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Dottorato in Ingegneria dell'Architettura e dell'Urbanistica

The Impact Of Urban Blocks Morphology On Urban Microclimate

The Case of Tirana North Boulevard

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Summary

Climate-responsive passive design is becoming an increasingly integral part of the urban environment in the light of climate adaptation challenges in cities. Patterns of urban blocks need to be explored to further understand the impact on urban microclimate. The design of urban morphology requires to positively adjust themselves to local climates conducted with knowledge- based investigation. Analyzing the contemporary urban blocks settlements and typological characteristics of the built environment is crucial to explore the relationship identified between urban morphology and density, building typology, and climate. Specifically, how can we i) Densify and design urban block fabrics to potentially improve the microclimate and the outdoor thermal comfort ii) Develop strategies to define the impact of the morphology and density of the building blocks on the urban climate iii) Investigate the concept of "density" in the topic of urban planning and positively apply it in the urban planning design as it has always been throughout the history of city structures iv) Integrate "new" bodies of knowledge, such as climatology, urban physics, meteorology, or computer science. This integration is necessary to the understanding of the energy phenomena that take place in the urban environment, whose large-scale impacts are still quite unknown and difficult to detect.
On the other side, modeling urban microclimate can assist urban planning decisions. Nonetheless, there is a lack of studies investigating the combined impact of urban block typology and urban indices on urban microclimate. Therefore, the present thesis analyzes the impact of these combined strategies on

outdoor thermal comfort. The objectives of the study are: i) How dissimilar are the outdoor thermal conditions within the courtyards of varying enclosure forms, orientations, Height to X/Y courtyard dimensions and other morphological indices; ii) What drives the inner courtyard thermal diversity; iii) Are there optimal spatial strategies for retaining a non- extreme and diverse courtyard microclimate in the context of the Mediterranean climate.

In this context, by using computational fluid dynamics techniques, three zones with different courtyard block prototypes (in a range of large/small, deep/shallow, regular/distorted) of a winning Project - Grimshaw – New Tirana Boulevard - including combinations of urban indices (façade to Site Ratio, Building height to X/Y courtyard dimensions). To assess urban outdoor comfort at pedestrian height we used UTCI: Universal Thermal Climate Index. The results showed that block typology and urban indices affect urban microclimate. In addition, to explore the impact of urban indices within the same zone, a total of 5 different scenarios (namely SC 01-SC05) for each urban zone configuration with different block typologies, were used for the numerical simulations. The results showed that the performance of a block typology depends on the urban index values. For instance, increasing façade to site ratio, improves the UTCI values in all three zones typologies. The novelties of this study lie in the numeric microclimate modelling and longitudinal validations with these real courtyard geometries and exploring scenarios for analyzing the Universal Thermal Climate Index (UTCI) maps and identify the dissimilarities in the UTCI maps of courtyards within the context of New Tirana Boulevard.

Due to this complexity, it is not possible to draw easy-to-apply and universally valid climate guidelines, because every city is different, and so are the districts, streets, and buildings across a city. For this reason, it is crucial to understand the net impact of architectural and planning choices on the environmental performance of cities, including urban microclimate. Architects, planners, and engineers need to expand their understanding of the microclimate impact of design choices and the impact of urban context on the building performance. However, the full significance of the correlation between urban metrics and performance cannot be assigned to one single metric, as the complex interaction of climate- form- energy occurring in the urban environment cannot be represented by one single variable. Additionally, due to the complexity of the planning and design processes and work with architects and planners is expected to develop more design-oriented tools.

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Introduction

Climate change is now pervasive in scientific, social, and political communities. There is clearly a detectable global warming trend in the long-term climate records. Vast resources are being processed, transported, and consumed to accommodate humans in our modern life (Mao and Norford, 2021). With over half of the global population residing in cities now and an arguably growing projection of urban settlements soon, the scale of this resource demand is profound, and the subsequent problems are unprecedentedly intensified in every aspect (Masson et al., 2020). As a matter of fact, the world is increasingly populated and urbanized. Cities are the places where we live and use almost 80% of the final energy, with associated dissipation of heat to the environment (Mi at al., 2019). However, even though cities occupy a negligible percentage of the earth's surface, they concentrate 75% of global CO_2 emissions (Burdett & Sudjic, 2011)., Koop, & van Leeuwen, 2017) and are warmer than their surroundings (Stone, 2012). This could lead to underestimation of the pace of warming of cities that is higher than that of rural environment.

