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Urban morphology indicators for solar energy analysis

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Abstract

Within the variation of energy performance at urban scale, the relation between solar irradiation and urban form takes a central role. The solar availability on façades which is influenced by the morphology of the urban context, is strictly related to building energy performance indeed. In this paper, we aim at identifying a set of urban morphology indicators (UMIs) that show the most accurate relations with the solar availability on façades (SI_y) in the Mediterranean context. The analysis that relates to 14 urban textures of Rome and Barcelona comprises seven UMIs: gross space index, floor space index, façade-to-site ratio, average building height, volume-area ratio, building aspect ratio and sky factor of building façades. The SI_y in each texture has been calculated with *Heliodon2* software, using normalised models; the relation between SI_y and UMIs were investigated using least-square regression analysis. Results suggest that gross space index, façade-to-site ratio and sky factor show very good correlation with SI_y (R^2 = 0,91) and could be used to develop a comparative assessment tool of solar performance at fabric scale. This could ease the work of urban planners and architects in the early stage of design, reducing both data and time normally needed to perform solar analyses at urban scale.

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Keywords: urban form; urban morphology indicators; density; solar irradiation; façades.

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1. Introduction

It is widely agreed that solar energy availability is a key variable to assess buildings energy performance in urban environment. On one hand, building's solar gains account for a significant part of the energy balance during both winter and summer; on the other hand, the potential for harvest solar energy in the urban context is directly connected to the potential for renewable energy systems to enhance energy efficiency at urban scale. Besides, solar availability in the urban context could vary significantly, according to different cities but especially to the morphology of urban texture [1–3]. Thus, it is essential to deeply explore the causal relation between urban geometry and solar energy, to provide a better understanding of our cities and ease planning decisions for a sustainable renovation process.

In this context, the solar performance of building façades is important not only because façades exceed roofs in terms of available area to harvest renewable energy, but above all because it is highly related to urban morphology. The building façade is one of the most important variable in relation to solar performance indeed, but inadequate if considered alone. Urban layout is well described by several urban morphology indicators (UMIs) that clearly express and measure the different properties of the texture. The UMIs are usually calculated as a ratio of urban quantities, surfaces, volumes or lengths and describe different aspects of urban geometry and physical density of built environment.

The aim of this paper is to identify the most suitable set of UMIs for the analysis of solar availability on façades in the Mediterranean compact city. It focuses on the solar performance of the vertical surfaces, since they are directly related to the building's solar gains which account for most part of the energy demand in the Mediterranean latitudes. The assessment of solar availability through UMIs could ease the implementation of solar analysis at urban scale, since the data required for the calculation are generally used in urban planning practice and are easily accessible for many cities.

2. Urban solar energy analysis

Referring to urban scale, this study characterizes for the Mediterranean compact city the causal relation urban morphology-solar energy through UMIs. Several studies reported the effect of each variable on solar performance [3–7]. Some of them consider real urban areas and related data in order to predict their solar potential using UMIs to better characterize the layout of the case studies [1,2,5,8]. Other studies focused on understanding the influence of urban morphology, described and controlled through UMIs, to optimize the solar potential of urban areas. The latter use normalised models derived from representative urban textures [9–11].

To perform solar energy analysis at urban scale, experts use specialised tools recently developed for the purpose, for example Radiance, DIVA, CitySim and SUNtool. These tools fostered the implementation of solar analysis in design practice. However, two factors still limit their widespread to urban planning and design: the specialist knowledge required to set up the simulation and the amount of time needed to realize the model at urban scale. For these reasons, this study focuses on defining a method that could reduce time and data necessary to carry out solar energy analyses at urban scale useful in the early stage of design process; this method is intended for architects and decision makers since do not require specialist knowledge.

3. Methodology

The analysis is carried out on 14 urban textures of Rome (Italy) and Barcelona (Spain) and comprises seven UMIs: 1) gross space index, 2) floor space index, 3) façade-to-site ratio, 4) average building height, 5) volume-area ratio, 6) building aspect ratio and 7) sky factor of building façades (Figures 1-2). Each index gives information on some qualitative aspects of the urban form, such as the shape of the buildings or the patterns of the street network. It has been already proven that the above-mentioned indicators have a causal relation with energy performance at urban scale [12–17].

Gross space index (GSI) and *floor space index* (FSI) are two of the most common density indicators. They describe respectively the compactness and the intensity of buildings in the urban textures. The GSI is defined as the ratio of the built-up area to the urban site area; the FSI is the ratio of the gross floor area to the urban site area. *Façade-to-site ratio* (VH_{urb}) is an index of vertical density for the urban texture that is the ratio of the building façades area to the