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Urban Form and Building Energy Performance in Shanghai Neighborhoods

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Abstract

Urban form is considered as two different concepts here: one as geometry and the other as a complex system. This paper uses simulation experiments to test the density and energy performance relationship in nine Shanghai neighborhoods, with the urban form defined as a complex system. The results show a complex pattern. When density is only related to geometry, the density seems to negatively impact building energy use intensity, following the widely perceived conclusion from previously studies. But when density is related to neighborhood typology, which determines many energy-related parameters, the relationship may be totally different. The study suggests that energy performance research of urban form at the neighborhood scale has to consider the historical, social and cultural contexts, which could lead to more comprehensive low energy and low carbon urban policies for Shanghai.

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Keywords: Shanghai neighborhoods; urban form; building energy performance; FAR; microclimate

1. Introduction

The relationship between urban form and building energy performance draws more and more attentions nowadays as building energy use has a significant share in the total energy use [1]. Many scholars have tried to identify this relationship using different definitions of urban form. Some scholars have focused on the geometry of urban form. For example, Pisello, Wong, Giridharan, Ratti and Rode examined how

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different geometries of urban form influence building energy performance through the building typology, urban heat island effect, daylight and mutual shading [2-6]. Another group, including Wang and Ye [7, 8], and Salat [9], began to test the idea of urban form as a complex system including geometry and other factors such as material types, characteristics of residents, housing units and neighborhoods, and construction years. However, most of the studies from this group examined only certain factors. But urban form is a multi-level concept, and the complex causal relationship relies on cross-disciplinary methods, and few studies have probed into it [10].

In this paper, we see urban form as much more than simply geometry, since it develops with many engineering constraints such as structure, HVAC system, material, users' behavior, etc.[9] and in different historical and cultural contexts. But different from traditional building energy simulation studies, the energy performance analysis of urban form needs to define the system boundary first, as urban form involves several spatial levels, including building, parcel, island (block), fabric (neighborhood) and district [11]. Because of its relative independence and autonomy in the development of its urban form, neighborhood is often chosen as the system boundary of the urban form for energy studies [6, 9, 12]. However, as discussed above, the relationship between neighborhood, as a complex system, and building energy performance has received relatively little attention in current studies.

This paper attempts to address this oversight by exploring the relationship between the complex system of urban form at the neighborhood level and building energy use through case studies of nine Shanghai neighborhoods. The urban forms of these neighborhoods were measured using the building density indicator of FAR (Floor Area Ratio). Thus how neighborhoods with different density measures perform in building energy use becomes the key research question of this paper. In previous planning studies, it was commonly recognized that density is generally negatively correlated with energy use [13, 14]. But with the understanding of a urban form as complex system, that viewpoint needs further examinations.

2. Study Areas And Datasets

This study selected nine Shanghai neighborhoods as research areas. Three neighborhood typologies were identified along with the historical development of Shanghai based on the study of Sha, et al, including historical patterns, workers' communities, and contemporary urban patterns [15]. Each typology has its unique fabric pattern and characteristics, which are distinctly shaped by the historical and social conditions. The first typology, the historical pattern, refers to the most prevalent neighborhood typology from the 1860s to the 1940s, known as Shanghai Lilong. This typology of neighborhood was originally built for the middle class and consisted of two to three-story dwellings constructed using brick, however nowadays its residence is mainly low to middle income people because the outdated building material and construction make this typology of neighborhood less appealing comparing to other neighborhood typologies. The second typology, called the "workers' community" encompasses the special districts designated as workers' housing when Shanghai mainly functioned as a manufacturing center. Buildings within this typology are typically slab block buildings of up to six stories. The third typology is the contemporary urban pattern, which features the large-scale real estate boom of the 1990s, characterized by clusters of large public building mass and towers [15]. The nine Shanghai neighborhoods selected to represent the three typologies with commercial, residential and mixed uses are shown in Table 1.

The spatial data, including the building footprints and building heights, were organized in ArcGIS, while the façade and roof materials and the window-wall ratio as the input for energy simulation were measured and determined based on field survey and Baidu Streetview, an online street view tool similar to Google Streetview but with more abundant data for Chinese cities. The measures of FAR and total floor area of all buildings were calculated in ArcGIS for each neighborhood.