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Temperature Comfort, Recreation and Historical Features in Open Spaces; the Path of Remembrance and Comradeship (PATH) in Ljubljana, Slovenia

Alenka Fikfak^{1*} Miha Konjar¹ Janez Peter Grom¹ Saja Kosanovic²
Martina Zbašnik-Senegačnik¹

1. Faculty of Architecture, University of Ljubljana, Slovenia

2. Department for Architecture, Faculty of Technical Sciences, University of Priština, Kosovska Mitrovica, Kosovo

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ABSTRACT

The built environment has a great impact on the quality of urban climate, a comfortable living environment, overheating, and detection of changes in Urban Heat Islands (UHI). Despite the effects that raised outdoor temperatures have on human well-being and health, being in open outdoor spaces is strongly encouraged. This article deals with open green urban areas. The study was focused on searching for the relationships between the various elements, such as outdoor thermal comfort, the urban heat island, green areas, and active leisure time. The well-being in open spaces has been studied on the case of The Path of Remembrance and Comradeship (PATH) in the city of Ljubljana, Slovenia. PATH is a circular recreation ground (almost 33 km long) and passes from the urban to the natural landscape area. PATH constitutes an important element of the urban space and confirms the identity and image of Ljubljana. It is most popular for walking and jogging. Overheating at the PATH was studied using multiple indicators, which were broken down into detail at five sites with different urban morphology, green areas, water, and paved areas.

1. Introduction

Climate change and world-wide climate-related extremes reflect their impact on human well-being and health. The built environment and building density significantly affect the quality of urban climate, comfortable living environment, overheating, and detection of changes in Urban Heat Islands (UHI). Increased ambient temperatures deteriorate the physical well-being of people causing problems, such as “heat stress in the form of heat syncope, thermal exhaustion, cardiovascular stress, cardiorespiratory diseases

and heat stroke”^[1]. Owing to the evolution of technologies we have become increasingly used to a balanced climatic comfort inside buildings, which increases, along with continuous modifications and variations subject to various climate influences, the sense of living discomfort outdoors. In general, outdoor thermal comfort is much more complex than indoor comfort, but the feeling of comfort is the expression of individuals’ wellbeing in their environment. Outdoor human thermal exposure is highly spatially variable and requires microscale assessment, because air tem-

*Corresponding Author:

Alenka Fikfak,

Faculty of Architecture, University of Ljubljana, Slovenia;

Email: alenka.fikfak@fa.uni-lj.si

perature alone does not fully capture the variability of the thermal conditions experienced in urban environments^[2,3,4]. Encouraging more people to use outdoor spaces will benefit cities from various perspectives, including physical, environmental, economic, and social aspects^[5,6].

Studies show that city residents walk in open spaces or use them (1) if there are green areas in their living environment, (2) if there is good accessibility to the green areas, and (3) if inhabitants have as many various open green areas available as possible^[7]. On the other hand, green areas are the most efficient element that helps to reduce the UHI effect. Trees mitigate air overheating, offer shade, and increase the feeling of humidity with their breathing leaves. Increasing the vegetation land cover could considerably reduce surface temperatures^[8]. Understanding and evaluating thermal comfort conditions in urban spaces is necessary, as this can have major implications for the development of cities because urban areas accommodate daily pedestrian traffic and various outdoor activities and contribute greatly to urban liveability and vitality^[9].

The studying of open green urban spaces was focused on searching for the relationships between the various elements, such as outdoor thermal comfort, urban heat island, green areas, and active leisure time. In many cities we witness the transformation of open spaces into the active use of these areas for recreation purposes, by connecting the individual spaces that build the public image of the city. Such cases are the following: The 20 Green Walks in Berlin (network uses Berlin's green corridors to link neighbouring city districts and the nearest recreational areas)^[10], The Emerald Necklace, a chain of parks linked by parkways and waterways in Boston and Brookline^[11], The Freedom Trail in Boston, a pedestrian trail to link important local landmarks as an urban historical reader of the city^[12], or Šetnica in Šibenik, Croatia, which connects the waterfront landscape to the history of fortress and urbanity of the city^[13].

