwater runoff which can increase its walkability.

4.1.6 Green parking lots

Parking lots contribute significantly to HIE. Asphalt, one of the most common paving materials used in parking lots, is a dark, heat-absorbing material [1-2]. When asphalt cools at night, all the heat it has absorbed during the day is released into the air, slowing the rate of nighttime cooling. This hot surface, combined with stormwater runoff from the parking lot also affects the surrounding water- bodies. When water is forced to flow quickly off the lot's surface, not enough time is allowed for evaporation to occur, again limiting natural cooling of the air. In addition, the land clearing needed to create space for parking lots diminishes tree cover and other natural vegetation that can help shade land and moderate temperatures. The environmental impacts of the HIE are varied. Hotter temperatures can lead to more CO2 emissions due to increased energy demand to cool neighboring buildings.

Figure 13 Green parking example

Typically, the emphasis in parking lot design is on accommodating vehicle movements, maximizing the number of parking spaces, and ensuring ease of maintenance and servicing [17]. Once these functional criteria are satisfied, “left-over” spaces may or may not be landscaped or dedicated for pedestrian use.

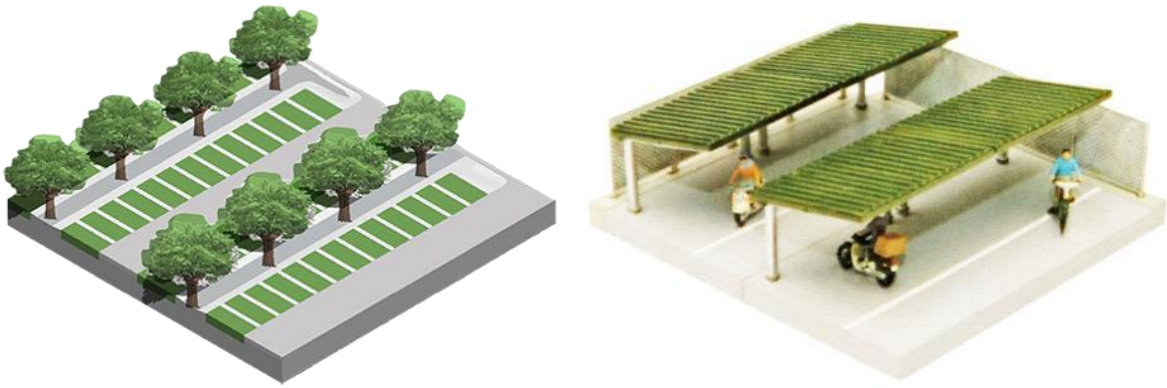

Figure 14 Design examples of green parking lots

To cope with these problems, certain cities have code and recommendations for the design of green parking lots. For example, the recommendations for the design of green parking in the city of Toronto [18] integrate smart growth recommendations and take into account urban design and environmental challenges in order to create parking spaces that are not only efficient, but safe, attractive and environmentally friendly. The recommendations include measures for greening the parking by planting trees, providing quality green areas, creating a grassy net on the places where cars are parked, atmospheric water management methods and using appropriate materials and technologies.

4.2 Actions/measures for City of Skopje

Based on analyzes of a number of measures that are applied in different cities in the world, 14 measures are proposed that are adapted for Skopje, so they can be applied by the municipalities or the City of Skopje

4.2.1 1.000.000 Trees for Skopje

Start an initiative with a goal for 1.000.000 Trees in Skopje. This need to be a cooperative effort between the City, community groups, businesses, and individuals aims to plant and provide long-term stewardship of one 1.000.000 trees planted throughout Skopje. The action should cover all places that are currently without trees org have shrubs and low-quality trees, as well as the space along the streets.

4.2.2 Tree Planting Competition

Organize a Tree Planting Competition. The contest is designed to help educate people on proper ways to plant trees and on the benefits of urban forestry for the community. These competitions can also be organized between secondary and elementary schools in Skopje, or among employees in various state institutions.

4.2.3 Free tree for your neighborhood

Evaluates neighborhoods and marks areas that are available for tree planting. Residents who commit to planting and watering the tree for two years can reserve their tree on the website or by mail. The trees are delivered, with planting and watering instructions.

4.2.4 Adopt-a-Median Tree Planting Program

This program aims to encourage more tree plantings in street medians to reduce the urban heat island effect. Adopt-a-Median allows groups to take responsibility of tree planting and maintenance of the median. Groups can either self-fund tree plantings, or by complying with city regulations, obtain funding from the specially created fund.

4.2.5 Skopje Green Factor

Adopt a minimum landscaping requirement, which will require that all new developments must provide for vegetative cover on the equivalent of 30% of the applicable property. The regulations ca applies to developments with more than minimal parameters regarding the area. Developers can use a menu of strategies, including planting new trees, preserving trees, and installing green roofs and green walls to meet this target. The city has to develop a worksheet to help applicants calculate a "score" that indicates whether various mixes of landscaping measures meet the requirements, which will allow developers to try different combinations of features.

4.2.6 Street Tree Code

Adopt a code that specifies that trees must be planted along both sides of a street, with one tree every 15–30 m. The selected trees must eventually be capable of reaching a minimum height of 12 m and a crown spread of 9 m.

4.2.7 Parking Lot Shading Ordinance

Adopt an ordinance that require enough trees be planted to shade 50% of new, or significantly altered, parking lots after 15 years of tree growth.

4.2.8 Parking Lots to Parks Project

Create a program and guidelines for sustainable parking lot design and conversion of the existing parking lots into green. The project needs to provide tools that will assist communities and developers with sustainable parking lot planning and in developing design standards.

4.2.9 Green Roof and Vertical Garden Property Tax Abatement Program

Adopt a property Tax Abatement Provision for properties with green roofs or vertical gardens. All properties that have or will develop a green roof, will be qualified for property tax abatement.

4.2.10 City Skopje Green Roof Program

Through this program the city will start construction of green roofs on public buildings, will do research to estimate impacts from green roofs, will provide grants to encourage green roof installations, and will educate the public about green roofs in general. This green roof program will help to raise visibility and increase public understanding of green roofs.

