Heat Islands and their Thermovision Monitoring in an Example of Public Space in Hradec Králové

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Abstract: - Global climate change has been discussed with increasing focus over the recent years, and as it has significant impacts on both the natural environment and human activities, it is necessary to prepare for and adapt to the possible changes in a good time in advance. Air temperature changes, also known as global warming, are one of the main effects of global climate change. Therefore, our towns and cities are likely to experience major changes in terms of air temperatures and the risk of heat island occurrence will be rising over time. Towns and cities should begin to prepare for this phenomenon, monitor the situation and propose such measures that would mitigate climate change impacts on the urban environment and urban population or at least would not add to the existing adverse impacts. This paper presents possible ways of identifying heat islands by thermovision monitoring in an example of two selected public spaces in Hradec Králové – náměstí 28. října and Riegrovo náměstí.

Key-Words: - Climate change, Heat islands, Thermovision monitoring, Public spaces, Hradec Králové

1 Introduction

Recently, global climate change, which affects a range of processes taking place on the Earth, has been discussed with increasing focus. As it has significant impacts on both the natural environment and human activities, it is necessary to prepare for and adapt to the possible changes in a good time in advance. The major climatic effects of global climate change include a change in air temperatures and the distribution of precipitations, and a higher number of hydrometeorological extremes. Even though the climate variability in the Czech Republic is rather high, a significant rising trend in air temperatures seems to be evident. Most of the hottest years recorded on the territory of the Czech Republic have been observed in last 25 years. Most climatic models expect that the air temperature will still rise in future.[6]Therefore, our towns and cities are likely to experience major changes in terms of air temperatures, and the risk of heat island occurrence will be rising over time. Towns and cities should begin to prepare for this phenomenon, monitor the situation and propose such measures that would mitigate climate change impacts on the urban environment and urban population or at least would not add to the existing adverse impacts. **This paper is to presents possible ways of identifying heat islands by thermovision monitoring in an example of two selected public spaces in Hradec Králové.**

2 Heat Islands

Heat islands are urban areas with a temperature higher than that of the surrounding countryside. Urban heat island intensity is defined as the difference between the urban air temperature and the surrounding countryside's air temperature. [8] This phenomenon is due to that developed urban areas absorb more heat than non-urbanised or countryside areas, so the primary factor is the difference in land use. Developed areas prevail and this changes the thermal response to solar radiation. As urbanised areas are characterised by the inability to reflect

solar radiation, their temperatures are higher. Structures such as buildings or streets add to the ability of built-up areas to retain heat whereas vegetation has the very opposite effect. This phenomenon is not limited to large cities only but has even been observed in towns with population under ten thousand. [1]

Providing larger space for the absorption of solar radiation and thus adding to the capacity to absorb solar radiation (also known as the canyon effect), high urban buildings are other factors in the generation of heat islands. Buildings block the flow of air that could cool the urbanised surface down. Besides physical development, urban temperature is also influenced by direct consequences of everyday human activities. In periods of low solar activity the effect of urban heat islands is also generated by car fumes, air condition technology or industrial fumes. [6]

3 Public Space

Public space is defined as any urban space free of buildings that is accessible to all the people living in or visiting the town or city, free of charge and at all times or a limited time (parks that close for night, for instance). The fundamental feature of a public space is that people can spend time there and the place must demonstrate utility for residents, i.e. the public space must be available to the population of the town or city for various locomotory (walking or cycling) or leisure time (sitting or playing) activities. [9]

Urban public space is made up of a network of streets, squares, greenery and other space that provide for the basic operations of the town or city – getting about a city and staying there. The system of urban public places is a result of a long-term process of a town's establishment and growth. Some authors, such as Jan Gehl [2], explicitly understand public space as a town's 'living rooms'. For that reason high standards in terms of space, operations and the ease of stay are applied to public space. The times of rising temperatures (as discussed above) impose modified quality standards on public space; in particular, greenery is becoming more important, as not only a beautifying but also a climatic element.