2. Methods and Materials

The focus of this study was to study UHI, i.e. to show long-wave radiation from the surface “due to the accumulation of heat in buildings and on concrete and asphalt land during the day”^[14]. We studied how the UHI impact changes and how this affects the use of open green spaces, particularly in the case study The Path of Remembrance and Comradeship (abbreviated PATH) in the city of Ljubljana, Slovenia. In Ljubljana albedo is lower also due to the green system, wind flows, diffuse solar radiation, lower pollution, and lower relative humidity. The most dynamic element of a city is circulation, which acts as a mechanism of exchange; it is not limited only to transport,

but creates a continuously changing network of social relations. The PATH lies at the heart of experiential, leisure, modern, recreational city living, thus promoting the element of mental health and human well-being.

The methodology employed for this study consists of a literature review and detailed mapping. The study of UHI changing and its impact on the comfort of living in an open space is focused on the characteristics of the open space and its relation to close areas – built and natural.

The study of “open spaces” in recreational areas of the PATH, as the axes connecting urban, peripheral, and rural part of the Municipality of Ljubljana, is oriented toward exploring the relations between elements of environmental quality features, landscape and land-use surface characteristics and urban morphology, with an emphasis on monitoring the differences in temperature comfort in an open space. The study implements historical, morphological, and typological research methodologies employing statistics, field observations, and on-site analyses, with the data used as follows:

(1) Geomorphological data by the Surveying and Mapping Authority of the Republic of Slovenia (SMRS, 2015). Analyses of geomorphological (topography, relief, terrain type) and climate conditions, and mapping of landscape characteristics (agricultural and natural conditions). Mapping spatial data using GIS ESRI ArcGIS software (ArcMap version 10.3.1) for visual representations and analyses;

(2) Thermal imagery from satellite Landsat 8 (Thermal Infrared Sensor) launched as the Landsat Data Continuity Mission - LDCM on 11 February 2013) mission. The satellite continues the acquisition of high-quality data that meet both NASA's and United States Geological Survey's (USGS) scientific and operational requirements for observing land use and land change (Landsat Project Description, 2016). Landsat 8 Thermal Band 10 was acquired from the USGS EarthExplorer user interface (USGS, 2017), an online search, discovery, and ordering tool. Thermal mapping. Calculation of land surface temperature from Landsat 8 imagery. Satellite images were transformed in a way to show surface heat in degrees Celsius. The images were processed in ESRI ArcGIS software (ArcMap version 10.3.1). The temperature calculations were done with the tool Raster Calculator which calculated the temperature values for each pixel separately. For the visual representation the initial 30 × 30 m grid was resampled using ArcMap Resample tool to a 1 × 1 m grid. A Bilinear Resampling Technique was used.

(3) In-situ observations and analysis. Fieldwork and photographic recording: site visits from October 2017 to July 2019. The locations were selected based on the

relation of open spaces with urban built structures and distance from parking areas.

3. Case study: City of Ljubljana

The City of Ljubljana is the largest urban area in Slovenia (Figure 1, 2); 13,87% of total Slovenian population, i.e. 285,857 inhabitants, resides in the City of Ljubljana [15]. The natural conditions in the Ljubljana metropolitan area carry environmental risks, especially regarding floods and earthquakes. The weather in Ljubljana is conditioned by the city's geographical position in a vast basin extending from Slovenia's pre-Alpine to karst areas. Ljubljana is at the transition between the Mediterranean and Continental climate. Climate changes are affecting local and global climate systems. In fact, climate change is affecting the system at every scale; it manifests not only in the rising of air, ground and water temperature, but also in changes in humidity, clouds, rain patterns, the strengthened frequency of weather events (fog, snow, storms), and the damage done by weather [16]. To restrain climate change it would be necessary to add ecosystem services to the world business [17]. The problems which are detected by the Ljubljana Master Plan are: urban sprawl in its periphery, transport and traffic regulations (application of sustainable mobility in process), degraded areas (so-called brownfields), non-rational use of plots, dispersed one-family housing and dwellings at the periphery, non-legal housing from the 1970–90s, earthquakes, floods, unfinished projects. Ljubljana's advantage is that it has many green areas and was proclaimed the 2016 European Green Capital [18]. This award is of great significance for Ljubljana, as it put it on the European and world map of sustainable cities. One of the largest green areas is the PATH, a circular recreation surface that was created as a historical memory at a location where the barbed wire ran during the second world war.

