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Heat resilience in public space and its applications in healthy and low carbon cities

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Abstract

Australian cities are experiencing more heat stress in the 21st century than ever before. Public life in a majority of Australian cities suffer from heat stress in urban heat islands. This paper presents the concept of spatial heat resilience as the capability of the built environment to support outdoor activities during heat stress conditions. Outdoor activities and urban microclimate parameters were observed in selected public spaces of Sydney, Melbourne and Adelaide. Outdoor neutral and critical thermal thresholds are determined. An indexing system to indicate spatial heat resilience is presented. Correlations between spatial heat resilience and urban surface covers, and potential applications in low carbon cities are discussed. Results indicate that outdoor activities decrease after the neutral thermal threshold of 28-32°C. Critical zero-activity situations can occur in the range of 30-48°C. Particularly public spaces with more tree canopy and natural landscapes have more resilience to heat stress. Heat mitigation during summer results in increased outdoor living. Heat resilient public spaces can provide high-performance outdoor environments in the context of climate change.

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Keywords: Heat resilience; low carbon cities; public space vitality; urban microclimates

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1. Introduction

Australia will face at least 0.6 °C (best scenario: B1) and at most 3.8 °C (worst scenario: A1F1) increase in its surface temperature by 2090 [1]. However, warmer urban scenarios can significantly affect the liveability of cities [2, 3]. Cities have an essential public health agenda to adapt their built environment to the coming warmer climates [3, 4]. Increased indoor air-conditioned in hotter microclimates cause higher demand for energy consumption and greater waste production in cities [5, 6]. Increased demand for energy consumption for air-conditioning, lighting, and transportation is frequently accompanied by exhausted waste heat production. This anthropogenic heat in urban settings creates a feedback loop with heat stress in the built environment. The feedback loop between heat stress in public space, outdoor space denial, and heat-generating indoor behaviours in the urban environment exacerbates the damaging capacity of heat stress in cities.

In the context of increasing urban heat stress, this paper presents the concept of spatial heat resilience as the capability of the built environment to support outdoor activities during heat stress conditions. Methods to measure spatial heat resilience, correlations to urban surface cover materials and application in reducing the demand for energy consumption in Australian cities are under particular focus.

2. Heat stress in the built environment

Unusually high heat arising from a high daily temperature insufficiently discharged overnight is denoted as heat stress in heat-health scholarship [7]. Hard-landscaped urban areas tend to get hotter during the day and may stay warmer during the night compared with their rural vicinities. Such urban-rural temperature difference frequently reaches 2°C and can peak at more than 12°C (Gartland 2008; Oke 2006; Wong & Yu 2008). The intensity of the UHI effect tends to be maximised when nocturnal surface temperature is reported in winter under clear sky.

Oke [8] highlights the urban structure, cover, fabric and metabolism as the major contributing factors to the UHI effect. Meanwhile, external factors including regional climate, seasonal factor and reference sites affect the magnitude of the UHI effect [9-11]. The magnitude of the UHI effect is usually reported to be higher at night time [12]. As such the UHI effect is frequently known as a night time phenomenon in urban climatology [9, 13, 14]. The urban-rural temperature difference begins to develop in the afternoon and peaks during the night, concentrated in highly developed urban areas (see Fig. 2.11). Due to heat storage in urban surface covers and heat-trapping urban structure, the latent heat remains in the built environment during early night time [9, 15, 16] and causes the urban areas to have extended UHI effect during the night. Yet, the heat stress tends to be higher in the afternoon in the built environment.

While a comfortable thermal environment can enhance people’s choices to spend more time outdoors, excess heat load can cause significant discomfort, altering the frequency and patterns of outdoor activities. Spatial configurations – contributing to urban microclimates – have the ability to alter the vitality of public space by providing thermal comfort and consequently facilitating outdoor activities.

Extensive thermal comfort research indicates that there are temperature ranges, in which the need for thermal adjustment is perceived to be neutral by most of the space participants (more than 80%) in the thermal sensation voting system [17]. In such thermal environments, occupants feel neither warm nor cold, and therefore, the ambient thermal conditions are perceived as ‘neutral’ [18]. The high threshold for thermal neutrality, measured via standard effective temperature (SET), is suggested to be 24.1°C for indoor steady state conditions [19]. Research in European context reveals up to 10°C variation in outdoors thermal neutrality in different cities [20]. A thermal comfort investigation in Sydney suggests that neutral temperature threshold in semi-outdoor environments (naturally ventilated buildings) is OUT_SET = 26.2°C [21]. Another Australian outdoor thermal comfort research reports comfortable outdoor temperature in summer varies between the minimum of 19.9°C (in Melbourne) and the maximum of 30.6°C (Adelaide in) [22].

Neutral thermal threshold (NTT) – in this study – refers to the upper limit of outdoor thermal neutrality. Indoor NTT is determined by the comparison between thermal sensation votes and indoor microclimate parameters (via SET indicator). Outdoor thermal environments change more rapidly compared with indoors. There is also limited chance to control the participants in outdoor environments. Heat sensitivity of outdoor activities may include changes in outdoor activity patterns, activity locations and in extreme conditions activity elimination.