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The use of outdoor microclimate analysis to support decision making process: Case study of Bufalini square in Cesena

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ABSTRACT

The study is aimed at evaluating the potential effects of alternative design solutions with different green elements on outdoor microclimate with relation to a real case study application. The study has been commissioned in the framework of the follow up of a design competition, launched by the Municipality of Cesena to reshape a square in the historic city center, when a public debate raised around the arrangement of trees and green surfaces envisaged by the architectural layout. Different options were considered and the design team and the public authorities sought for evidences on the deriving benefits in the respective configurations in order to properly drive the process. Thus the scientific research approach was applied to investigate the potential impacts according to a microclimate oriented perspective. The outcomes showed that green surfaces significantly improved the outdoor comfort conditions compared to original paved ones and that a minor contribution derived by the trees arrangement. The paper reports the applied methodology according to the specific context, the interpretation of results and how they have been translated into user friendly visualizations in order to make them understandable to a broader and non technical audience.

1. Context and background

The paper reports a study performed coupling the scientific approach of academic research with the very practical objectives and implications of a concrete application in the urban environment. The study is aimed at considering the potential effects of different design solutions developed to reshape a public space of a small city of northern Italy in terms of outdoor microclimate. The study was commissioned with relation to the outcomes of a design competition launched by the Municipality of Cesena in 2011 with the purpose to select the best proposal to completely redesign the layout of Bufalini square – in the heart of the historic city center – where also the renown Malatesta library (one of the most ancient library, dating back to 1452) faces. The square is characterized by a quite regular space exactly in front of the main elevation of the Library and is separated from a second public space by a longstanding line of oak trees (*Quercus ilex* L.) that the winning project of the competition, by "Ceredi Architecture and Engineering Office", envisages to replace completely re-arranging the green surfaces. A public debate raised on the opportunity to remove the existing trees simply to follow architectural purposes and a citizens association asked the Mayor and his staff to reconsider the decisional process including other parameters that may lead to a more conscious choice. Convinced of the quality of the design strategy, the winning team – demonstrating an uncommon and wise sense of cooperation and of self assessment attitude – sought for the competences of the Department of Architecture of University of Bologna in order to analyze the project from a different and more environmentally focused perspective. The involved academic research team combined expertise dealing with urban regeneration, outdoor thermal comfort analyses, design optimization and included also a landscape designer with the purpose to properly consider the properties of vegetation and its relation with the urban environment.

The study assumed as starting position that climatic conditions in the urban environment are typically analyzed in the scientific literature according to three main topics:

a) the effects and impacts of Urban Heat Island (UHI) affecting the dense urban areas;
b) the influence on outdoor microclimate conditions in confined urban spaces such as squares;
c) the outdoor thermal comfort perception in urban open spaces.

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The influence of global warming and climate change on the urban environment and their relation with temperature increase and UHI recurrence have been widely investigated in the scientific literature, both with relation to the increase of energy demand for cooling and to impacts on health (Akbari & Kolokotsa, 2016; D'Ippoliti et al., 2010; Robine, Cheung, Le Roy, Van Oyen, & Herrmann, 2003; Santamouris et al., 2001; Santamouris, Cartalis, Synnefa, & Kolokotsa, 2015; Ward, Lauf, Kleinschmit, & Endlicher, 2016), pointing out the potential role of vegetation in mitigating the effects (Gaspari & Giacomello, 2012; Noro & Lazzarin, 2015, 2015; Shashua-Bar, Pearlmutter, & Erell, 2011; Shiflett et al., 2017; Wang, Zhao, Yang, & Song, 2016) and this is the reason why the commissioned study shifted the public debate from an ideological approach to an environmental one in order to evaluate the architectural solution and its relation with the vegetation.

The notion of UHI, widely investigated in the last thirty years by Oke (1982) and others, can be summarized as addressed in a recent research titled (UHI Project (2018): "The UHI is a microclimatic phenomenon that occurs in the metropolitan areas. It consists in a significant increasing of the temperature in the urban area respect to the surrounding peri-urban and rural neighbourhoods."