4.2.11 Vertical Gardens Initiative

Vertical Gardens initiative will be providing grant to citizens to develop vertical gardens on their walls. In addition to encouraging plantings that cover blank walls, the grants will also support landscaping that adds significant evapotranspiration and shade for parking garages and sidewalks. Program goals are improving overall aesthetics, pedestrian comfort, air quality, and reducing the heat island effect. Grants cannot exceed certain percentage of the total project cost or some set maximum amount, and contributions can be in kind. Tenants, property owners, and registered nonprofits can all apply.

4.2.12 Green Alleys

Green Alleys initiative will promote the use of permeable pavement any time it needs to repave an alley or construct an new one. The city will develop a guidelines handbook, that will show how the green alleys need to be constructed, and how they improve the environment.

4.2.13 Introduce code for installation of cold roofs

Traditionally in Macedonia, the roofs are made of ceramides and are dark red. This material and color contribute to the large warming of roofs throughout the city. In this direction, the city will have to adopt code with recommendations for the roofs design for residential and commercial buildings. The code will introduce the need to use materials that have high albedo and reflect the heat and thus significantly contribute to the heat islands mitigation.

4.2.14 Increasing the number of trees in the parks

The main target of this measure should be the Central City park, in which there are ares with small number of trees, so with this measure additional trees should be planted in those places. This measure should be applied to other existing parks where the density of trees is not sufficient.

4.3 Actions/measures for Skopje citizens

Follow the tips below to help reduce the heat island effect and improve your community's resilience to heat waves [33].

4.3.1 Increase shade around your home

Planting trees and other vegetation lowers surface and air temperatures by providing shade and cooling through evapotranspiration. Trees and vegetation that directly shade your home can decrease the need for air conditioning, making your home more comfortable and reducing your energy bill. Trees also protect your family's health by improving air quality, by providing cooling shade for outdoor activities, and reducing exposure to harmful UV radiation.

4.3.2 Install green roofs

A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs provide shade and remove heat from the air through evapotranspiration, reducing temperatures of the roof surface and the surrounding air. Green roofs absorb heat and act as insulators for your home, reducing energy needed to provide cooling and heating (which decreases your energy bill), improving indoor comfort, and lowering heat stress associated with heat waves.

4.3.3 Install cool roofs

Cool (or reflective) roofs help to reflect sunlight and heat away from your home, reducing roof temperatures. This allows for your home to stay cooler, reducing the amount of air conditioning needed during hot days. According to a study conducted in California1, cool roofs can provide annual energy savings of almost 50 cents per square foot. Such energy savings can also result in better air quality in your community and fewer greenhouse gases emitted to the atmosphere.

4.3.4 Use energy-efficient appliances and equipment

Using efficient appliances and equipment in your home can help to lighten the load on the electric grid during heat waves, thus ensuring a more reliable supply of electricity to your community. When purchasing products, look for EPA's ENERGY STAR label to help you make the most energy-efficient decision. You can find the ENERGY STAR label on more than 60 kinds of products, including appliances, lighting, heating and cooling equipment, electronics, and office equipment. Replacing your old appliances and equipment with ENERGY STAR-qualified products can also help save you money.

4.3.5 Check on your friends, family, and neighbors

Heat waves can be dangerous for people's health and safety, particularly for the elderly, young, sick, and poor. Checking on your friends, family, and neighbors during hot days and making sure they have access to air conditioning or cooling centers will help to prevent heat-related illnesses and death.

4.4 Innovative measures

In this chapter, several interesting and unusual measures that can be used to reduce the effect of the heat islands are proposed.

4.4.1.1 Portable green gardens

For achieving quick results, portable green gardens can be used for cooling and decorate the central city area. Examples of portable green gardens are shown in Figure 15, Figure 16 and Figure 17.

Figure 15 Portable green garden

This interesting urban equipment can be made by adjusting old containers or designing them entirely from the beginning.

Figure 16 Portable green garden made of old containers used for rest and relaxation

Such equipment can be used as a space for rest and relaxation in areas where it is impossible to lay green spaces in a short period of time.

Figure 17 Portable green park example

4.4.1.2 City green camping

Another interesting idea for a portable garden is the adaptation of an old camp trailer to a mobile garden where leisure time can be "camping" in the city center.

Figure 18 Urban green camping

4.4.1.3 Portable green gardens

In places where trees cannot be planted, portable vertical gardens can be installed. While they will influence the reduction of the effect of urban heat islands, they will also contribute to building a more beautiful natural space in the central areas of the city. An example of vertical gardens is given on Figure 19.

Figure 19 Portable vertical gardens

4.4.1.4 Urban agriculture

So far, attention has mainly focused on reducing the effect of Urban Heat Island, but through this measure, the idea is to see how this effect can be exploited. One of the exciting opportunities is Urban Agriculture, with crops that require a relatively warmer climate than the one in the area. The idea is to use the microclimate and create parks where plants that fit newly created urban microclimate are planted. Figure 20 shows the Michigan Urban Agriculture Initiative (MUFI) that is being implemented in the city of Detroit and includes an agricultural garden, an orchard and a kindergarten [34].

Figure 20 Michigan Urban Agriculture Initiative (MUFI) that is being implemented in the city of Detroit and includes an agricultural garden, an orchard and a kindergarten [34]

4.4.1.5 Green roof with restaurant

Green roofs can be turned into interesting and attractive locations that will enable citizens to stay in the green and natural surroundings in urban areas of the city and have a beautiful view

of the surroundings. Figure 21 shows the green roof on which a garden and restaurant is made — the Stedman's restaurant in Copenhagen [35] which is one of the city's main attractions.