The monitoring of urban greenery and the preparation of specialised greenery passports are one of the oldest GIS applications (not only) in public administration. Thermovision imaging can produce additional data for assessing the real consequences of having greenery at specific places in the town or city and help to prevent one of the most apparent phenomenon connected with global warming – the generation of heat islands. [6]

Consequently, continuing communication to town planners and architects could significantly reduce the heat shocks urban population is exposed to when getting about a town and, particularly in large cities, staying inside air-conditioned buildings. [5]

Not only trees and greenery but also the types of material used in public space affect how people feel at a specific place in a town or city. All town planners and architects should bear this in mind. Man-made structures reduce thermal comfort whereas trees, bodies of water and greenery add to it.

Consequently, continuing communication to town planners and architects could significantly reduce the heat shocks urban population is exposed to when getting about a town and, particularly in large cities, staying inside air-conditioned buildings.

4 Thermovision Monitoring

Infrared thermography, or thermovision (this term is motivated by the name of the Thermovision company, now FLIR, the first manufacturer of specialised infrared cameras), allows examining the distribution of the thermal field on an object's surface. This method requires no physical contact at all and is based on analysing the infrared energy radiated from an object. Thermogram, the picture output of thermovision imaging, converts the infrared spectrum, invisible to human eye, to a visible result.

Thermovision records are published as video recordings and still 'pictures' that can be geo-referenced using GIS tools, which is a precondition for being able to analyse the output at a later time. If interpreted correctly, accurately localised and superimposed on underlying cartographic maps, thermovision records allow accurate and effective examination of the phenomena researched.

Fig. 1: Street Profile without Greenery (top – Gočárova třída) Compared with Street Profile with Greenery (bottom – třída Karla IV.) in Hradec Králové

Source: Chartered City of Hradec Králové

5 Case Study in Hradec Králové

5.1 Technical Parameters of Thermovision Monitoring in Hradec Králové

Thermovision imaging of selected public spaces was done in Hradec Králové as part of the project *Settlement Adaptation to Climate Change – Practical Solutions and Sharing of Experience* out of the initiative of the Metropolitan Authority of the Chartered City of Hradec Králové as a participating member of the project. Thermovision imaging of two public spaces was done with a pilotless drone with a thermovision camera on 18 and 19 August 2016 between 11 and 14 o'clock. The purpose was to measure the surface temperature and the emissivity (in regular summer climate) of the materials used and to establish how changes in the share of greenery and shade-providing elements (grown trees) affect the total climate and the environmental quality of the public space.

The imaging was done using a Robodrone Kingfisher drone (manufactured by Robodrone Industries s. r. o. Brno) and an Optris PI 640 thermovision camera (Optris GMBH) lent by courtesy of KELCOM International, spol. s r. o. Hradec Králové. Data were interpreted and evaluated by the IT Department of the Hradec Králové Metropolitan Authority.

Optris PI 640 Camera's Parameters

- Optical resolution: 640 x 480 pixels
- Temperature range: from -20 °C to 900 °C
- Spectral range: from 7.5 to 13 µm
- Image refresh rate 32 Hz
- Smallest thermography infrared VGA camera in the world. [4]