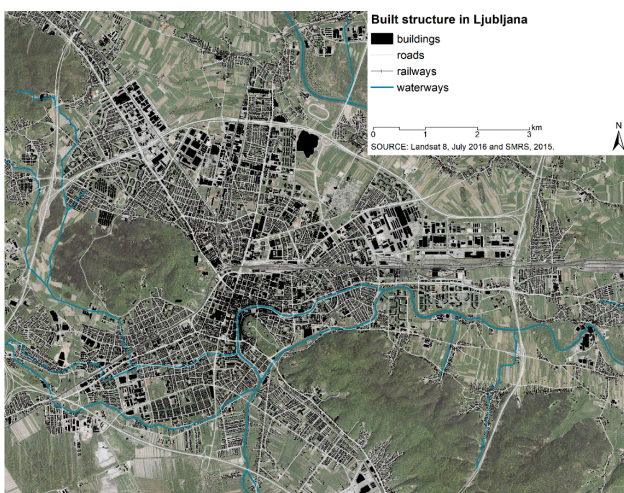


Figure 1. Ljubljana, built and green structure

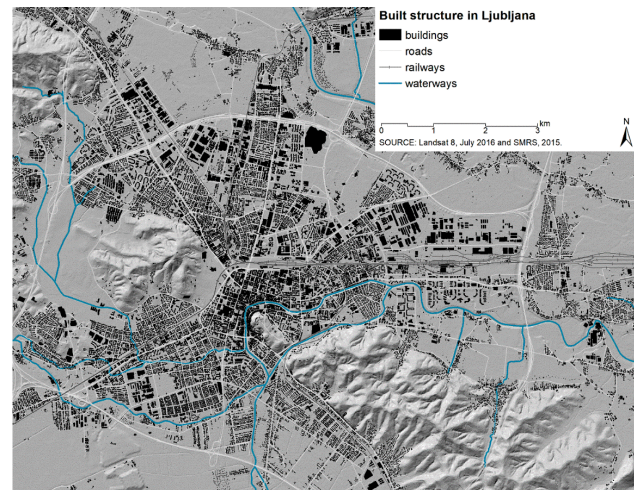


Figure 2. Ljubljana morphology of the built area and terrain model (DTM)

3.1 The Path of Remembrance and Comradeship (PATH)

After the German invasion of Yugoslavia, the Italian fascist army marched into Ljubljana on 11th April 1941. With the aim of successfully crushing resistance here as swiftly as possible, at the end of February 1942 the fascists began to enclose Ljubljana with a barbed wire fence in order to isolate, better said, separate the city from the countryside. At the end of 1942 the barbed wire fence was 29,663 m long. Ljubljana was strongly guarded – it was surrounded by 206 fortifications of various size. Everyone who wanted to enter or leave the city was thoroughly checked. After the capitulation of Italy on 8th September 1943, Ljubljana was occupied by the Germans, who increased the level of violence. Ljubljana was liberated on 9th May 1945 – after it was enclosed by a barbed wire barrier for 1,170 days. After World War II PATH was developed to commemorate the time during the war when Ljubljana was surrounded by a wire fence. The initial ideas about developing these urban and landscape features included the idea of a memorial run along the route. The memory of the National Liberation Struggle was evoked in the marches along “the paths of remembrance and comradeship”, which reflected the faith in common values and beliefs [19].