Figure 21 Green roof example: Stedman's restaurant in Copenhagen [35]

4.5 Action plan for local heat islands in Skopje

With the use of statistical GIS tools, the areas where there is a higher concentration of very hot or very cold points were detected. The points in these areas are connected in a cluster and the formed areas are analyzed. The results of this analysis are shown on Figure 22

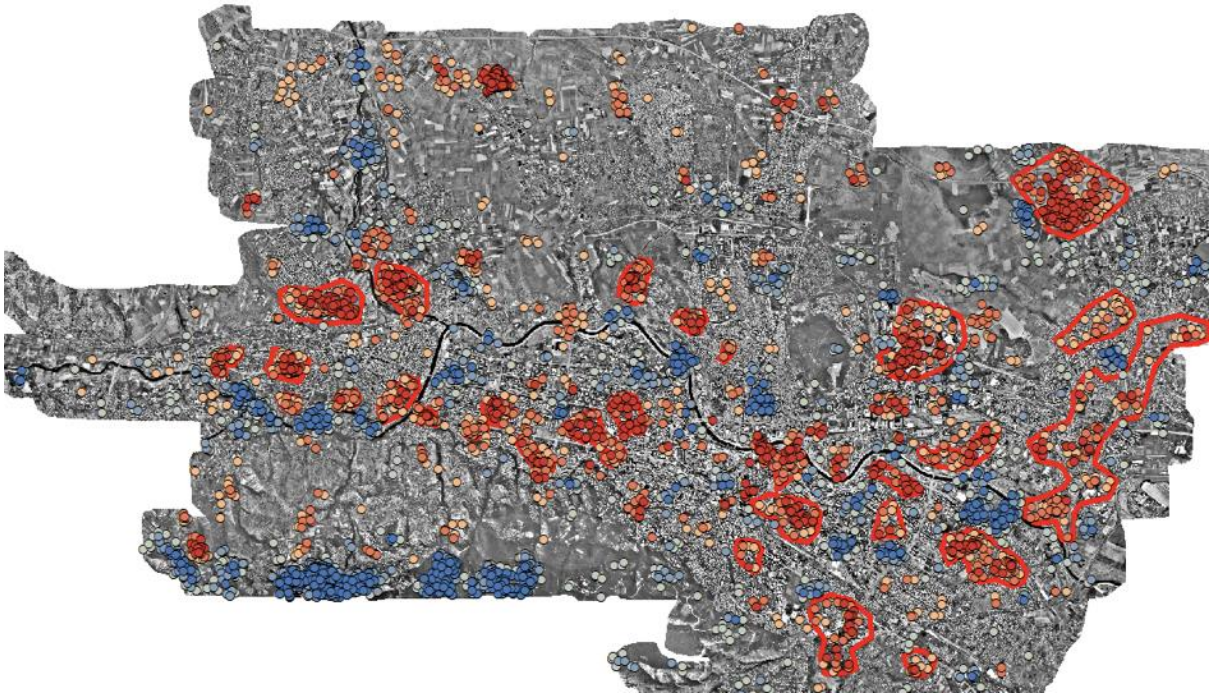

Figure 22 Map of hot and cold islands in Skopje

Based on the results shown on Figure 22, several areas are chosen for detailed analysis and micro mitigation measures proposal. First we chose city center and two additional areas that are close to the center are also selected: Debar Maalo and the New Railway Station in Madzir Maalo. As interesting one the area around Plastic Street is included. As part of the industrial regions in Skopje show greater warming, we chose industrial zone around the factory MZT for detailed analysis.

For each of the analyzed areas, a thermal image, as well as an RGB image is shown. The thermal images use the palette shown in the next figure.

Figure 23 The color palate used for thermal images

4.5.1 Debar Maalo

4.5.1.1 Analysis

The part of Debar Maalo which is shown in the following image is dense populated, with houses and buildings that do not have or have a small yard. The streets are relatively small without trees and green parts around them. Due to this condition, a relatively small number of measures can be applied here.

Figure 24 Thermal image of Debar Maalo

Figure 25 RGB Image of Debar Maalo

4.5.1.2 Proposed measures

Based on the analysis made and the potentials for application of the specific solutions, the following measures are proposed for this location which are schematically shown in the following figure.