Robodrone Kingfisher Drone's Parameters

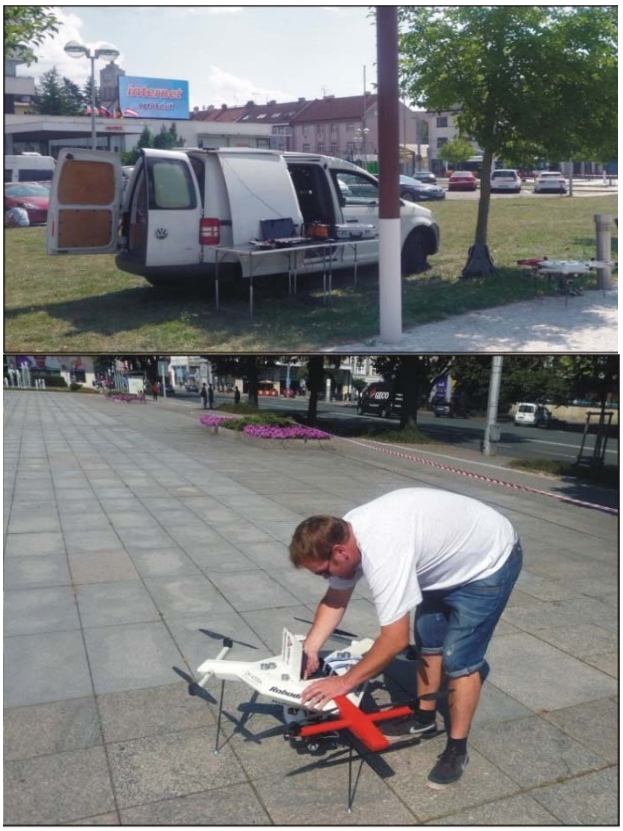
The Robodrone Kingfisher pilotless drone is a universal platform able to carry a FullHD optical camera, thermo camera or other sensors of up to 5 kilograms; the data captured by the camera or sensor are transmitted by digital encoded transmission into any computer device over a distance of up to 3 kilometres. Cameras are fitted onto an integrated three-axis stabilised holder – a gimbal. [7]

Table 1 - Specifications

• Max weight [kg]	10
• Max endurance [min]	45
• Max distance range [km]	15
• Max speed [km/h]	40
• Body dimensions [mm]	1200x1400x220
• Wind resistance [m/s]	< 8 (17.9mph / 28.8km/h)
• Servicing intervals [hrs]	50 / 100
• Max ceiling [m]	1000 AGL
• Take-off preparation [min]	< 5
• Operating temperature	-10 ~ + 400 °C

Source: [3]

Fig. 2: Mobile Base and Drone Preparations for Imaging Flight



Source: Author's archive

5.2 Monitoring of the Public Space Estimated to Pose the Risk of Heat Island Generation

Two squares in the city centre were selected for thermovision monitoring that had recently been renovated and acquired a substantially new look: *náměstí 28. října* and *Riegrovo náměstí*.

Náměstí 28. října

The space of this square was formed as a result of the regulatory plan made by architect Liska between 1912 and 1914. Built between 1928 and 1932, the Church of the Lord's Divine Heart dominates the square with its tower. The square's ground plan is an isosceles triangle of an approximate depth of 90 meters and a width of the base (the segment in front of the church) of 100 meters. The triangle ground plan is defined by a fork of historical ways – now the streets *S.K. Neumanna* and *U Koruny* – people call the square *the Spike*. The square used to be a place of occasional markets, and daily markets at a later time; in 1948 the square is referred to as *a market square at a crossing of state roads*. The square was a fruit and vegetable market until the mid. 1970s, when the market was transferred to the market hall in the neighbouring *Blažíčkovo náměstí*. However, as the general public did not welcome this transfer having the market back in *náměstí 28. října* was under consideration when planning the renovation of the square.

Between 1979 and 1982 the *Kovoprojekta* building (now housing the Financial Authority) was erected along the south line of the square, the *PRIOR* department store (now *TESCO* shopping mall) was developed along the south-east line after the demolition of buildings in *Dukelská* street, and *Dům služeb* (now housing *Obchodní banka*) and a *Česká pojišťovna* building were erected next to *PRIOR* in 1978–1981 and the 1990s, respectively. However, as the square's space as such had not been developed in any way over many decades, it became a rather undelightful place with poor grass areas, several damaged benches, cracked asphalt surface and middle-sized concrete tiles. [10]

That is why the square and the adjacent streets were renovated in 2012 and 2013. Prior to the renovation the share of greenery in the square's total area was about 30% and the square had 18 grown trees that produced shade. After the renovation the share of greenery is under 12% and the square has four grown trees.

