

# THE IMPORTANCE OF THERMAL COMFORT OF THE URBAN ENVIRONMENT DURING SPATIAL PLANNING AND CONSTRUCTION

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**Abstract:** Urban areas in Bosnia and Herzegovina have been recording population growth. The city of Bijeljina has undergone major transformations in the appearance and purpose of the area due to the intensive construction process that is necessary to meet the needs of the increased population. The lack of greenery and the increased number of objects in a small area, as well as the intensified traffic, lead to discomfort among the population, which is manifested by many diseases related to thermal stress. There are many bioclimatic indices used to define the thermal comfort of an area. This paper will present the physiological subjective temperature (PST), which was analyzed for a period of 14 years (2005 - 2018) in the city of Bijeljina. Knowing the thermal comfort of an area before construction and before creating a spatial plan is important for reducing the number of people affected by heat stress and for providing guidelines for planning a more pleasant environment.

**Keywords:** urban environment, thermal comfort, PST, heat islands.

## 1. INTRODUCTION

The distribution of the population in Bosnia and Herzegovina is uneven. Such population of the country led to completely different sides, overcrowding of cities on the one hand and neglect of villages and rural areas on the other. The sudden growth of urban areas affected their characteristics and led to changes in natural and social elements. According to the 2018 Revision of World Urbanization Prospect, 68% of the world population is expected to live in urban areas [1–2].

Densely populated urban areas record higher temperatures compared with the surrounding environment. The appearance of higher tempera-

tures than the environment due to the level of urbanization that modifies land use represents a phenomenon of urban heat islands [2, 3]. A large amount of concrete, reduced green areas, increased traffic density and a daily flow of cars lead to an increase in temperature in urban areas and the creation of inadequate conditions for the population in the form of poor thermal comfort. Adaptation of the population to the new temperature conditions is very difficult, especially for chronic patients. Bioclimatic indices are the subject of numerous studies by various authors in Bosnia and Herzegovina and around the world. In the last 10 years, thermal comfort defined through the analysis

of bioclimatic indices has been researched by numerous authors in the Balkans [4–10].

Bijeljina is a typical example of a heat island in Bosnia and Herzegovina. The construction of buildings from the beginning of the 20th century made a complete transformation of the space and created an urban environment from a small town [11]. Within this research, the thermal comfort of the population was analyzed through the bioclimatic index Physiological subjective temperature in the city of Bijeljina for a period of 14 years, and it showed the importance of knowledge of bioclimatic analysis of thermal comfort during construction and spatial change. The analysis of the thermal comfort of Bijeljina so far has included various indices, of which WBGT [12–13] heat load index [11] and UTCI [13–14] should be mentioned. The index of physiological subjective temperature

represents one of the bioclimatic indices that are important for understanding the heat load of the human organism in a certain environment and as such is included in this research.

## 2. METHODOLOGY

The city of Bijeljina is located in the northeast part of Bosnia and Herzegovina. It borders the Republic of Serbia to the east, the Republic of Croatia to the north, Brčko District to the west and the municipalities of Lopare and Ugljevik and the City of Zvornik to the south. It is characterized by a favorable geographical position at the crossroads between Serbia, Croatia, Brčko District and the Federation of BiH (figure 1).



*Figure 1. The position of the City of Bijeljina in Bosnia and Herzegovina [15]*

The total population of the city is 42 278 [16], which is 16.1% higher than in 1991 [12,17]. The population density is 1 497 inhabitants per km<sup>2</sup>, which is much higher than the population density of Bosnia and Herzegovina which is 68.9 inhabitants per km<sup>2</sup> [17] and the population density of Europe in general which is 188 inhabitants per km<sup>2</sup> [18]. The influx of population to Bijeljina, which has been going on since the beginning of the 20<sup>th</sup> century, has led to changes in the appearance and functioning of the city itself. The needs of the population for housing, education and work have imposed a rapid construction process, which often does not follow spatial norms.

Omissions such as the proximity of buildings to the street or any other object, the absence of trees or their replacement with lawns and buildings, overload of some streets with multi-story buildings, insufficient parking spaces and many others created overcrowding and led to discomfort in people, which in combination with high temperatures is manifested by the appearance of mild or severe health problems [11].

In addition to the change of the space in the form of constructing multi-story buildings, natural climate elements also affect the creation of discomfort in the population. The city is characterized by high temperatures during a large part of the year, with the warmest months being June, July and August, followed by a lack of wind and often higher humidity. 2019 was one of the warmest in the last 100 years in the research area. August had an average 2 °C higher average air temperature [19], November was one of the five warmest in the last 150 years, with an average monthly temperature of 11.3 °C [20] and December was the tenth warmest since 1861 [21]. Average monthly and annual wind speeds do not exceed 2 m/s. Humidity, which also affects thermal comfort, is the highest during the winter months [22]. It is

necessary to mention that the meteorological station for Bijeljina is located outside the urban and densely populated zone of the city, in a settlement with ground floor, one-story and two-story houses, next to green areas, which suggests that the temperature in the city center is slightly higher than shown at the station [11].