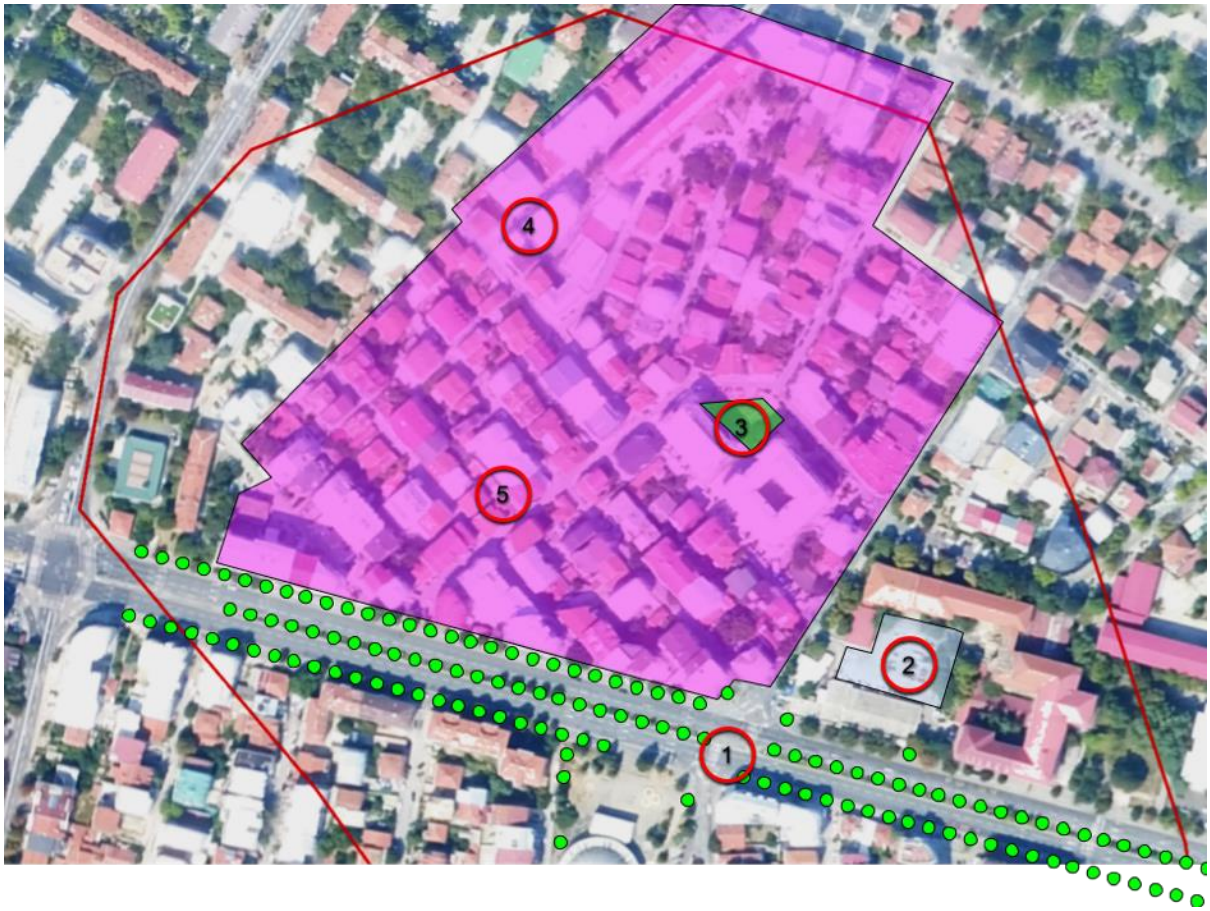

Figure 26 Proposed heat island mitigation measures for Debar Maalo

ID	Type	Measure Description
DM-m1	Urban Forestry	Planting trees on the sidewalks as well as on the island on the Partizanska boulevard. On this part of the Partizanska Boulevard there is not a sufficient number of trees.
DM-m2	Green packing lot	Conversion of the parking lot in front of the Faculty of Architecture in a green parking lot. Currently, there are trees on this parking lot, but there are opportunities to rearrange and increase the number of trees and green parts.
DM-m3	Urban Forestry	Landscaping the park across Kino Karpos. This part is insufficiently landscaped, so it is necessary to plant more trees and to enrich the space.
DM-m4	Cool roof	Installing cool roofs on buildings that are covered with tiles or with roofs of dark material.
DM-m5	Vertical gardens	Installation of vertical gardens through the streets of Crvena Voda, Mayakovsky, Blagoy Davkov and Gjorgja Pulevski

4.5.2 New train station and Madzir Maalo

4.5.2.1 Analysis

The new train station is a massive structure with a large concrete surface that is directly exposed to the sun and as such is easily overheated, resulting in a significant increase in the temperature in its surroundings. Additionally, in the area surrounding the train station, most

of the parking lots are almost without any trees, and that additionally contributes to the higher temperatures of this area.

The Madzir Maalo is very urban part with private houses and buildings that do not have or have a tiny yard. The streets are very narrow and are mostly without trees and green parts on them. The temperature increase in this part of the city it is not as big as in Debar Maalo, due to the closeness of the river Vardar.

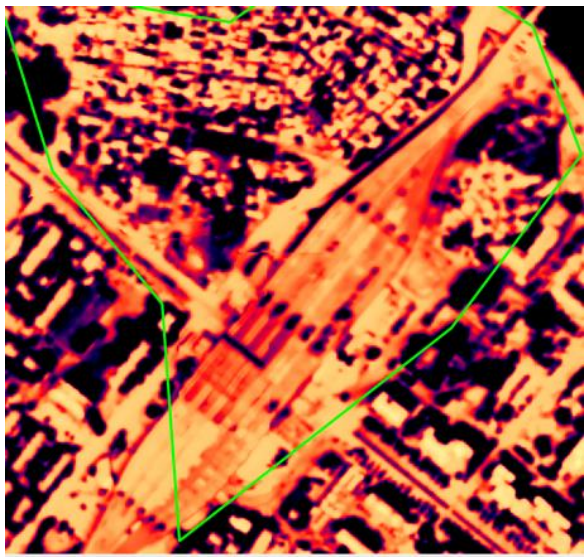

Figure 27 Thermal image of New train station and Madzir Maalo

Figure 28 RGB Image of New train station and Madzir Maalo

4.5.2.2 Proposed measures

Based on the conducted analysis and the potentials for application, the proposed measures for this part of the city are schematically shown on the following image.

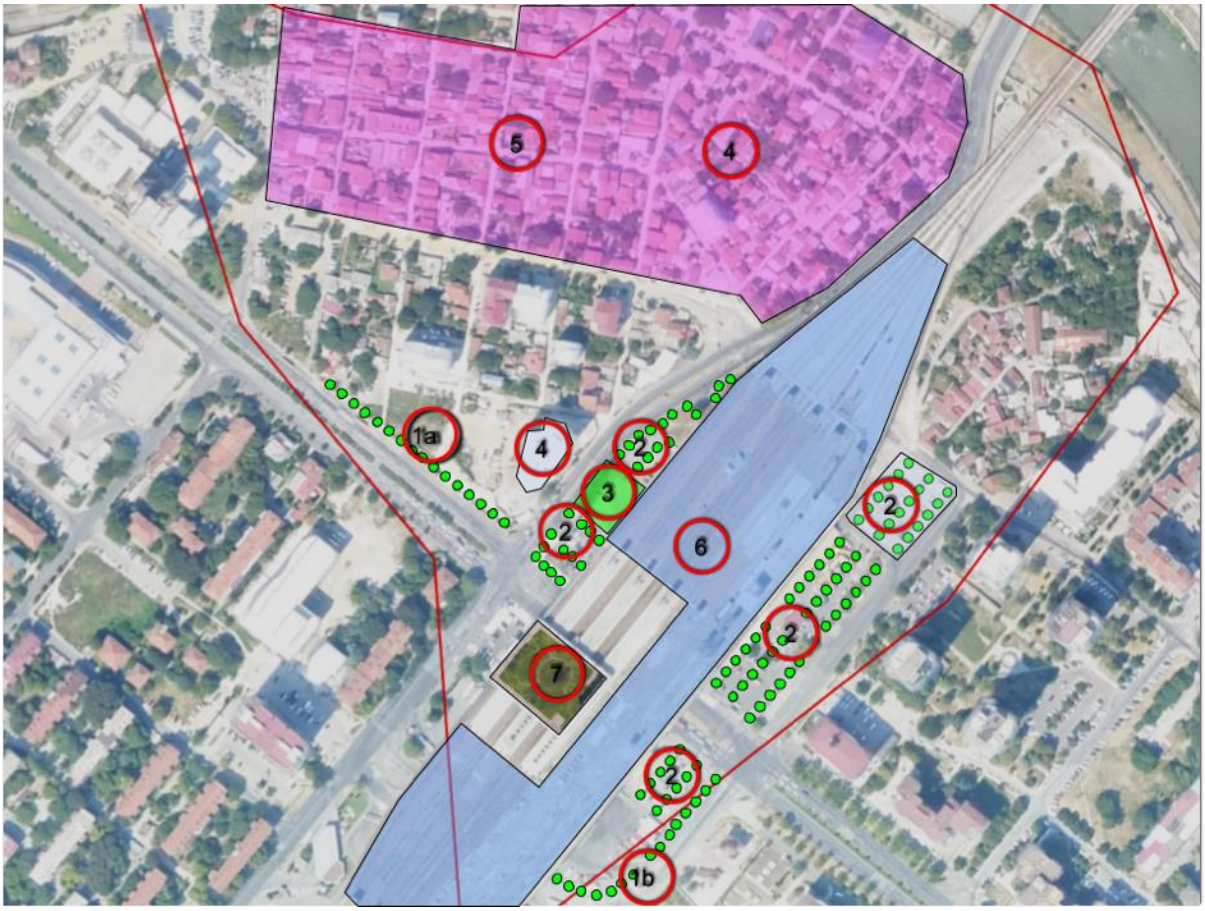

Figure 29 Proposed heat island mitigation measures for New train station and Madzir Maalo