3.2 The PATH as Recreational Area

The first walk along the wire was organised in 1957. In the following decades a path was formed along the path where the wire once ran, a green ring around Ljubljana, connecting the possibility of everyday recreation and the historical memory. To commemorate the anniversary of liberation each year at the beginning of May tens of thou-

sands of people walk the PATH in approx. eight hours. Participants can begin their journey at various points and run or walk along the path as much as they want to.

The PATH is presently 4 m wide, almost 33 km long and covered with gravel (Figure 3). Along the green area adjacent to the PATH 7,400 trees of 49 tree species have been planted. Due to urban development the PATH runs along city streets in places between tower blocks, blending into the city tempo. Equipped with benches for resting, water fountains, and other urban furniture (outdoor parkour facilities, outdoor fitness areas and trails). The trail is used by many residents of Ljubljana each day. The most popular form of recreation on it is walking and jogging. Cycling is also permitted on condition that pedestrians are not endangered. In the proximity of some of the PATH's points there are rent-a-bike stations, the BicikeLj self-service bike rental system, etc. City bus routes with stops near the PATH are marked on the map as are the nearest car parks.

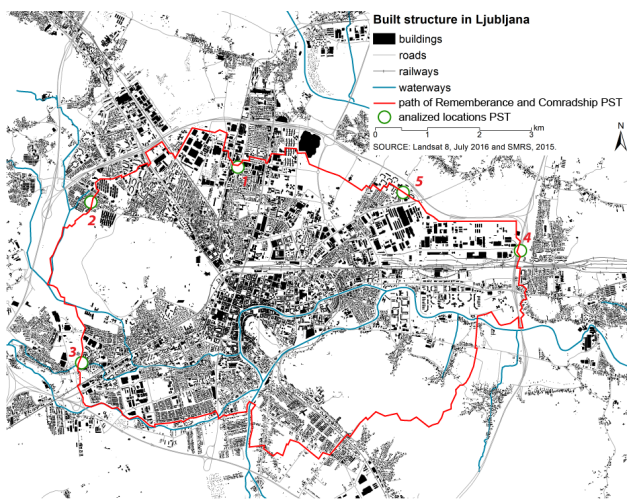


Figure 3. The PATH and locations (detailed analysis)

Nowadays, the PATH constitutes an important element of the urban space and without any doubt confirms the identity and image of Ljubljana. In 2004 and 2005, the City of Ljubljana decided to radically change the overall image of the PATH around Ljubljana, and thus directly influence the image of the PATH in the consciousness of the population of Ljubljana^[19]. Today the PATH is an element of socialising and connections between various residential areas, recreational areas, business areas, and open spaces. It passes from the urban to the natural landscape. The relief ranges from flat to undulating. It is an element connecting urban periphery while passing through various experiential ambiances. Besides evoking the historical memory, the PATH is today one of the largest green areas in Ljubljana, the biggest city park (larger than Central Park in New York), and the longest tree-lined promenade.

It is maintained by the Zeleni prstan (Green Ring) society, which has around 1500 members. It is difficult to estimate the daily number of visitors to the PATH, as many of its sections are located in residential areas. An important part of its story is the annual Run along the Path. In 2016, the 60th walk Along the Wire recorded 36,828 participants^[20].

The PATH includes places of remembrance as war memorials, while it also carries out the function of the city's recreation ground and communication. Because of this, the PATH is a unique reminder of the past and a unique urban planning feature. With its story, image, and practical application, the PATH is also the city's tourist attraction.

4. Results: Well-being in Open Spaces

The perception of urban climate, in terms of natural landscape and its surfaces, involves the information about the following levels and links among them:

(1) density and openness of: size of the lot (area), dimension and orientation of open spaces, presence of the user, density of the culture and its natural surface, density of vegetation, etc;

(2) connections between physical elements in space: between flat and rugged terrain, water and its surrounding, and open spaces and green surfaces, plants and trees to open spaces, etc.;

(3) surfaces and materials: type of crops and their absorption (green or blue) – surfaces and materials: water, green areas, paved (natural, sand paths); dimension of the element (tree height and canopy), vegetation type (tall vegetation impacts shadowing), bare soil and water, etc.