Fig. 3. Orthophoto Map of Náměstí 28. října in Hradec Králové
Prior to Renovation – 2005

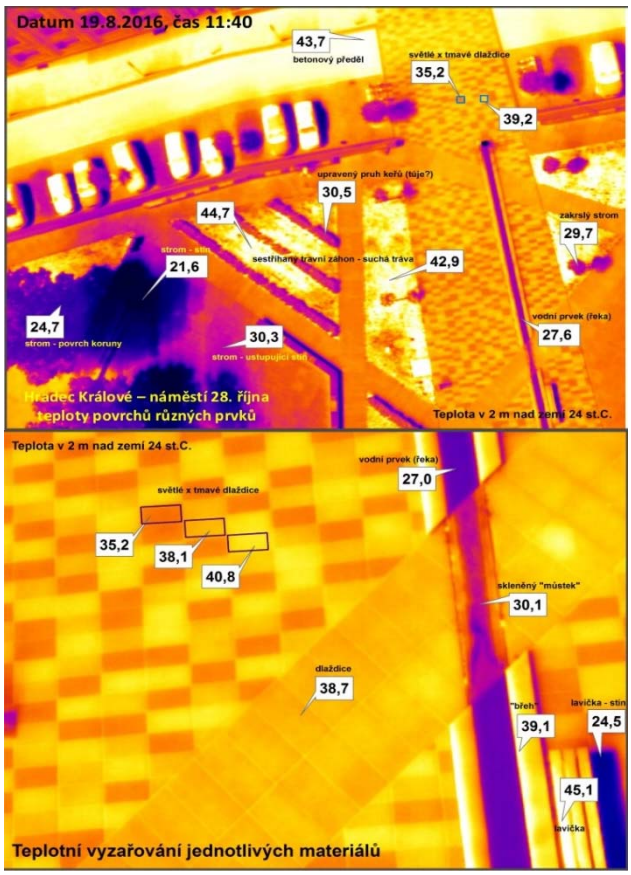
After Renovation – 2015

Source: GIS of the Municipality Hradec Králové

Fig. 4. Green Areas and Their Shares in Square's Total Area Compared (SW ArcGIS 10.3.)

Source: GIS of the Municipality Hradec Králové

Fig. 5. Example of Thermovision Recording – Material Heat Radiation at Air Temperature 24 °C (at 2 m above ground) – in degrees of Celsius



Source: GIS of the Municipality Hradec Králové

Riegrovo náměstí

In fact, *Riegrovo náměstí* is the space in front of the railway station that had taken the shape of a rectangle of 80 x 160 meters. The space is dominated by the railway station building erected in 1929–1935. Adjacent to it is the post office building erected in the south of the railway station in 1932–1934, and *Kňourek* houses built along the south line of the square in 1931–1939. However, this development did not enclose the space, the south-east corner was developed with houses at a later time and buildings in *Haškova* street and *Sladkovského* street stretched into the square as well. The parterre of the space lacked any special urbanistic treatment and was designed in a purely utilitarian way – a road around the space and a grassy area in the centre divided by another connecting road. However, by that time the space had acquired a specific function as a public transport terminal – a node of interchange between trains and buses. The square saw further changes at the turn of the 1960s and 1970s, when the block of houses in front of the dairy was pulled down and the

Černigov Hotel erected. The square's space was still based on the original utilitarian design and continued to be modified according to how current transportation needs required. A large paved surface was situated in front of the railway station building, with the city public transport terminal in the south and the long-distance bus transport terminal in the north. The centre of the space is made up of two rectangular lawns divided by a pedestrian pavement from south to north. Along the southern lawn there are bicycle stands and probably the largest bicycle 'parking lot' in Hradec Králové. More trees were planted in the grassy areas in the 1970s, adding heterogeneous solitary conifers to the older locust tree avenue going from south to north. This description clearly shows that a substantial renovation of this space was needed. [10]

The renovation of *Riegrovo náměstí* was completed in 2008, and the share of greenery in the total area shrank from 22% to about 9%. The number of grown trees dropped from 16 to eight; although seventy-nine small trees have been planted, these are for decoration and provide no significant shade. There are some new green areas in the square: one bed and an area with plant litter prevailing; the only major grassy area is situated in front of the Černigov Hotel car park.