ID	Type	Measures description
NT-m1a	Urban Forestry	Planting trees along the sidewalks as well as on the island on the boulevard Kuzman Josifovski Pitu. There is not a sufficient number of trees on this section of the street, and this measure is necessary for cooling and decoration of the area.
NT-m1б	Urban Forestry	Planting trees along the sidewalks of the street that is parallel to the train station
NT-m2	Green packing lot	Conversion of parking lots around the New Railway Station in green parking lots. Currently, there are almost no trees in this parking lots. Greening these parking lots will significantly contribute to reducing temperatures and additionally to beautification the area.
NT-m3	Urban Forestry	Landscaping and transformation the space in front of Macedonian Post which is located on the north-west side of the railway station. This part is insufficiently landscaped, so it is necessary to plant more trees.
NT-m4	Cool roof	Installation of cool roofs on the houses in Madzir Maalo
NT-m5	Vertical gardens	Installation of vertical gardens on houses through the streets of Madzir Maalo

NT-m6	Cool roof	Covering the concrete surface of the train station with bright paint or materials that will reflect the heat, unlike the current state of absorption.
NT-m7	Green roof	Build a green roof over the platforms of the train station. This project can significantly contribute to the beautification and cooling of the area. Additionally, the green roof can become a waiting room or restaurant for passengers.

4.5.3 Plasticarska Street

4.5.3.1 Analysis

In this part of the city, around the Plasticarska Street (part of the boulevard Nikola Karev) there are almost no trees planted on the sidewalks. Sidewalks are used to park vehicles that additionally worsen the condition.

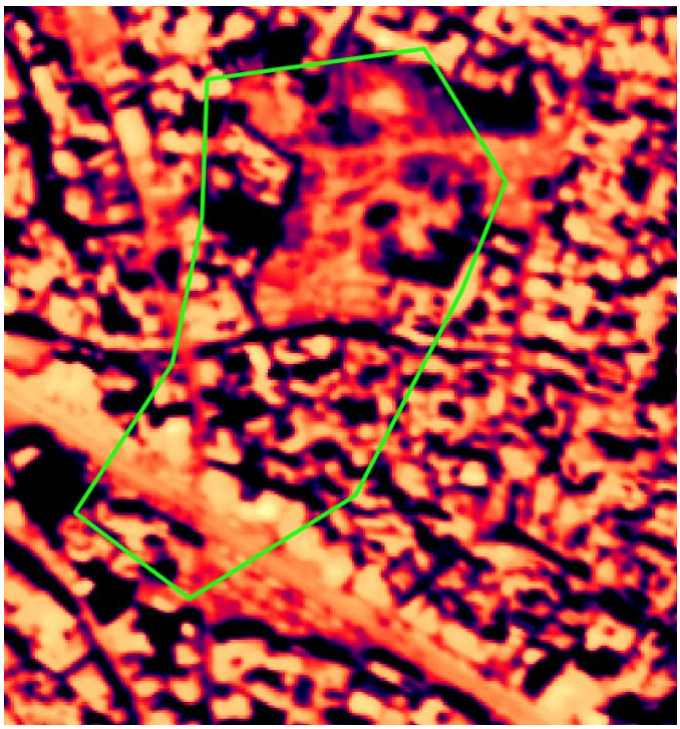

Figure 30 Thermal image of the area around Plasticarska Street

Figure 31 RGB image of the area around Plasticarska Street

A particular problem is this part of the city, are the empty areas that are located between the streets of Pere Toshev and Crimea. This space is not landscaped correctly and as such, it

heats the environment. From the thermal images, it can be concluded that it additionally heat the environment and significantly contributes to the warming of this region. The part of Chair, is with dense private houses and buildings that do not have or have a very small yard. The streets are relatively small without trees and greenery on them.

4.5.3.2 Proposed measures

Based on the conducted analysis and the potentials for application, the proposed measures for this part of the city are schematically shown on the following image.

