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The influence of Korea's green parking project on the thermal environment of a residential street

Jong-Hwa Park [a], Jeongseob Kim [a], D.K. Yoon [b], Gi-Hyoug Cho [a, *]

[a] School of Urban and Environmental Engineering, Ulsan National Institute of Science and Technology, Republic of Korea
[b] Department of Urban Planning & Engineering, Yonsei University, Republic of Korea

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ABSTRACT

The green parking project in Korea is an urban regeneration policy created to solve a shortage of parking space in residential streets by removing the fences of detached houses and creating parking spaces inside residential properties. The purpose of this study is to examine the influence of the green parking project on the thermal environment of a residential street. Two focused study areas were chosen in Ulsan, Korea and the physical features of each street were classified into five elements: walls, fenestra, ground pavement, vegetation, and other objects on streets. The radiant temperature of each element was collected three times a day with a thermal infrared camera at 3 spots in each street, and pedestrian's exposure to each element was measured using ArcGIS 10.2. The analytical results indicated that green parking may reduce pedestrian's exposure to high radiant temperatures on the street through the replacement of pavement materials on ground, increased exposure to vegetation, decreased exposure to the parked car, and increased shading on pedestrian walkways. This study suggests that the green parking project has the potential to improve the thermal environment of outdoor spaces for pedestrians.

1. Introduction

Rapid urban growth intensifies the population concentration in cities, making them highly dense. The heated air of the dense inner city resulting from solar radiation tends to be 2–5 °C higher than that in surrounding rural areas (Ackerman, 1985; Taha, 1997; Tan & Li, 2015). One of the main causes of this urban heat island (UHI) phenomenon is the increased proportion of artificial impervious surfaces and the relatively lower proportion of natural land cover in urban settings (Jusuf, Wong, Hagen, Anggoro, & Hong, 2007; Onishi, Cao, Ito, Shi, & Imura, 2010; Wong & Yu, 2005). In urban areas, a considerable amount of the impervious surface comprises parking lots covered by concrete or asphalt (Onishi et al., 2010). Indeed, approximately 10% of the land cover in U.S. cities (McPherson, 2001) and 7% of downtown areas in Japanese cities (Nakamura, Shoji, & Muneta, 2007) are parking lots. To mitigate the adverse effects of the resulting increased temperature and to provide pleasurable outdoor spaces for pedestrians, researchers have emphasized the role of urban planners and urban designers in creating a thermally comfortable urban area (Jamei, Rajagopalan, Seyedmahmoudian, & Jamei, 2016). Converting parking spaces in the city to greener spaces would be one of the effective interventions to improve the thermal conditions of outdoor spaces.

The green parking project (or the "fence removal campaign") in Korea is an attempt to modify the façade of residential buildings by removing fences to create parking spaces in residential properties. The main purpose of the green parking project in Korea was to solve a shortage of parking spaces that existed in detached housing blocks. In the 1970s and 1980s, Korea experienced rapid urbanization. Between 1970 and 1990, the urban population of South Korea grew from 40% to 78% of the total population. What took the United States 90 years to accomplish took Korea 20 years (Henderson, 2002). Accordingly, a vast number of housing developments were created in a very short period, but increased demand for motorization and the possession of private vehicles were not appropriately accounted for in residential land development. Consequently, residents in detached housing areas had to occupy public streets outside their properties to park their private vehicles.

With private vehicles occupying streets in residential areas,

* Corresponding author. School of Urban and Environmental Engineering, Ulsan National Institute of Science and Technology, Building 106, 801-7, Ulsan, 689-798, Republic of Korea.
E-mail addresses: pjs1216z@nate.com (J.-H. Park), jskim14@unist.ac.kr (J. Kim), dkyoon@yonsei.ac.kr (D.K. Yoon), gicho@unist.ac.kr (G.-H. Cho).

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Fig. 1. (a) before and (b) after view of how green parking project transforms residential street.

there has been growing concern over the deteriorating environmental quality of these detached housing areas and their increased accident risk for pedestrians (Park, 2006). In response to these mounting concerns, the strategies of the green parking project include removing the wall or fence from an individual property, modifying the façade of residential buildings to make them an open structure, and creating parking spaces inside the properties with the financial support of the city government (Fig. 1).

