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Professional paper

IMPACT OF APPROPRIATE ORIENTATION OF RESIDENTIAL BUILDINGS ON ENERGY EFFICIENCY: A CASE STUDY IN TETOVO, NORTH MACEDONIA

Lindihana GOXHA*, Erda BESIMI, Fjolla IBRAIMI

Department of Architecture, Faculty of Applied Sciences, University of Tetovo, NMK
**Corresponding Author: e-mail: lindihana.goxha@unite.edu.mk*

Abstract

While sustainable urban development has become very important nowadays, the tendency of the population to move to the city is continually expanding and this causes higher consumption of energy to satisfy the requirements of the residents. A high percentage of this energy is used for HVAC and lighting of residential buildings. For this reason, the purpose of this research is to analyze the appropriate orientation of buildings witch is defined by site planning including the geometry of the buildings, by examining a residential neighborhood within a Tetovo. This paper detects the potential for innovative design strategies to drive substantial energy savings and promote environmentally responsible living. Building orientation within a neighborhood plays an important role in using the power of the sun. The study also explores the important role of site planning in the neighborhood's energy efficiency ecosystem. The arrangement of buildings within the site play a dual role in promoting sustainability. Analyzed position of the residential buildings based on the openings in different orientations gives us the right to make the conclusion, that in Tetovo neighborhood the position of the greatest number of residential buildings is based on sustainable site plan which opens the dimension of energy efficiency related to the exposure to the sun. Southeast and southwest orientation are suitable for optimal use of solar energy increasing the energy efficiency of the buildings. In Tetovo, a city with a continental climate, the angle at which buildings are positioned relative to the sun's path can significantly impact energy consumption.

Keywords: Energy efficiency, residential buildings, orientation, site planning, energy savings.

1. Introduction

Building orientation plays a critical role in energy consumption and overall sustainability. By strategically designing buildings to maximize or minimize solar exposure based on their orientation, architects and engineers can significantly impact energy usage for heating, cooling, and lighting.

Understanding dynamics by orientating buildings according to sun exposure, allows architects and builders to optimize building designs for energy efficiency. Additionally, retrofitting existing buildings with features like adjustable shading devices or high-performance glazing can help mitigate energy consumption regardless of their orientation.

In the context of transitioning existing building stock to climate-neutral standards, reevaluating and potentially modifying building orientations can be a key part of achieving sustainability goals. This might involve not only physical adjustments to the buildings themselves but also considering urban planning strategies to optimize overall energy usage within communities.

The energy consumption at residential buildings, is continuously increasing. Furthermore, due to their long lifespan, 70–80% of the buildings that should be climate-neutral by 2050 have already been built and equipped with non-climate-neutral technologies. Most of the building stock will have to be converted to climate-neutral buildings over the next 30 years (Geske, 2022).

2. Energy Efficiency Strategies and Recommendations in North Macedonia

Energy efficiency is a valuable resource which creates a winning solution in many categories in the society: money saving, increase of the living comfort, protection of the environment, improvement of the economy on the general level in the state. Building energy use has grown in the last 20 years. Buildings today account for 40% of energy consumption in world's developed countries, 33% in commercial buildings and 67% in residential (Janssen,2004)
The territory of Macedonia is rich in solar radiation, which is confirmed by the country's insolation map. According to (Aronova et al., 2015) meteorological observations conducted from April 2004 to March 2010 show that the inflow of solar energy in almost the entire country is greater than 1400 kWh/m², and in some parts even 1600 kWh/m², with global horizontal irradiation of 1500 kWh/m2, while global irradiation at optimal slope 1800 kWh/m².
Building geometries and surrounding area characteristics can affect the availability and use of solar energy and the energy demands of a building. The shape of a building and the urban conditions in which it is located directly affect the availability of solar radiation. Most solar retrofit concepts claim to affect a building's thermal energy requirements (Goxha, Rufati, 2023). Building energy consumption depends on many factors including the number of occupants, building orientation, the number of appliances used, air conditioner performance, window/opening materials, shading as well as the materials of roof and walls.
Building orientation and site planning are amongst the important factor in determining the building eco-friendliness. Accordingly, they can help the designers to determine which area will be affected by receiving direct sunlight to the building façade. An important clue in developing energy efficient facades for energy efficient building is the knowledge about the distribution of solar radiation due to orientation.
In Tetovo, urban planning plays a crucial role in influencing energy use and promoting sustainability. Incorporating energy-efficient building standards into urban planning regulations ensures that new construction and redevelopment projects meet high-performance standards for energy efficiency. This includes requirements for insulation, efficient heating and cooling systems, and use of renewable energy sources.