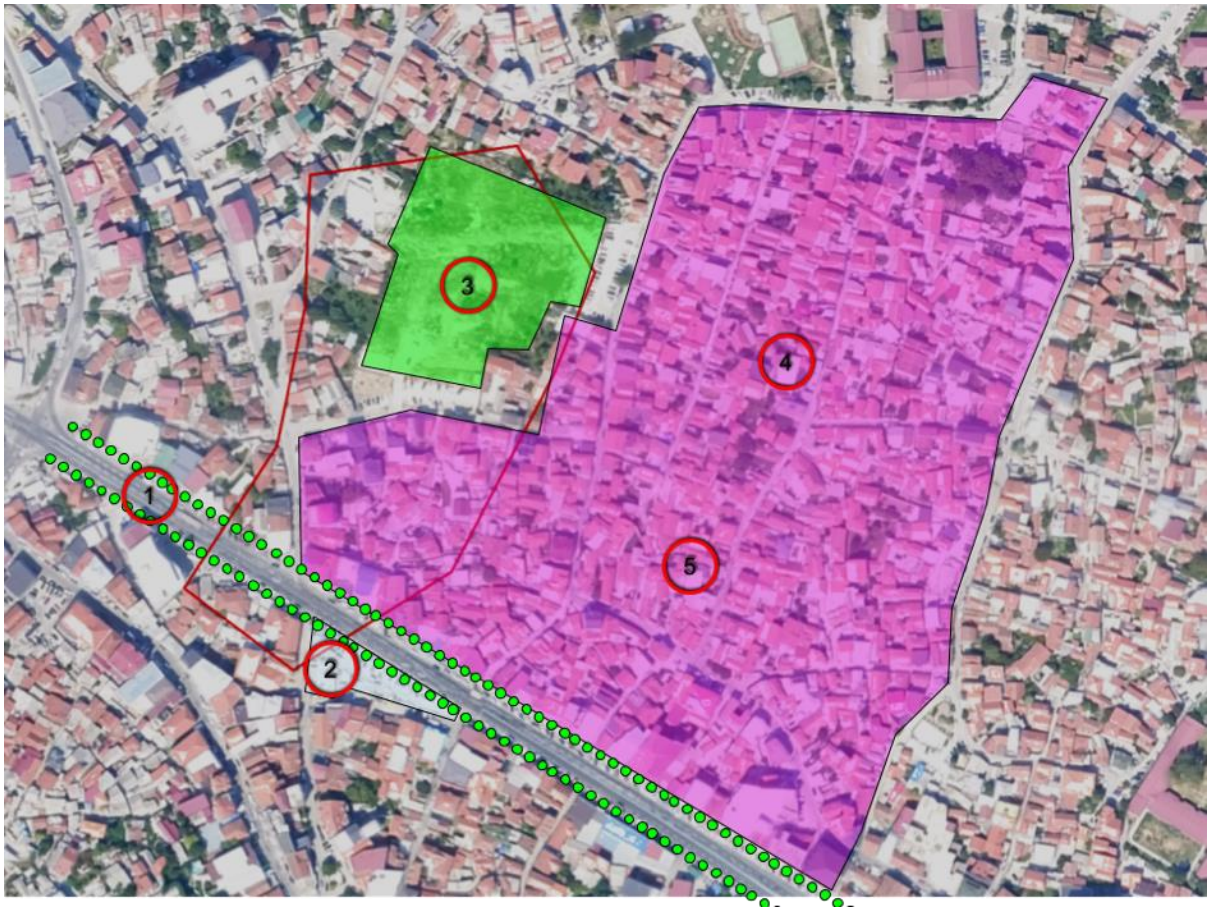

Figure 32 Proposed heat island mitigation measures for the area around Plasticarska Street

ID	Type	Measure description
PS-m1	Urban Forestry	Planting trees on the sidewalks of the boulevard Nikola Karev. There are almost no trees on this part of the street, which is why the temperatures are much higher. The existence of street shops and the use of sidewalks for parking may be a problem in applying this action.
PS-m2	Green packing lot	Conversion of the parking to a green parking lot. This parking space is not currently regulated, and there are almost no trees. So any intervention will improve the situation.
PS-m3	Urban Forestry	The empty area located between the streets Pere Toshev and Crimea with no landscaping at all. This additionally warms the environment and significantly contributes to the warming of this region. Landscaping of this area will substantially enhance the

		enviroment and will contribute to the cooling of the entire area. Because there is no park close to this region, this will be a valuable recreational space for people living in this region
PS-m4	Cool roof	Installation of cool roofs. Almost all roofs are of non-reflective material, and this measure can significantly contribute to the cooling of the environment
PS-m5	Vertical gardens	Placing vertical gardens on houses through the streets.

4.5.4 Industrial area around MZT factory

4.5.4.1 Analysis

Besides the existence of heat islands in the populated parts of the, the industrial zones also have a big influence on the urban heat islands in Skopje. The main reason for this phenomenon is the closeness of the zone to the city center (the industrial zone are joined with the city). For example this industrial zone is just one kilometer away of Novo Lisice and 1.5 kilometers form Aerodrom municipality which is one of the most populated areas in Skopje .

This zone is overflowing with large industrial halls that have non-reflective roofs, that are the main reason for temperature increase and significantly warm the environment. An additional problem is a large number of parking lots that have no or tiny green areas. All this results in the appearance of an area that is significantly hotter than the environment.

Figure 33 Thermal image of the Industrial area around MZT factory

Figure 34 RGB image of the Industrial area around MZT factory

4.5.4.2 Proposed measures

Based on the conducted analysis and the potentials for application, the proposed measures for this part of the city are schematically shown on the following image.