For research on the thermal comfort of Bijeljina, the bioclimatic index Physiological Subjective Temperature (PST) was used, which represents the human feeling of the thermal environment. The heat sensation in the skin is a consequence of the signals sent by hot and cold receptors in the skin and the nervous system. The thermal influence of the environment is represented by the average radiation temperature around the skin surface. Current ambient conditions affect the intensity of heat exchange between man and the atmosphere and the basic level of total heat accumulation. Physiological subjective temperature represents the level of thermal stimulus located near the skin surface after 15 - 20 minutes of intensive adaptation process [23].

Two types of data - meteorological and physiological - are needed to calculate the human thermal balance. Meteorological data in this research refer to daily average values of meteorological parameters. For physiological data, universals were used that represent constants in the model. Those are metabolic heat of 135 Wm<sup>-2</sup> for a human moving speed of 1.1 ms<sup>-1</sup>, skin temperature of 32 °C, thermal insulation of 1 clo achieved at rest at a temperature of 21 °C and relative humidity of 50% and includes a person dressed in a business suit, albedo leather of 30%, albedo earth of 17% and skin moisture that is a dimensionless size [24, 25, 26].

The period of 14 years, from 2005 to 2018, was analyzed. The calculation of this index was done through the program BioKlima 2.6 [27]. The range of heat load values is given in Table 1 [28].

**Table 1.** Range of physiological subjective temperature values

Category	Numerical value
Frozen	< -36.00
Very cold	-36.00 – -16.10
Cold	-16.00 – 4.00
Chilly	-4.10 – 14.00
Comfortable	14.10 – 24.00
Warm	24.10 – 34.00
Hot	34.10 – 44.00
Very hot	44.10 – 54.00
Sweating	> 54.00



### 3. RESULTS

In the researched area, in the observed period of 14 years, six of the nine categories of this bioclimatic index were recorded. Those are the categories Cold, Chilly, Comfortable, Warm, Hot and Very Hot. For the human body, the most favorable days are within the category of Comfortable and their schedule and presence, or absence, during the months.

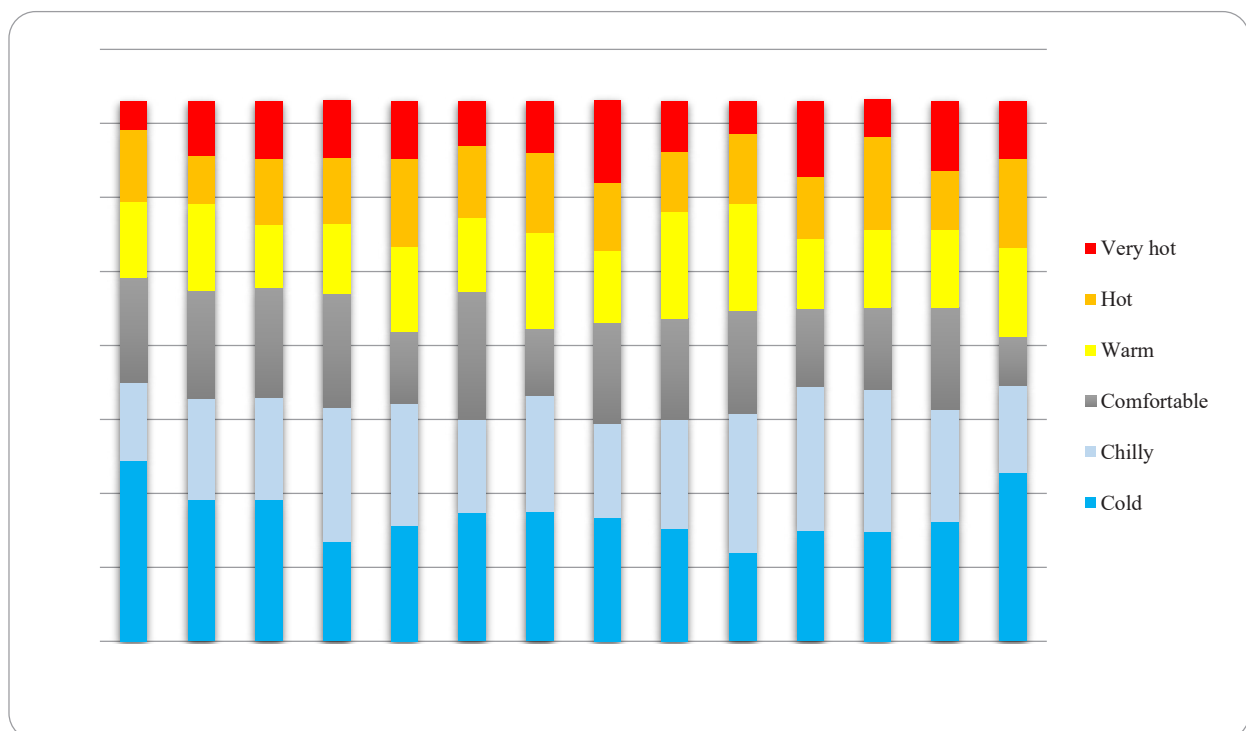
Category Cold, with values between - 16.00 and - 4.00, is present on average 86 days a year, in January, February, March, October, November and December. Category Chilly, with values between - 4.10 and 14.00, is present on average 76 days a year, in January, February, March, April, October, November and December, and slightly weaker during May and September. Category comfortable, with values between 14.10 and 24.00, is present on average 64 days a year, during the spring and autumn months, with occasional occurrences during the summer months as well.