3. Urban planning and energy use in Tetovo

Like many cities in transition economies, Tetovo faces several urban development challenges, including rapid urbanization, inadequate infrastructure, environmental degradation, and socio-economic disparities. These challenges require holistic and sustainable approaches to urban planning and development.
The impact of building orientation and site planning on energy efficiency in Tetovo's residential neighborhoods offers valuable insights into sustainable urban development in the region. In this paper we explore a case study of residential buildings within a Tetovo neighborhood, situated in the scenic landscapes of North Macedonia.
Since the city has a long history dating back to ancient times, with influences from various civilizations including the Byzantine, Ottoman, and Yugoslav periods. This diverse historical heritage is reflected in its architecture, culture, and traditions. This city has a hybrid spatial configuration (Ferati, Saidi, 2020) with characteristics of both the organic and planned concepts of spatial organization. It tends to develop into a model with a relatively geometrical shape, given that the post-war public space network is the most common element that is transferred from plan to subsequent plan. Generally, organic concept, is usually described by irregular street network, compact spatial configuration, mixed use activities and hierarchical network of centers and sub-centers.

The main general principles for the design of the new modern city are geometric and hierarchical street network decentralization (and dislocation of the center); mono-functional zoning; new industrial zones; new residential typology. Cities planned based on these functionalist principles were losing their human scale. They became car dependent, fragmented, segregated, anti-social, sterile, and monotonous (Commission of the European Communities 1990). In figure 1 is shown the hybrid spatial configuration of Tetovo with a positioned analyzed neighborhood in the central part of the city.

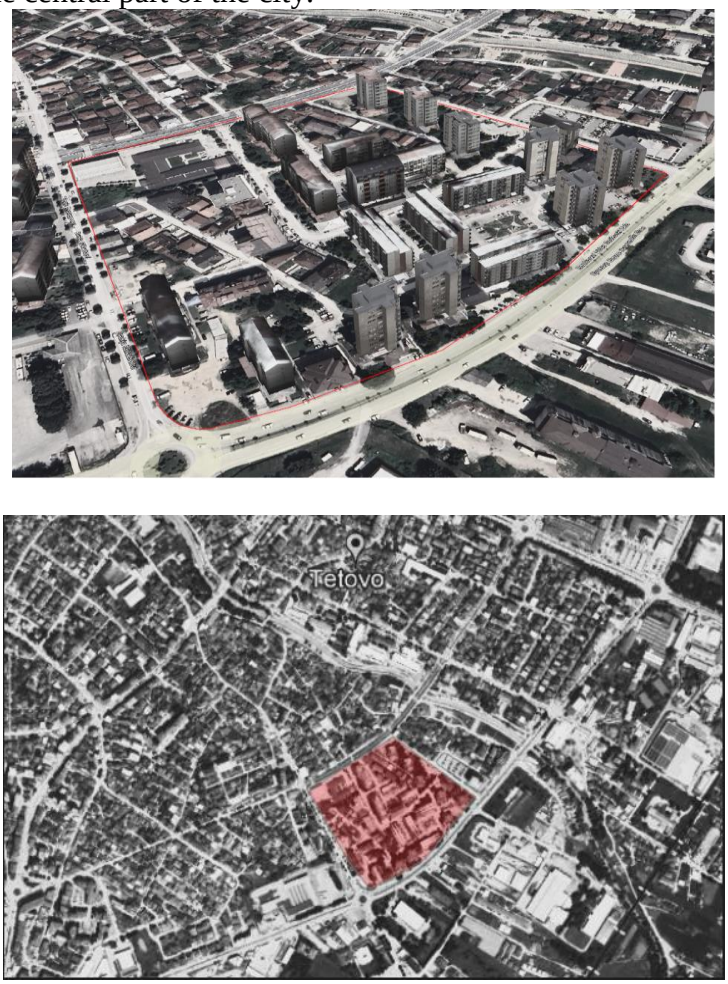


Figure 1. Current spatial configuration of Tetovo, retrieved http://www.google.com/earth/index.html