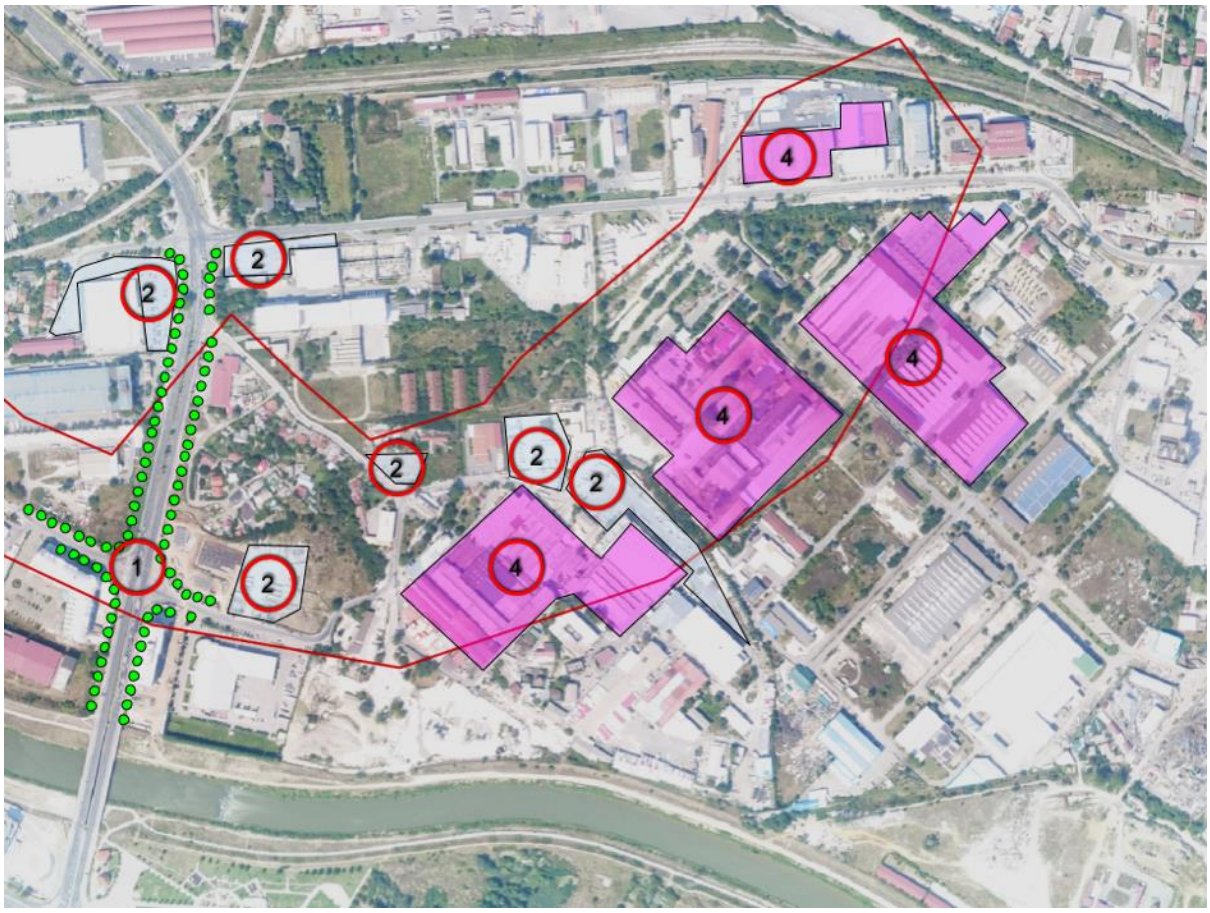

Figure 35 Proposed heat island mitigation measures for the Industrial area around MZT factory

ID	Type	Measures description
IZ-m1	Urban Forestry	Planting trees on the sidewalks on the boulevard Kiro Gligorov. On this part of the boulevard Kiro Gligorov there are small number of planted trees, so it is necessary to increase the number of trees on both sides of the boulevard as well as on the central island.
IZ-m2	Green packing lot	In this part of the city, there are a large number of parking lots that are without or with a minimal green area. With this measure, it is necessary to rearrange the parking lots in green parking lots.
IZ-m4	Cool roof	Installation of cool roofs. Almost all roofs of industrial buildings are old and are of non-reflective material, so this measure can significantly contribute to the cooling of the environment

4.5.5 Measures for the city center

4.5.5.1 Analysis

In order to raise awareness of dealing with the heat islands, in addition to the standard measures, in the central city area, several interesting and easily noticeable measures are needed.

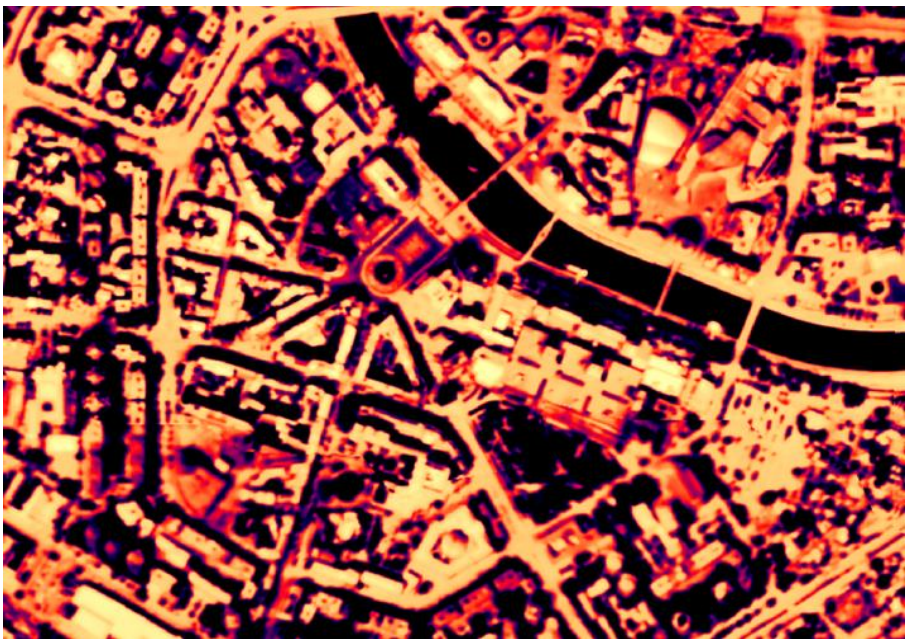

Figure 36 Thermal image of the city center

Figure 37 RGB image of the city center

4.5.5.2 Proposed measures

Based on the conducted analysis and the potentials for application, the measures shown on the following image are proposed.