In the context of urban climate, we still talk about the natural landscape as part of the built environment rather than extra-urban agricultural areas.

In terms of the impact of outside temperature, a maximum of 29.5 °C was defined by Pogačar et al.^[21] as the parameter defining the threshold value for detecting heat waves. Below we give the results of mapping and observation of changes in selected areas of the PATH (Figure 4, 5, 6), which has the function as a borderline between urban and rural environmental structures. Given the activities underway in one or the other location, the following is important:

(1) The PATH runs through residential, trade, commercial, and industrial parts of the city. Most areas are vegetated, while some parts have no green elements. Increased UHI is recorded in these areas.

(2) The PATH is an area of activities, as each location on its route is visited with a clear purpose of recreation. We assume that the visit of the individual sections is subject to urban climate quality. Based on observations, we find that the most visited places of the path are the tree-

lined areas or areas that are part of green areas of the urban landscape.

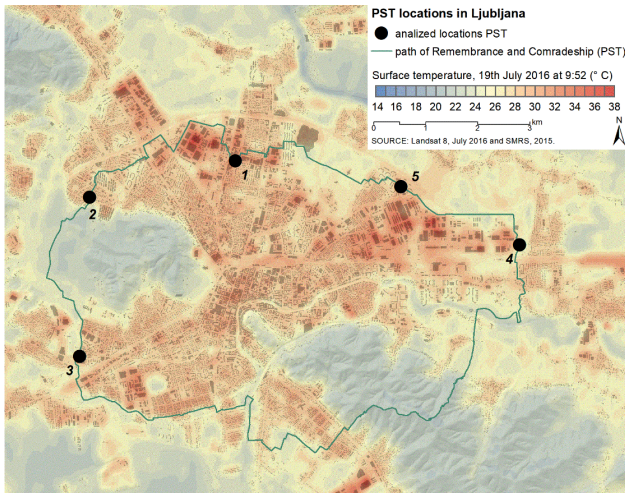


Figure 4. Surface temperature in the city of Ljubljana, PATH locations (detailed analysis)

this site, the PATH is not tree-lined, which significantly decreases the quality of its climate. This site reflects most of the negative elements: impact of air pollution, visual degradation of surfaces, no tree line. These elements significantly prevail over the surrounding natural landscape. Overheating and variations in UHI are the highest in areas with dense and high-rise construction morphology (sites 1, 5). Here, building density has a significant impact on UHI, but not necessarily a negative impact on the desire to use the path. This is the case at site 4.

Results of studying urban climate in terms of natural landscape and its surfaces on the PATH (Table 1, 2): the PATH is integrated into space so that most sections are located in the natural landscape. This lends a distinctive character to the path, i.e. urban recreation features. In sections where the path is part of the natural landscape, lines of trees are added, providing the path with high-quality ambience and climate features. In terms of spatial orientation, some sections, despite being covered in vegetation, lack quality, as the impact of neighbouring indicators of overheating prevails (site 3).

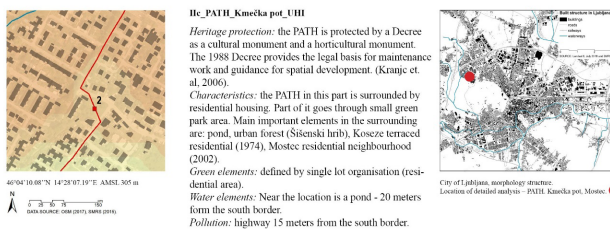


Figure 5. The PATH Kmečka pot, Mostec in Ljubljana: UHI detailed analysis.