Figure 2. Random part of the neighborhood (author)

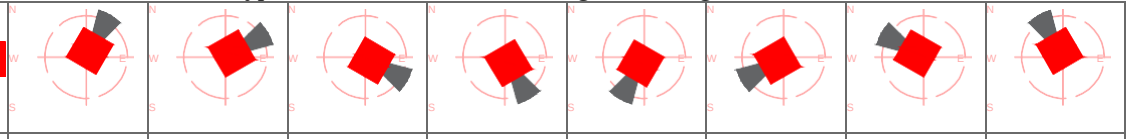
3.1 Analysis of Building Orientation into the analyzed neighborhood:

Building orientation is a long-term decision that affects energy performance over the entire life cycle of the building. Considering factors like maintenance requirements, durability, and future adaptation can ensure that the chosen orientation continues to deliver optimal energy efficiency and performance over time. A well selected orientation allows a building to attain optimal energy performance throughout its entire life cycle by adopting solutions to achieve energy efficiency for heating, lighting, and cooling. Factor such as, the actual need for natural light, play specific role in determining the best orientation for a building.

Table 1 presents seven general types of residential buildings within analyzed neighborhood. Each type defines different wall openings within the different geometry (Type 1-7) while

subtypes are based on different orientation (south, north, west or east). Also there is presented the number of buildings in each subtype.

Table 1. Types and number of the buildings according to the orientation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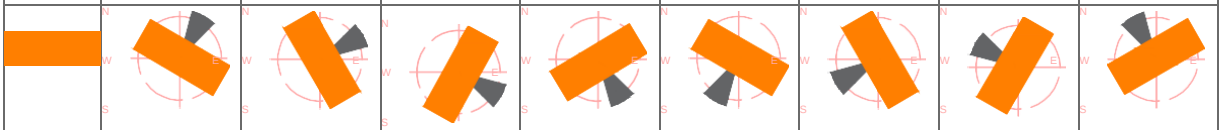
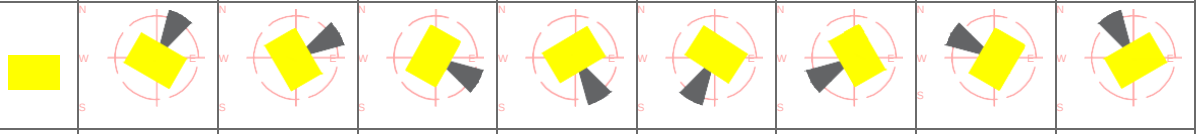
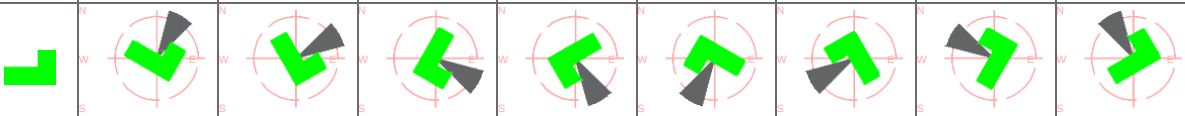
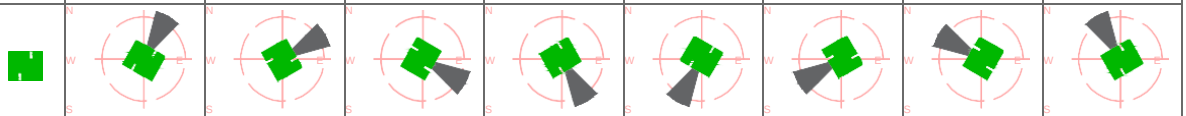
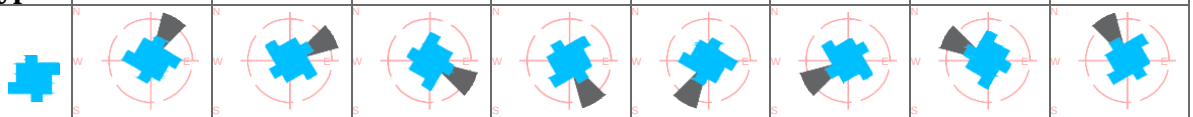
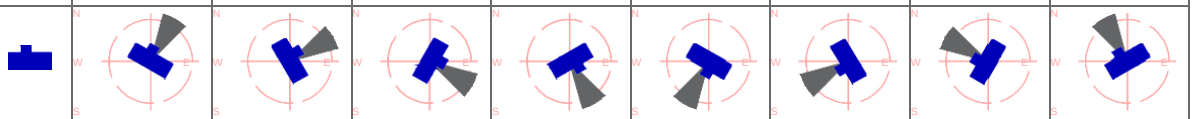
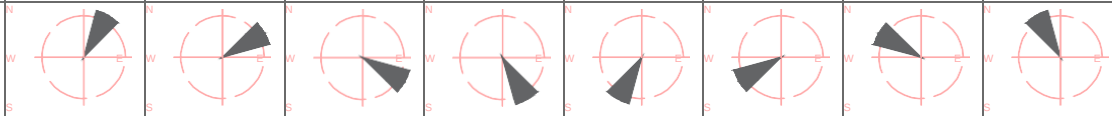
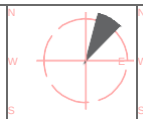
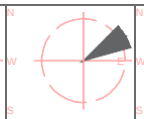
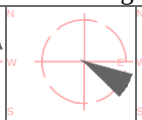
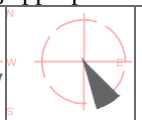
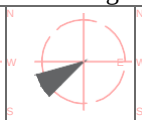
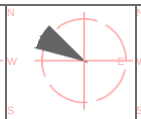
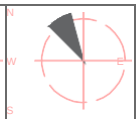
								