Category Warm, with values between 24.10 and 34.00, is present on average 56 days a year, in the period from April to October. Category Hot, with values between 34.10 and 44.00, is present on average 48 days a year, in the period from May to September. Category Very hot, with values

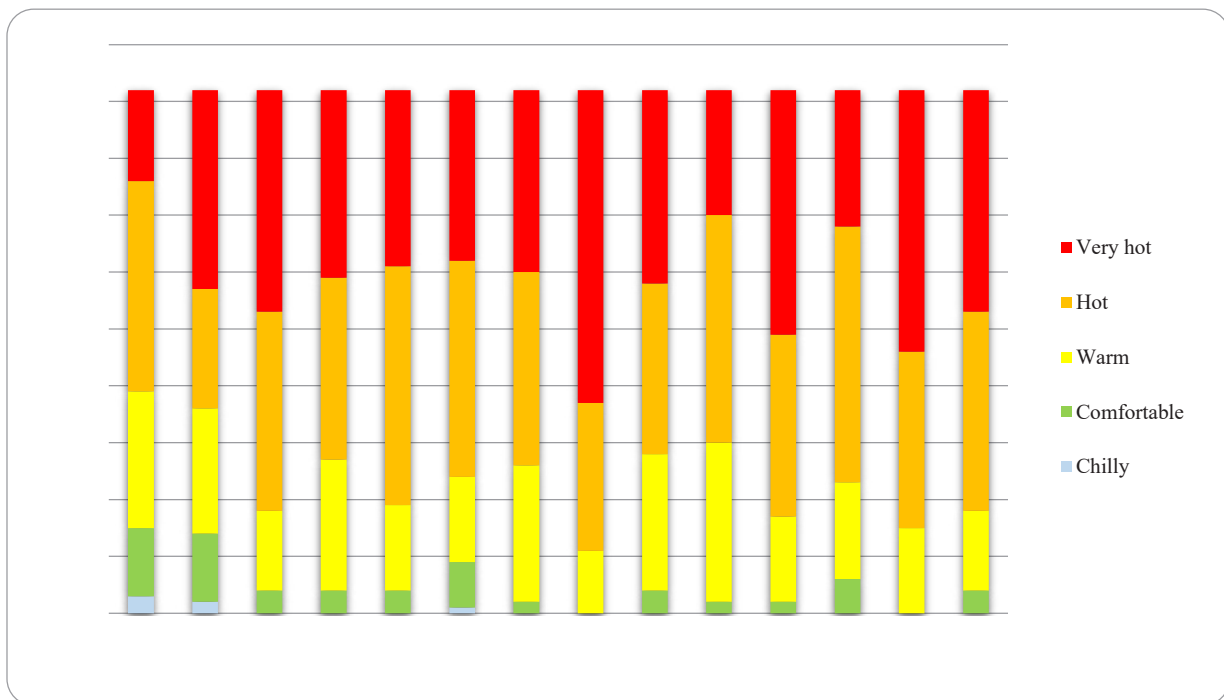
between 44.10 and 54.00, is present on average 37 days a year, during the months of June, July, August, rarely May and September.

The number of days of different categories is variable for the researched index. The first three categories (cold, chilly and comfortable) collectively show a decline during the observed period, giving way to warmer categories (warm, hot and very hot). The ratio of all categories during the observed period is shown in Figure 2.