Fig. 6. Orthophoto Map of Riegrovo náměstí in Hradec Králové

Prior to Renovation – 2005

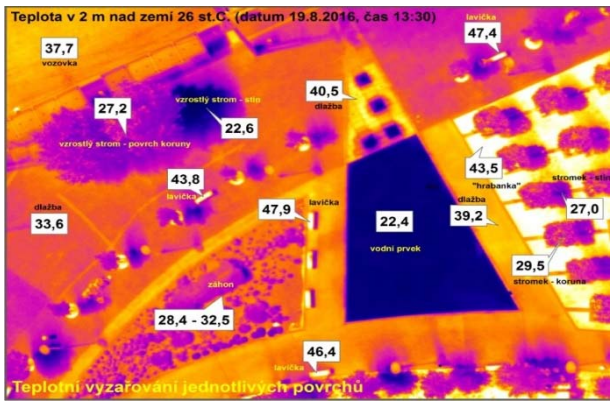
After Renovation – 2015

Source: GIS of the Municipality Hradec Králové

Fig. 7. Green Areas and Their Shares in Square's Total Area Compared (SW ArcGIS 10.3.)

Source: GIS of the Municipality Hradec Králové

Fig. 8. Example of Thermovision Recording – Material Heat Radiation at Air Temperature 26 °C (at 2 m above ground) – in degrees of Celsius



Source: Author's archive

Even though the climatic conditions at the time of imaging were typical of the season and the time rather than extreme – clear sky most of the time and air temperatures between 24 and 26 °C as measured in shade at 2 m above ground – some materials used in the renovation of the public space radiated accumulated heat to a marked degree.

The thermovision records clearly show the difference in the surface temperatures of the different types of paving.

Grown trees and water have a clear positive impact on the overall microclimate. However, the vast majority of benches in *Riegrovo náměstí* are situated near the decorative trees in the 'plant litter' area and face the motion of the sun, so the shade is cast in the opposite direction. This will not be comfortable for anyone wishing to have a rest or waiting for their train or bus – the benches are exposed to direct sunshine between 10 and 15 o'clock in summer. This had its effect on the surface temperature, which exceeded 40 °C (with air temperature of 26 °C). Any renovation requires that architects take also this factor into account and make a thorough on-site survey before starting their designing work.

6 Conclusions and Recommendations

The measurements clearly show that materials have major impact on public space climate even in relatively mild typical summertime climate with direct sunshine (24–26 °C and calm). Such public space is likely to transform into a heat island that is certain to 'drive out' people and the places designed for rest – benches and playground features – will become useless. Designers should be able to find out and check the information about the heat radiation of the construction materials they plan to use.

- The thermovision records clearly show the difference in the surface temperatures of the different types of paving.
- Grown trees and water have a clear positive impact on the overall microclimate.
- But it is evident that many benches receive no shade.

In *Riegrovo náměstí*, for example, **most benches are situated near the decorative trees in the 'plant litter' area but face the motion of the sun**, so the shade is cast on the other side of the benches, which are exposed to direct sunshine in summer between 10 and 15 o'clock.

This had its effect on the surface temperature, which exceeded 40 °C (with air temperature of 26 °C). This factor should be taken into account by designers in designing any public space renovation.

- The thermal reflectivity of the materials considered to be used in public space renovation needs to be taken into account.
- Underrating the role of greenery (both green areas and grown trees) should be prevented.
- Water enlivens the space and cools it down.
- Consider the position of the sun in summer when choosing where to place exterior equipment, such as benches or playgrounds.

Create shade-casting elements, such as trees, avenues, canopies or sun umbrellas in suitable positions.

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