Evaluation of Mitigation Strategies of The Urban Heat Island Effect in Mediterranean Area: The Case Study of Largo Annigoni in Florence

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Francesco Alberti · Mourad Amer · Yasser Mahgoub · Paola Gallo · Adriana Galderisi · Eric Strauss *Editors*

Urban and Transit Planning

Towards Liveable Communities: Urban places and Design Spaces

Second Edition

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Editors

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Second Edition

A culmination of selected research papers from the fifth version of the international conference on Urban Planning & Architectural Design for Sustainable Development (UPADSD) of Florence, Italy (2020).

Springer

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ISSN 2522-8714 ISSN 2522-8722 (electronic)
Advances in Science, Technology & Innovation
IEREK Interdisciplinary Series for Sustainable Development
ISBN 978-3-030-97045-1 ISBN 978-3-030-97046-8 (eBook)
https://doi.org/10.1007/978-3-030-97046-8

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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Preface

Metropolitan areas currently face several new challenges and pressures. The many functions of a city are involved in affecting the social, economic, and environmental concerns of its residents. Urbanization is a constantly changing phenomenon. Cities with rapidly expanding populations can be helped by urban planning that combines physical redevelopment with improving the social, economic, and environmental characteristics of its current and future residents. Cities consist of both formal and informal settlements that can be improved through effective urban planning and transportation improvements. Involuntary removal of individuals must be sustainable as well as sensitive to issues of access and gender. Traditional transportation systems must be designed to take account of climate change and the fragmentation of habitat in the process of city decentralization.

The worldwide pandemic has called into question the traditional models of urban concentration and suburbanization as well the tools used to solve problems of environmental degradation, cultural preservation, inadequate housing, and economic opportunity. High unemployment and social instability do not lead to cities that can prosper in the future. Physical improvements and programs designed to improve personal skills may help to increase the ability of residents to escape poverty. Communities that have been disadvantaged by the process of urbanization can be rejuvenated through a careful application of techniques that preserve its heritage and maintain accessibility with the advice of the current residents.

Barriers to metropolitan development can be identified by a partnership between urban planners and residents of those communities that need governmental assistance. The goal of resiliency of the current public infrastructure is a common theme throughout these new techniques which must be discovered, researched, and implemented in order to solve these traditional problems. Unplanned growth places pressures on both individuals and governments to provide a framework that advances the well-being of all members of society. This book represents a collection of well-researched ideas focused on both the cities with developed as well as developing infrastructure. Urban waterfront spaces are an excellent laboratory to demonstrate solutions to problems caused by waste disposal and visual blight in a way that improves the choices available to future generations that will live in the area.

The effect of the global economy, local climate, and historical perspectives is necessary to redesign public facilities that provide for accessibility as well as adequate public facilities. Renewable energy is another way that improved structural design that considers the cultural background of the residents can begin the process of urban regeneration that benefits the citizens currently residing in those areas most in need of improvement. Urban regeneration can benefit from innovative techniques that reduce urban heat islands.

Public participation to improve design as well as improved human interaction with the built environment is a common theme throughout most of the chapters. Cultural values as well as facility needs can be accomplished through site design that works in tandem with those most affected by the improvements. Public and private spaces can be redesigned to provide for an improvement of the quality of urban life in self-sufficient neighborhoods based on the diminishment of environmental risk. The symbolic significance of the current constructed form must not be underestimated. Parks can be designed to provide safe spaces for human interaction, security, and pedestrian hospitality within a dense environment.

The image of the city is important to all its current residents. Another topic covered extensively is sustainability of current urban form in order to provide diversity and opportunity to all individuals regardless of their physical, social, or economic status. Urban planning techniques and implementation tools can be used to advance the abilities of individuals to prosper considering the new challenges facing them.

East Lansing, USA Eric Strauss

Acknowledgments We would like to thank the authors of the research papers that were selected for addition in this book. We would also like to thank the reviewers who contributed with their knowledge and constructive feedback in hopes of ensuring the manuscript is of the best quality possible. A special thanks goes to the Editors of this book for their foresight in organizing this volume and diligence in doing a professional job in editing it. Finally, we would like to express our appreciation to the IEREK team for supporting the publication of the best research papers submitted to the conference.

Introduction

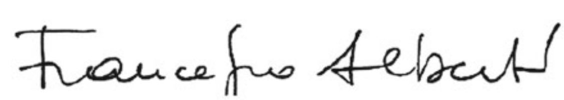
In light of ongoing circumstances, the world has changed profoundly. The health crisis, in the face of which even the richest countries found themselves unprepared, has somehow increased the perception of the other global crises—environmental, climatic, and social—which have been at the center of international debate for a long time, but have continued to deteriorate to date in the absence of major changes in development models in both advanced and emerging economies.

