Sustainable Cities and Society 26 (2016) 9–26

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

Impact of Urban Cool Island measures on outdoor climate and pedestrian comfort: Simulations for a new district of Toulouse, France

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ARTICLE INFO

Article history:
Received 14 February 2016
Received in revised form 7 May 2016
Accepted 10 May 2016
Available online 12 May 2016

Keywords:
Urban Cool Islands
Outdoor thermal comfort
ENVI-met
Physiological equivalent temperature
Microclimate mitigation strategies

ABSTRACT

One of the first airmail services in the world, the *Aeropostale*, was located at the *Montaudran* airport of Toulouse, France. This landmark and its surroundings will be refurbished in the years to come and will be transformed into a mixed-use development, the Aerospace Campus, with residential buildings, and commercial, sports, educational and cultural facilities. This new district has been planned mostly on the basis of heritage and functional rules. The UCI project (from "Urban Cool Islands") is a French national research project that discusses procedures aiming at incorporating a set of reasoned measures for local climate adaptation into this new urban area that will be set as a landmark development. This research aims to analyse and compare various suitable, resilient urban design strategies to provide support for their application in the *Montaudran* district, focusing on mitigating urban heat island effects in summer conditions. Three main methodological steps were undertaken: (1) the initial urban plan was assessed relative to a set of well-known urban morphology parameters and a microclimate analysis; (2) a set of urban design variations was established based on important microclimate adaptation measures as well as on the constraints and opportunities of the original plan; (3) the microclimate was modelled and the thermal comfort of pedestrians analysed. Results pointed out the major influence of water and green features on the mitigation of urban heat islands, notably in daytime. Besides creating an important urban cool island for pedestrians, the results showed great opportunities for supporting decision makers on specific integrated actions towards a truly sustainable neighbourhood.

1. Introduction

In France, most of the metropolitan areas have been intensively spreading outwards, which has led more and more residents to move farther away from the city centre (Hoffmann-Martinot & Wollmann, 2007). In the city of Toulouse, some new empty areas on the outskirts of its old centre have been entirely planned to accommodate multiple activities, based mostly on functional, social, heritage, and economic aspects.

The UCI project (from "Urban Cool Islands") is a French national research project that has discussed procedures with urban planners and investors in the aim of incorporating a set of reasoned measures for local climate adaptation in a particular new urban area in the city of Toulouse that is expected to become a landmark reference.

This research analyses and compares different suitable, resilient urban design strategies to provide support for their application in the particular real-life case of the Montaudran district of Toulouse, focusing on mitigating Urban Heat Islands effect (UHI) effects in summer conditions and including a quantitative assessment of their impacts.

Our study approach combines knowledge from theoretical and applied research concerning local city planning decisions, integrating an evaluation of the planners' demands, compatible strategies, microclimate modelling and outdoor thermal comfort assessment, for a certain number of design choices.

2. Literature review

Cities currently concentrate more than half of the world's population (Population-Reference-Bureau, 2009). In France, around 80% of its population lives in urban environments. Such concentrations of people and their different activities has put major stress on the natural and built environment.

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http://dx.doi.org/10.1016/j.scs.2016.05.003

Current urbanization is marked by significant changes in the natural surfaces and in the built morphology, which alters the thermal, moisture and aerodynamic properties of these environments, leading to a new, human-induced climate. This new urban climate, often characterized by urban heat islands (UHI) (Oke, 1988), has several possible causes and effects. Anthropogenic heat emissions, pollution and energy consumption in towns and cities (Chow et al., 2014; Santamouris, Synnefa & Karlessi, 2011), intensive land use and high urban density associated with buildings presenting high thermal masses and heat storage properties (Harlan & Ruddell, 2011), urban street canyon configurations that result in reduced long-wave radiation emission to the sky during the night (Ashtiani, Mirzaei, & Haghighat, 2014; Santamouris et al., 2001; Smith & Levermore, 2008), reduced wind speed due to the significant roughness length of urban centres (Santamouris et al., 2001), absence of green areas and presence of low-albedo materials with reduced permeability (Chen, Ooka, Huang, & Tsuchiya, 2009; Smith & Levermore, 2008; Santamouris et al., 2001) are known to be the most significant causes of UHI.

Nevertheless, UHI can be exacerbated in a climate change context and introduce negative effects on health through heat stress and the stimulation of ground-level ozone, which can cause respiratory problems (Kleerekoper, van Esch, & Salcedo, 2012). Furthermore, UHI may also worsen episodes of heat waves, bringing us to face several other consequences such as a reduction of the efficiency of passive cooling modes in buildings, a significant increase in the energy demand of buildings and also the deterioration of climatic quality in public spaces (Colombert, 2008).