The arrangement of urban fabric and the distance between the buildings can also influence microclimatic conditions requiring to carefully consider the specific layout of a site when performing any kind of analyses. Outdoor comfort is indeed strongly influenced by material properties and energy use that shall impact on the main variables at local microclimate level: Temperature, Solar Radiation, Wind distribution, Wind Speed, Absolute and Relative Humidity as demonstrated by the studies of (Santamouris (2001), 2014), Stavrakakis et al. (2012) and CRES (CRES RUROS, 2004). The scientific literature provided relevant references for the study with relation to thermophysical properties such as solar reflectance (Berdahl and Bretx (1997); Levinson, Chen, Berdahl, Rosado, and Medina (2014)), albedo (Qin, 2015) and to implications concerning material choices, like cool pavements or cool materials (Chen, Wang, & Zhu, 2017; Santamouris, Synnefa, & Karlessi, 2011; Santamouris, 2013), and other mitigation techniques (Hendel, Gutierrez, Colombert, Diab, & Royon, 2016; Yang, Wang, Kalousha, & Dylla, 2016).

As confirmed by Givoni (Givoni et al., 2003), Johansson (Johansson, Thorsson, Emmanuel, & Krüger, 2014) and Andrade (Andrade, Alcoforado, & Oliveira, 2011) material properties and the shape of a confined space strongly influence outdoor thermal comfort perception by the users. Matzarikis (Matzarakis, Mayer, & Iziomon, 1999; Naboni, 2014; Taleghani, Kleerekper, Tenpierik, & van den Dobbelsteen, 2015) and Lin (Lin, Matzarakis, & Hwang, 2010) provided notions about the Comfort Sensation Index called Physiological Equivalent Temperature (PET) also in Urban Climate studies (Jamei, Rajagopalan, Seyedmahmoudian, & Jamei, 2016; Ketterer & Matzarakis, 2014b; Matzarakis, Rutz, & Mayer, 2007; REBUS©, 2018; RE-MED©, 2018). (Hoppe (1999) and Nagato and Tetsumi (2011) use modified Effective Temperature (ET*) derived by Gagge (Gagge, Stolwijk, & Nishi, 1971; Gagge, Fobelets, & Berglund, 1986), while Brode (Bröde et al., 2012) used the UTCI (Universal Thermal Climate Index).

After the research team preliminary reported the environmental implications and the potential role of the existing vegetation in the project to the design team, to the public authorities and the citizen association, it was decided to investigate three different design options.

2. Objectives and methodology

The study aimed at evaluating the influence of the existing vegetation on the microclimatic conditions with relation to the possible reconfiguration of the square. The situations were considered:

1) configuration 1 corresponding to the existing square layout including the old oak trees (*Quercus ilex* L.);
2) configuration 2 corresponding to the winning project layout removing the existing trees (*Quercus ilex* L.) and including a re-arranged green surface with new trees;
3) configuration 3 corresponding to the winning project layout embedding the existing trees (*Quercus ilex* L.) but reducing the total number of trees and vegetation.

Fig. 1. Cesena location.

The scope was to rate the outdoor microclimate in the site considering the urban comfort according to the design variations. A major objective was also to provide an easy way to visualize results and make them comparable in order to let the local community to consciously express a preference towards a specific solution.

2.1. Case study definition and description

The case study is a quite regular shaped square "Piazza Bufalini" in the historic center of Cesena, a small city of northern Italy (Fig. 1). The most relevant actions envisaged by the winning project deal with the replacement of the existing flooring surface with inert materials (gravel or paved paths), the removal of the existing oak trees (*Quercus ilex L.*), the introduction of 25 *Pyrus calleryana* 'Chantecleer' to emphasize the regular façade of Malatesta Library, the creation of a lawn with reading spots for spring and summer seasons, and medium-size flowerbeds with grasses (Poaceae) and weed (perennial weeds). Fig. 2 compares the existing configuration with new one.

The case study is approximated to a square of 125 m, larger than the involved site and including its surroundings in order to provide the general context and to limit, at the same time, on-board errors (boundary errors) that may typically affect simulation processes (Fig. 3). Boundary errors are usually due to the resolution of the equations on which the simulation software are based with relation to the boundary of the investigated area that is virtually extracted from its context. This leads to alter the results on the boundary due to a lack of data as explained in the literature (Forouzandeh, 2018), thus enlarging the simulated area is possible to focus on the core site obtaining reliable outcomes and mitigating the alterations in the surroundings.