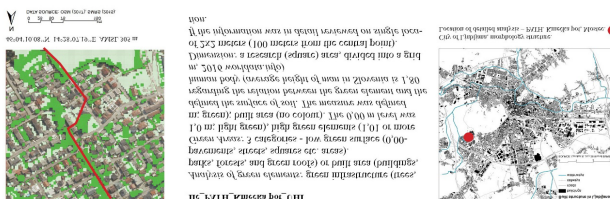


Figure 6. The PATH Kmečka pot, Mostec in Ljubljana: green areas detailed analysis.

The results of studying urban climate in terms of construction density in the case of PATH (Figure 7, Table 1, 2): in many sections, it is located in densely populated areas. A high UHI is detected in these areas, which does not depend on the character of the PATH but rather on the surrounding morphology of structures, their materials, size, ventilation, etc. This directly affects the path's quality. The space with the least quality in terms of urban climate is site 4, where the path is integrated into the empty space of the infrastructural landscape (motorway corridor). At



Figure 7. The PATH sites in Ljubljana – morphology, green areas, UHI

Table 1. Average temperature and proportion of area occupied by buildings or/and green areas (according to the zoned land use)

PATH sections where the point is located (image c, UHI)	Buffer	Min temperature in the area	Max temperature in the area	Average temperature in the area	Surface area [m ²]	Proportion of area occupied by buildings (not all built-up areas are considered, e.g. road infrastructure)	Proportion of area covered in green areas according to the zoned land use in the municipal spatial plan (forest, agricultural land, green areas, water)
Section at Vodovodna between Slovenčeva and Verovškova (1a-1c)	100 m	29	32	30,6	31374,94	38,31	1,35
	200 m	28	32	30,2	125581,04	35,12	1,60
Section between Ulica bratov Bezlajev and Kmečka pot toward Koseški bajer (2a-2c)	100 m	26	28	27,0	31374,94	17,62	7,53
	200 m	22	28	26,9	125581,04	17,90	17,75
Section at Cesta na Vrhovce crossing (3a.3c)	100 m	24	29	26,3	31374,94	12,70	58,59
	200 m	24	29	26,4	125581,04	14,70	49,60
Section at the end of Letališka cesta at the western city ring (1a-4c)	100 m	24	27	25,1	31374,94	0,38	44,60
	200 m	24	30	26,0	125581,04	3,04	42,45
Section toward Ulica Gradnikove brigade in Nove Jarše (5a-5c)	100 m	27	29	28,5	31374,94	18,67	11,79
	200 m	27	30	28,4	125581,04	19,54	4,67

Table 2. Detailed analysis of green elements, 3 categories (relation to Figure 7)

	A - total area in m ²	B - low green, surface	C - high green elem.	B+C v m ²	A/ B+C %	A/ B %	A/ C %
1b - PATH_Vodovodna street	150000	8344	17768	26112	16,32	5,22	11,11
2b - PATH_Kmečka path	160000	31560	35696	67256	42,04	19,73	22,31
3b - PATH_Street to Vrhovce	160000	43740	39248	82988	51,87	27,34	24,53
4b - PATH_Letališka street	160000	79572	19716	99288	62,06	49,73	12,32
5b - Nove Jarše_	160000	24320	34132	58452	36,53	15,20	21,33

5. Discussion

The study of the PATH to understand its potential as a “well-being” recreational area, explored through activities (recreation and socializing), which have a significant impact on urban living in connection with rural living, has opened several points to discuss: relation to green areas, history and meaning of the single location, connections between different urban and rural spaces, communication needs between humans, etc. But the main discussion in the research presented was around the question of overheating of open spaces. Overheating was studied using multiple indicators, which were broken down into detail at each site.

Over the decades, the PATH phenomenon grew organically both functionally and in terms of content. It acquired elements (vegetation, water, urban furniture, etc.) which affected the reduction in UHI. The result is a large green recreation area, which improves the micro-climate in the city and allows for a healthy lifestyle to its residents. In the case of the PATH, orientation is one of the key elements precisely in the built environment, particularly in high-rise areas, as spaces overheat more than the areas transitioning into the natural landscape. In terms of orientation it is particularly important that the setting of the buildings allows for enough ventilation. Another important feature of the PATH is its orientation in relation to insolation, in terms of direct illumination of the path in combination with vegetation (trees). There are various negative manifestations of the

latter: walking direction, no tree lines and direct sunlight – in combination with high air temperatures the discomfort to skin and eyes exposed to the sun is great.