Motivated by these challenges, urban sustainability holds great attention to tackle energy and environmental issues (Sharifi, 2021). Buildings, which incorporate most human activities in the urban areas, are identified as having the highest economic mitigation potential of any other energy sector. At a time when climate change presents the most critical threat to humanity (IPCC 2018), UN predictions of nine billion people living in cities by 2050 and the wake of a global COVID-19 pandemic request for an urgent rethink of how we design cities for all (da Silva Corrêa & Perl, 2022). It is now more important than ever to evaluate the need for density, access to open space as well as fresh air, intertwined with social justice, support livability and resilience. A 'comfortable and stimulating public realm that encourages social interaction' (Llewelyn-Davies 2007: 99) has long been considered an important criterion for a thriving public realm. In Europe, more than 74% of the population lives in urban areas (United Nations, 2020), and over 90% of the urban population is exposed to air pollution (Neves, 2018). Currently, air pollution and heat stress are two major concerns (Oke and Maxwell, 1975; Kumar et al. 2015, Mentaschi et al., 2022 Ricci at al., 2018). Air pollution and heat stress are major concerns associated with the livability, resilience and sustainability of cities. They directly affect health and comfort and are associated with augmented morbidity and mortality (Urban et. al., 2014, Palusci et al., 2022, Lokys et al., 2018)

This phenomenon is closely related to the level of urbanization and the urban morphology, i.e., the form and the structure of the urban area, the physical characteristics of the buildings and their mutual arrangement (Kamal et al., 2021). The growing concern for the risks posed by climate change to the livability of cities has certainly also contributed to an increase in the awareness of the impact of the built environment on urban microclimate. Nevertheless, attempts to integrate climate principles in the planning, design and renovation of cities and buildings are still scarce, or not effective (Mosler & Hobson, 2021).
The study of urban climate is considered as one of the most important areas in this field of research today (Masson et al., 2020). Starting from the pioneering study by Howard on the climate of London (1888), urban climatology has turned into an established academic discipline (Webb, 2017). Urban climate can be seen as the resulting modification introduced in the environment by urban structure and activities taking place in cities (Mills, 2014).
Oke (1984) advocated the need for a greater consideration of climate principles in urban planning yet in the 1980s, encouraging urban climatologists to translate their knowledge into practical applications and guidelines for the design of street canyon geometry. Since then, the body of knowledge in urban climatology has grown, as well as the computation capabilities to carry out more advanced modelling studies (Al Savafi, 2018), 35. Souch& Grimmond, 2006). Today, a wide and multidisciplinary research community recognizes the importance of interactions among buildings in the urban environment to assess urban sustainability and energy performance (Emmanuel and Steemers, 2018).
However, it is still rare to find good applications of climate principles in urban planning and architectural practice. The basic concepts of urban climatology are often unknown also to building energy modelers that normally carry out energy performance simulations just neglecting any urban effect. The poor importance given to urban climate in planning and design is partially due to the absence of

microclimate regulations. As Futcher and Mills rightly point out (Futcher and Mills, 2015), no one is accountable for the microclimate and energy impact of new buildings beyond their envelope, and this should be better regulated to achieve sustainable urban development. Other motivations behind this persistent gap between urban climatology and planning are still those enumerated by Oke: “the inherent complexity of the subject, its interdisciplinary nature and lack of meaningful dialogue between planners and the climatological research community” (Oke, 1984).

The communication gap between climatologists and designers, including planners, architects and building engineers, is basically due to the lack of a common ground in terms of vocabulary, educational background, and scale of analysis (Hebbert, 2014). In this perspective, investigating urban morphology can support the systematic understanding of urban features to characterize the size, shape and structure of a city with all its constituent elements (Hunt & Watkiss, 2011). In such a complex organization, there is an interdependence between part and whole: the primary elements of a city, such as plots, streets, constructed and open spaces (Huang et al. 2018), are combined according to specific planning principles, resulting in several potential urban forms (e.g., compact, fragmented, and dispersed city). Urban morphology analyses the relationship between these elements, highlighting the underlying rules and principles driving the development of urban form (Mobaraki & Vehbi, 2022). The concept of urban form, intended as the result of the combination of a set of elements, encompasses physical and nonphysical aspects, such as geometry (e.g., width, length, height), spatial arrangements, typologies (e.g., blocks and housing types) or density features (e.g., building density, population density), which can be rigorously defined and measured through a morphometric approach (Jabareen, 2006)
In the Mediterranean cities the urban fabric is very compact and continuous, and the most common building typology is the courtyard type. The arrangement of buildings and urban blocks generates a dense network of public street canyons and inner courtyards for multipurpose outdoor activities (Lizana et al., 2022). All these are characteristic attributes of the “compact Mediterranean city”, where compactness here refers to one specific physical characteristic, namely the ratio of building footprints to urban site area (known also as “plan area density” or “site coverage ratio) (Kain et al., 2022). On the other site, a broad set of urban form attributes and associated metrics with relevance for urban climate and