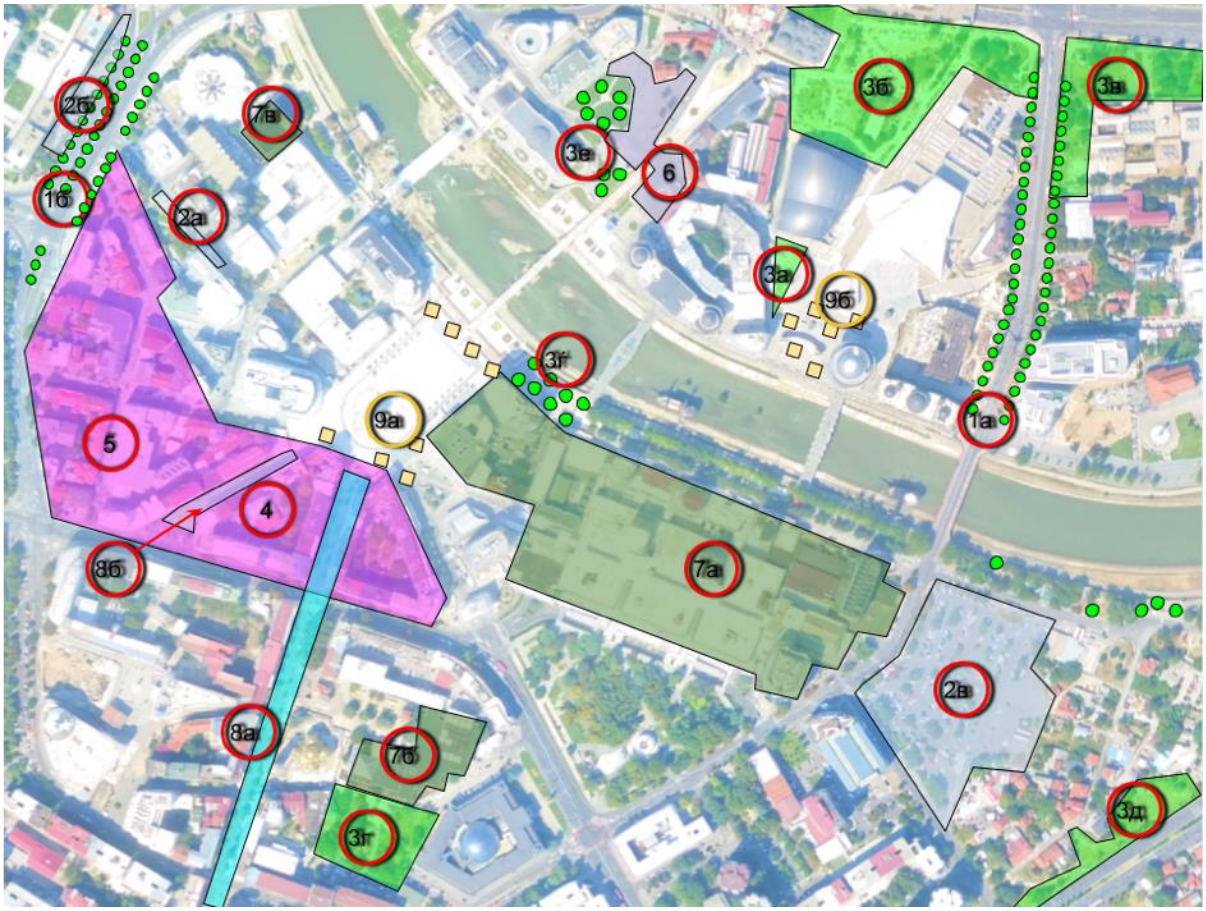

Figure 38 Proposed heat island mitigation measures for the city center

ID	Type	Measure description
CE-m1a	Urban Forestry	Planting trees along the sidewalks of the boulevard Krste Petkov Misirkov. There is not a sufficient number of trees on this section of the boulevard, and this measure is necessary for cooling and beautification of the area.
CE-m1б	Urban Forestry	Planting trees along the sidewalks as well as on the island on the VMRO Boulevard.
CE-m2a	Green packing lot	Conversion of the parking lot in front of a Telecom in a green parking lot. On this parking there is a need to increase the number of trees and to set up an appropriate green pavement.
CE-m2б	Green packing lot	Conversion of the parking lot on VMRO Boulevard in a green parking lot. On this parking there is a need to increase the number of trees and to set up an appropriate green pavement.
CE-m2в	Green packing lot	Conversion of the parking lot across the Holliday Inn in a green parking lot. On this parking there is a need to increase the number of trees and to set up an appropriate green pavement.
CE-m3a	Urban Forestry	Horticultural arrangement of the space in front of the Ministry of Environment. In this area there are grass islands, so they need to be enriched with trees.

CE-m3б	Urban Forestry	Landscaping of the park behind the new Philharmonic. This part is not green enough, so it is necessary to plant more trees and to enrich the space.
CE-m3в	Urban Forestry	Landscaping in front of the University Library. This part is insufficiently arranged, so it is necessary to plant more trees and to enrich the space.
CE-m3г	Urban Forestry	Landscaping of the park behind the Dom na ARM. This part is not green enough, so it is necessary to plant more trees and to enrich the space. In this section there is a parking lot that needs to be converted into a green parking lot.
CE-m3д	Urban Forestry	Landscaping of the area along the Koco Racin Boulevard in front and across the Olympic Pool. This part is not green enough, so it is necessary to plant more trees and to enrich the space
CE-m3ѓ	Urban Forestry	Increasing the number of trees on the right side of Vardar. Especially in the part in front of the Telecom the trees are missing, so it is necessary to increase the number of trees
CE-m3e	Urban Forestry	Increasing the number of trees in front of the Holocaust Museum.
CE-m4	Cool roofs	Installation of cool roofs on houses in the city center
CE-m5	Vertical gardens	Installing vertical gardens of houses on the streets in the city center.
CE-m6	Cool pavement	Covering the square in front of St. Dimtrija church with white paint or materials that will reflect the heat.
CE-m7a	Green roof	Build a green roof over the GTC Mall. This project can significantly contribute to the beautification and cooling of the space. Additionally, the green roof can be made commercially available, so it can be converted into a restaurant or park.
CE-m7б	Green roof	Construction of a green roof over the Dom na ARM. This project can significantly contribute to the beautification and cooling of the space. In addition, the green roof can be made and commercially available so it can be converted into a restaurant or a park, or it can be used for cultural events.
CE-m7б	Green roof	Construction of a green roof above the garage Thessaloniki Congress. This project can significantly contribute to the beautification and cooling of the space. Additionally, the green roof can be made commercially available so it can be converted into a restaurant.

CE-m8a	Urban Forestry	Converting the Macedonia street in a park. The goal is to cover the whole street with trees and green spaces	
CE-m8б	Urban Forestry	Converting the street Nikola Vaptsarov in the park. The goal is to cover the whole street with trees and green spaces	
CE-m9a	Mobile green equipment	Installing portable urban gardens and portable vertical gardens on Macedonia Square	
CE-m9a	Mobile green equipment	Installing portable urban gardens and portable vertical gardens on Mother Teresa Square	

5 Conclusion

Based on this analysis, Skopje has the effect of urban heat islands, although this is not strongly expressed as in the other larger cities. However, in order to deal with this phenomenon, it is necessary to implement a number of measures to make the city a pleasant place to live.

Within this study, more than 70 measures and actions have been proposed that will help to deal with the effects of the heat island in Skopje. Several areas of Skopje have been analysed in details, but this does not mean that this effect is not present in the rest of the city. Therefore, the same or similar measures should be applied in all areas that are detected on the map given in Figure 2.

Additionally, since most of the measures that prevent the effect of urban heat islands also affect the reduction of pollution, an effort should be made to implement most of the proposed measures. In this regard, the analyses and tests should be continued, especially having in mind that the effect of the heat islands is most noticeable during winter nights, which directly correlates with the increased air pollution. One of the reasons may be the

impact of the effect of the heat island on the winds, so their direction is changed towards the center of the city and thus affecting air pollution in the city center.

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