According to the research topic, a special emphasis was put on the content mentioned below, which particularly address the relationship between the natural environment and the green structure with an impact on the PATH:

Urban morphology – the surrounding fabric certainly impacts overheating and the severity of UHI. In the case of the PATH, suggest that there is a major difference in the areas where the PATH passes from the natural landscape to the built environment. The reduction in UHI in open spaces can be increased by providing such building morphology that allows for ventilation of the site, as winds decrease air temperatures. Strong winds increase atmospheric mixing, lowering the urban-rural temperature difference^[22]. O’Malley et al.^[1] elaborate the significance of urban morphology, which “reduced speed of wind caused by design and layout of the built environment”.

Green areas – PATH is the largest green area in Ljubljana and it contributed to it being awarded the title of the 2016 European Green Capital. Green areas improve the micro-climate, enrich the air with O₂, and deplete the air of CO₂. Vegetation regulates moisture – on hot, dry days it releases moisture into the surroundings, in could mornings it absorbs moisture as dew from the air. Vegetation cleans the air – dust settles on the leaves which are then washed off by rain. Vegetation provides the habitat to

many organisms and increases the biodiversity. Birds nest in the branches of trees and bushes. Green areas reduce UHI – the plants use part of the heat from solar radiation for photosynthesis, part of it is then reflected back into the environment, and part of it is absorbed. On a hot summer day an asphalt or concrete surface heats up to 80–85 °C, while green surfaces heat up to only 25 °C. In any case, the city is a much friendlier urban place if high-quality green mobility is taken care of. Trees of a height of 5–10 m help to control the overheating of surfaces in buildings^[23]; however, in the case of the PATH “thick hedges of a height of 1.5 m green”^[23] have fewer significant cooling effects on the air as it is important to create both cool air and shade up to a person’s height.

Water is another element that has beneficial impacts on UHI reduction and the wellbeing of users. This can be observed in the Mostec section of the PATH, where the path becomes part of the urban setup of the lake recreation area (proximity of site 2, unfortunately in summer heat coupled with insects, with negative effects on users). According to Slingerland^[24] “it can be seen that water is a good mitigation measure, because DTS (Distributed Temperature Sensing) measurements show that a minimum of 14% of daily incoming solar energy is absorbed by surface water“. However, the benefits of water are felt only when it is an inherent part of the development. When the water element is not immediately nearby, it no longer directly affects UHI reduction, as the water surface itself overheats and lacks the high reflective effect that could reduce UHI.

Pavements are important, as additional radiation from the ground creates walking discomfort (in the case of the PATH). To this effect, it is necessary to promote the use of “cool pavements”. The term has mainly referred to reflective pavements that help lower surface temperatures and reduce the amount of heat absorbed into the pavement^[22]. With the growing interest and application of permeable pavements – which allow air, water, and water vapor into the voids of a pavement, keeping the material cool when moist – some practitioners have expanded the definition of cool pavements to include permeable pavements as well^[22]. The cooling of surfaces is boosted by adding various water features, which have positive effects on the psychological well-being.

The PATH was developed in a place where the barbed wire once ran around Occupied Ljubljana. The memorials on the path are a reminder of the hard times when the passage from and to the city was difficult and dangerous – a daily reminder how history should not repeat itself.

6. Conclusions

It is important to reduce the UHI not only in densely built-up urban areas (where UHI is the highest), but also in

areas that indirectly affect a person’s quality of life: open spaces as squares, promenades, and recreation areas. All this knowledge can be used to understand the emergence of green, paved, and water surfaces in the urban environment and the value of connections with the rural space (footpaths, cycling routes, etc.). And in the case of the PATH – to preserve this historical memory.

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