energy performance is available today, but the proposed approaches are often partitioned and limited to few attributes. Moreover, the use in practice made by professionals in regenerative design is very limited. Architects, urban designers, planners, and policymakers are generally aware of the importance of the issue, but they often turn out to be frustrated to include this knowledge when making decisions (Apreda et al., 2020). The unintended interaction among urban form, microclimate and energy and the associated variables together with the difficulties to isolate the urban form from other drivers of microclimate and energy performance requires a more holistic comprehension of the relevance, suitability, and effectiveness of metrics in the description of cities' functioning (Silva et al., 2017). Several density metrics—such as porosity, compactness, plot ratio and vertical density—have been defined and used to measure these attributes and have proved to be indicators of outdoor comfort conditions and energy performance of buildings. For example, compactness, plot ratio and building volume density are directly related to summer air temperatures in the case of the Mediterranean climate (Massetti et al., 2014).

As such, the present study explores the impact of building morphology on the outdoor thermal comfort. It aims to reveal how major urban morphological features, including surrounding building height configuration, surrounding building layout form and neighborhood compactness, affect the thermal comfort conditions of the street at different periods. The findings of this study provide valuable insights for future urban design to create a thermally comfortable environment. Such a goal is addressed through a parametric investigation by modelling different urban blocks zones, selected among the new Tirana City Development with the Computational Fluid Dynamics (CFD) ENVI-met v5.5.1 model. This study aims to arrange a robust comparative framework by combining on a case-by-case basis urban blocks, different configurations are analyzed by correlating morphometric descriptors to highlight the practical implications of urban geometry on microclimate conditions. For this purpose, in-depth analyses are of paramount importance: detailed investigations of the impact of different morphologies on thermal stress; and the identification of parameters and indicators that can describe the various characteristics of the urban morphology quantitatively. The relevance of this work is related to the presence of a constantly evolving urban environment, that necessarily requires a quantitative approach able to correlate morphological variations with changing microclimate conditions.

The study explores how urban patterns can be used as parameters to create integrated urban environments, which are more sustainable and comfortable. Main elements of contemporary cities including their spatial qualities and climatic context, are studied. Specifically, Mediterranean case studies of urban block focused on environmental design aspects of contemporary architecture in a broad range of climatic conditions and building types are analyzed.

The thesis is composed of three main sections.
Chapter 1 and chapter 2 shows an overview of the relationships between architecture, climate and energy and their development throughout history, highlighting the crucial events that marked the transformation from the vernacular architecture to the climatic and energy vulnerability of the contemporary city. The status of energy codes and climate change adaptation policies are also explored. An in-depth analysis is then dedicated to the heat island phenomenon, its causes and consequences and the overall relationship among urban morphology microclimates.
In chapters 3 and 4 the urban development of the city of Tirana is analyzed. The analysis is done through the main master plans that have shaped the city. The North Boulevard Central Park project of Grimshaw, representing the contemporary city of Tirana, is explored. This project will be the continuation of the main boulevard, which contains various historical traces over time and will represent the connection between the historic city and the new one in the north. Through this analysis, it is emphasized how the perimeter block typology has been developed over time in the city of Tirana.
In chapter 5, (methodology) the studied literature mainly on urban morphology and urban microclimate explored from the city urban block settlements are used as guidelines to analyze the microclimate of different building block types of the winning urban project competition in Mediterranean city of Tirana. In the results (chapter 6) relationships are identified between the morphology parameters and the climatic performances of the urban. The analytical and graphical relationships point out the parameters with respect to the microclimatic performances. At the same time, they identify the urban courtyard configurations that have a better outdoor thermal performance in the Mediterranean context of the city of Tirana, during summer.
Finally, in chapter 7 the main findings and conclusions are drawn, and further works are outlined, based on the achieved results.