The values of the warmer months are the most important for the research of thermal comfort in the area of Bijeljina. During the warmest period of the year, more precisely during the months of June, July and August, five categories were recorded. Those are the categories Chilly, Comfortable, Warm, Hot and Very Hot. Categories Chilly and Comfortable show a decrease in the number of days during the observed period for the given months. Category Chilly last appeared in 2010. In the observed period, three days were recorded in 2005, two days in 2006 and one day in 2010. Category Comfortable shows a significant decrease in the number of days. The exception is 2010 when this period lasted eight days, and 2016, with six days. The total number of days in the other three categories shows a slight increase during the summer months (Figure 3).



*Figure 2. Ratio of PST categories during the year for the observed period (2005 - 2018)*



**Figure 3.** The ratio of PST categories during the summer months for the observed period (2005 – 2018)

#### 4. DISCUSSION

Daily values of the bioclimatic index PST show unfavorable results. The months of June, July and August have the highest values of this index, and at the same time, the highest number of days in the Very hot category. During these months, there are a few pleasant days, which show a decline from year to year. Certain years such as 2012 and 2017, had 0 days in the category Comfortable, in the observed period.

High temperatures, supported by other meteorological factors in urban areas with little greenery, a lot of traffic and more and more concrete, cause overheating of the human organism and its dysfunction. This results in health problems associated with thermal discomfort such as heat rash, heat exhaustion, rhabdomyolysis, heat cramps, heat stroke and heart attack, etc. [29].

The main shortcoming in the urbanization system in Bijeljina is reflected in the reduction of green areas due to multi-story buildings. Most of the tall trees were cut down for the construction of multi-story buildings, business and residential. Many areas with tall trees have been replaced by parking spaces with little or no flowers or grass. This approach to the urbanization of Bijeljina led to

increased temperatures of the city in relation to the environment, and the creation of a thermal island. Many cities in Europe with more green areas and better traffic regulation, despite the high population density, have greater comfort and are more pleasant for the human body. The use of greenery contributes to the reduction of heat in urban areas through evapotranspiration and improves heat exchange by helping the urban energy balance [30]. Research in Milan has shown a positive effect of tall trees on the comfort of the population [31].

All of the above shows the importance of knowing the bioclimatic conditions and the state of the comfort of the organism when planning, modifying or building a certain space. This is especially important for urban environments, where comfort must be a priority due to the growing presence of urban heat islands. Understanding the meteorological effects of urban planning and the impact of urban design on human quality of life is therefore of increasing importance [2]. Assessing the thermal comfort of the population, especially today, in conditions of rising temperatures and urban expansion is a necessary initial phase in careful urban design [32].

## 5. CONCLUSION

The sudden urbanization of Bijeljina led to the creation of a thermal island with temperatures higher than the surrounding area. Such conditions favor the development of thermal discomfort that can be monitored by analyzing bioclimatic indices. This research uses the index of physiological subjective temperature because it provides valid information about the adaptation of the organism to the factors of the environment in which it is located.

The excessive process of urbanization has led to the reduction of green areas in the city, which are important for reducing the temperature of the air and surrounding buildings. In addition, the increased concentration of traffic due to inadequate construction and lack of parking spaces is an important reason for the problem.

The importance of including bioclimatic evaluation in spatial planning and its application during construction is becoming increasingly important because the construction process is placed in the comfort of the population. In the future, it is necessary to include bioclimatic evaluation in the planning process to adequately implement changes in space so that they minimally affect the discomfort and health of the population.

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## ЗНАЧАЈ ТЕРМАЛНОГ КОМФОРА УРБАНЕ СРЕДИНЕ ПРИЛИКОМ ПРОСТОРНОГ ПЛАНИРАЊА И ИЗГРАДЊЕ ОБЈЕКТА

**Сажетак:** Урбане средине у Босни и Херцеговини бележе раст популације. Град Бијељина претрпео је велике трансформације у изгледу и намени простора услед интензивног процеса изградње који је неопходан да би се задовољиле потребе повећаног броја становника. Недостатак зеленила и повећан број објеката на малом простору, као и интензитет саобраћаја доводе до нелагоде код становништва које се манифестује низом болести повезаних са термалним стресом. Постоји велики број биоклиматских индекса који се користе за дефинисање термалног комфора неког подручја. У овом раду биће представљена физиолошка субјективна температура (PST), која је анализирана за период од 14 година (2005–2018) у граду Бијељини. Познавање термалног комфора неког простора пре изградње и дефинисања просторног плана од значаја је ради смањења броја оболелих од топлотног стреса и давања смерница за планирање пријатнијег окружења.

**Кључне ријечи:** урбана средина, термални комфор, PST, топлотна острва.

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