The existing literature on the subject of the green parking project has focused on evaluation of the project with respect to crime (Kim & Park, 2013; Kim, Kim, & Hwang, 2011), the formation of a sense of community (Baek, Kim, & Lee, 2010; Koo & Kim, 2009), and the quality of the resulting pedestrian environment (Ko, Lee, & Ahn, 2006). However, far too little attention has been paid to evaluating policy interventions in residential settlements for the thermal environment of outdoor spaces. In urban planning and design, making outdoor spaces attractive to people, and ultimately used by them, has become an increasingly important goal (Chen & Ng, 2012), and the green parking policy in Korea is one of the strategies designed to achieve that goal. In this study, we intend to address how the policy, aimed to provide parking spaces and increased green space in residential areas, has affected the thermal environment of a residential street.

2. Literature review

The conventional role of fences on a property is to protect an individual's territory and define the physical boundaries of private ownership. However, the previous literature has shown that the effect of fences on enhancing security might be minimal. Kim and Park (2014), for example, surveyed 152 prisoners who were convicted of burglary to examine whether the existence of fences on a property reduced crimes, and they found that the existence of fences might actually increase crimes because it blocks visual surveillance of the area. Kim et al., (2011) also showed that the improvement of natural surveillance by removing fences reduced perceived crime risk for residents. Ko et al., (2006), meanwhile, examined the relationships between the quality of a pedestrian environment and the sense of community and found that the green parking project enhanced the vitality of the pedestrian environment, which contributed to a higher sense of community in the neighborhood. Previous studies on the green parking project have revealed the positive influences of the project on the neighborhood, but few studies have examined the effects of the green parking project on the thermal environment of the street.

The existing literature examining the thermal effects of parking facilities and taking a microscopic approach to them have primarily focused on the influence of surface or pavement materials on temperature. Takebayashi and Moriyama (2009), for example, using an infrared camera, evaluated the thermal effect of converting asphalt-covered parking areas to grass-covered spaces. The results showed that the sensible heat flux was reduced from 100 to 150 W m^{-2} in the daytime to around 50 W m^{-2} at night, in comparison with asphalt. Ca, Asaeda, and Abu (1998) measured the thermal conditions of parking lots at noon in the summer and reported that the ground temperature of a concrete parking lot was 15 °C higher than that parking lot with a grassy field. With regard to air temperature, when measured 1.2 m above the ground, a concrete parking was 2 °C higher than the parking lots with a grassy field. Onishi et al., (2010), meanwhile, showed that planting grass slightly reduced the land surface temperature over the whole study area in spring and summer. For an individual parking lot, the maximum land surface temperature decreased by 7.26 °C in the summer.

A relatively large number of research projects on outdoor thermal comfort have been conducted in various climates around the world (Ali-Toudert & Mayer, 2007; Chen and Ng. 2012; Hong & Lin, 2015; Jamei et al., 2016; Krüger, Minella, & Rasia, 2011; Pearlmutter, Berliner, & Shaviv, 2006, 2007; Shashua-Bar, Pearlmutter, & Erell, 2011). Overall, these studies have found that the aspect ratios and orientations of street canyons (Ahmed, 2003; Ali-Toudert & Mayer, 2007; Johansson, 2006; Perini & Magliocco, 2014; Taleb & Taleb, 2014), sky view factors (Charalampopoulos, Tsiros, Chronopoulou-Sereli, & Matzarakis, 2013; Lin, Matzarakis, & Hwang, 2010; Yan et al., 2014), street trees (Shahidan, Shariff, Jones, Salleh, & Abdullah, 2010; Srivanit & Hokao, 2013; Yang, Lau, & Qian, 2011), and urban parks (Chang & Li, 2014; Feyisa, Dons, & Meilby, 2014; Klemm, Heusinkveld, Lenzholzer, Jacobs, & Van Hove, 2015; Skoulika, Santamouris, Kolokotsa, & Boemi, 2014) all affect outdoor thermal comfort.

The common indicator used to identify outdoor thermal comfort is the Physiological Equivalent Temperature (PET), and the most important meteorological factor affecting PET during daytime is mean radiant temperature (MRT) (Matzarakis, Rutz, & Mayer, 2007; Thorsson et al., 2014). Conceptually, MRT can be defined using the measured surface temperature of surrounding walls and surfaces and their positions with respect to the person. For estimating MRT, therefore, it is necessary to measure radiant temperatures and the angle between the person and the surrounding surfaces. Since integral radiation measurements and the calculation of angular