“Climate change projections suggest that European summer heat waves will become more frequent and severe during this century, consistent with the observed trend of the past decades” (Fischer & Schar, 2010). Concurrently, urbanization may pose serious challenges concerning human thermal comfort and health in cities (Kovats, Van Esch, & Salcedi 2008; McCarthy, Best, & Betts 2010).

In the coming decades, sustainable urban planning should respond to two major challenges: promoting adaptation measures to mitigate local climate change effects, and balancing the various conflicting spatial demands (Van Hove et al., 2015). A certain number of urban planning strategies would allow UHI effects to be mitigated. For instance, many studies have indicated the noteworthy cooling effect of increasing vegetation surfaces in urban areas (Yokobori & Ohta, 2009; Ng, Chen, Wang, & Yuan, 2012; Wong & Cheng, 2005; Yan et al., 2014). Urban form regarding the height and space between buildings is considered to be another important feature determining local climate (Theeuwes et al., 2014; Ali-Toudert & Mayer, 2006; Oke, 2006). Modifying the surface albedo of urban spaces may also play a crucial role in creating urban cool islands (Saneinejad, Moonen, & Carmeliet 2014), (Salata et al., 2015). Many studies found in the literature have already measured the most significant parameters involved in the UHI phenomenon through parametric studies (Taleghani et al., 2014) (Ali-Toudert & Mayer, 2006), generic urban cases (Allegrini, Dorer, & Carmeliet, 2015), field measurements of many existing situations (Kruger, Minella, & Rasia, 2011), multi-temporal satellite observation of existing situations (Kikon, Singh, Singh, & Vyas, 2016). However, very few studies have attempted to evaluate and compare scenarios while accompanying actual on-going planning regarding the suitability or the impact of known measures on the creation of more climate-adapted urban spaces. Specific examples of real planning are important to test established statements in different realistic situations.

3. Research methodology

To achieve the objective described above, the following main methodological steps were taken:

(1) Assessment of the proposed urban plan of Montaudran Aerospace campus and discussions with urban planners regarding its design opportunities and constraints relative to its climate adaptation for the summer season;

(2) Definition of a set of reference urban variations to the initial plan, based on the local planning guidelines and on the main microclimate adaptation measures;

(3) Comparative analysis of the initial urban plan and its variations regarding their outdoor microclimate effects, using computer-modelling simulations;

(4) Evaluation of outdoor thermal comfort of pedestrians on a few important local itineraries.

Each methodological procedure will be furtherly discussed in the next section.

4. Case study

The work conducted by this research project integrates the design process of an important urban planning project in Toulouse, France: the Toulouse Montaudran Aerospace Campus.

This new district, covering more than 56 ha in southeast Toulouse, will replace the historic Montaudran aerodrome, home of one of the first airmail services in the world. The district of Montaudran currently possesses the emblematic 1.8 km long, 30 m wide runway (Fig. 1). This landmark and its surroundings will be refurbished and transformed into a mixed-used urban site, the “Aerospace campus”, with residential buildings, and commercial, sports, educational, scientific and cultural activities.

The Toulouse community also has strong ambitions regarding the environmental quality of this urban district, especially concerning the transport network, rainwater management, bioclimatic design of buildings (355,000 m^2) and renewable energy installations.

The Montaudran neighbourhood is located at the southeast of Toulouse, about 6 km from its downtown and equidistant from the Blagnac International Airport (Fig. 2). Montaudran is bordered by the expressway A620 and A61 and is situated at the former airdrome of AirFrance. This site remains the last large-scale buildable zone into metropolitan area of Toulouse.

ZAC Toulouse Montaudran Aerospace will enable the development of a new neighbourhood among: existing Montaudran residential and Ormeaux districts; an economic development hub; and the Rangueil Campus (Fig. 3).

This urban area is marked by a significant infrastructure:

- a ring road (A620) which borders the Southeast of the site and connects the district to other districts and towns;
- a railway that links the district to other cities;
- bus lanes, which will link the Montaudran district to the Toulouse subway.

The plan of Montaudran Aerospace provides for a wide network of circulation, which allows a certain fluidity of movement on already existing cycle tracks and promotes easy pedestrian access to public transport. From the specified land-use planning of Montaudran, three major connections were chosen for the analysis of pedestrians’ thermal comfort: the path that connects the train station to the main square; the path that connects the main square to the Forum, via the old runway, and the path that connects the main square to the sports park (Fig. 4).