Type 2	0	2	2	2	1	5	0	2
								
Type 3	3	0	2	3	6	1	2	0
								
Type 4	1	0	0	0	2	2	1	0
								
Type 5	0	3	0	0	0	0	0	0
								
Type 6	0	1	0	3	0	1	0	0
								
Type 7	0	0	2	0	2	0	0	0
								
OTHER	2	0	2	1	3	0	2	0

3.2 Determination of subtypes: As shown in table 1, some orientations have low number of buildings, therefore we developed the study according to the table 2, appropriate orientation is based on the largest number of buildings. South-facing buildings, for instance, can take advantage of passive solar heating during the winter months, reducing the need for artificial

heating. Conversely, north-facing buildings might require more insulation or alternative heating strategies to compensate for reduced sunlight exposure.
East and west-facing buildings experience different solar radiation patterns throughout the day. East-facing buildings receive more sunlight in the morning, which can be beneficial for spaces like kitchens or offices where occupants are more active during the morning hours. West-facing buildings, on the other hand, receive more sunlight in the afternoon and evening, which might contribute to increased cooling loads during warmer months.

Table 2. Determining appropriate orientation of buildings

TOTAL								
	8	7	8	9	17	11	5	2

4. Conclusions

The study emphasizes the crucial role of building orientation and site planning in optimizing energy efficiency, particularly in a city like Tetovo with a continental climate. By strategically positioning buildings within a neighborhood, taking into account factors such as the sun's path and exposure to sunlight, energy consumption can be significantly reduced.
The findings suggest that in Tetovo's neighborhoods, there's a trend towards adopting sustainable site plans that prioritize optimal building orientation. Specifically, residential buildings are often positioned to maximize exposure to sunlight, with southeast and southwest orientations being particularly advantageous for harnessing solar energy. By aligning buildings in this way, not only can energy efficiency be improved, but overall sustainability can also be promoted. This approach not only benefits individual buildings but contributes to the broader energy efficiency ecosystem of the neighborhood.

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