If, on the one hand, this more acute perception of the impending threats to mankind has accelerated mitigation and adaptation policies to global change, mobilizing significant resources towards the so-called ecological transition and the increase of urban resilience in the industrialized world; on the other hand, it is news these days the alarm raised by UN Secretary General, Antonio Guterres, on how the pandemic, increasing the gap between the Global North and South, is putting the planet off track to achieve the Sustainable Development Goals set by the UN Agenda 2030.

Focusing on SDG no. 11 “Sustainable Cities and Communities”—which deals with people’s living space, where social issues and impacts from human activities are concentrated, and is therefore the one more evidently linked with each of the other 16 SDGs—the papers that make up the three sections of this book give evidence of how disciplinary research is already able to provide advanced analysis tools and innovative design approaches to appropriately address, at all different scales and latitudes, the challenges we face.

Compiled and Edited during the pandemic, the Second Edition of Urban and Transportation Planning, we remain oblivious as to what the situation caused globally by the new Coronavirus variants will be, when, in a few weeks, the volume will be finally released. Its preparation and whole production process, from the selection to the revision and editing of the papers, undertaken during the pandemic, is only incidentally mentioned in a few of its chapters, since for the most part, they derive from research previously initiated. In fact, only one, in part three, explores its cause-and-effect relationships with the built environment in the context of metropolitan cities in India.

With that being said, the hope is that the health tragedy we are going through can be soon left behind and remembered as a painful, late, but decisive turning point in the collective awareness and in worldwide governments’ assumption of responsibility, so that research lines and concepts such as those presented in the following pages find everywhere a fertile ground to germinate and hybridize, helping world regions, cities, and communities to become better places to live in.



Francesco Alberti

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Past and Future: City’s Image and Preservation

Evaluation of Mitigation Strategies of the Urban Heat Island Effect in Mediterranean Area. The Case Study of Largo Annigoni in Florence (Italy)

Rosa Romano, Paola Gallo, and Alessandra Donato

Abstract

Global warming is the most-documented phenomenon of climate change. Any increase in global temperature effects on human health has a severe impact on the citizen's well-being and the overall environmental quality of urban contests (IPCC, Global Warming of 1.5 °C. An IPCC Special Report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, 2018). Numerous studies report the specific impact of current and projected urban overheating on the increase of the energy demand for cooling purposes during the warm period. Urban climate and the phenomenon of 'Urban Heat Island Intensity' (UHI) have been extensively investigated in the last decades and a lot of research has been conducted in South Europe (Santamouris, Energy and climate in the urban built environment, 2013). Moreover, the EU policies promote research and innovation actions on urban regeneration through nature-based solutions, both using and improving existing technologies to face challenges, as well as exploring more novel materials and architectural components, for improving well-being in urban areas. In this work, an evaluation of the impacts of a design proposal developed for the urban regeneration of Largo Annigoni in Florence is done to reduce heat stress at a micro-urban scale of the built environment. Simulation of microclimate conditions of the analyzed area was performed using the three-dimensional software ENVI-met for urban modelling comparing indexes of environmental comfort such as Mean Radiant Temperature, the PMV Index (Predicted Mean Vote), and the PET Index (Physiologically Equivalent Temperature). Besides, climate-adaptive design became an important tool to encourage the regeneration of contemporary cities, with a particular focus on the effects generated from the combination of innovative technologies for mitigation and adaptation to climate change of urban space.

Keywords

Climate adaptive design • Urban heat islands • Urban regeneration • ENVI-met • Environmental comfort

1 Introduction

According to global climate change scenarios, the IPCC (2018) reported that "in many regions land and sea, even if the greenhouse gases emissions are drastically reduced, temperatures are increasing at 0.2 °C per decade (approximately 1 °C above pre-industrial levels), precipitation patterns are changing, sea levels are rising, and climate-related extreme events such as heatwaves and heavy precipitation are growing in frequency and intensity." Furthermore, in the urban area, global warming and associated changes in temperature can have significant implications on public health (Armstrong et al., 2015; Hajat et al., 2010), energy consumptions (Santamouris, 2013), and outdoor thermal comfort (Evola et al., 2017). Consequently, cities need to adapt to avoid or reduce the negative impacts caused by climate change, such as weather-related deaths and economic losses from climate-related extreme events in the future. This situation requires a response not only from the national governments but also from the local authorities. The integration of future climate variability in urban planning processes at

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F. Alberti et al. (eds.), *Urban and Transit Planning*, Advances in Science, Technology & Innovation,
https://doi.org/10.1007/978-3-030-97046-8_6

the local level can assess and select adaptation options and strategies, considering the particular geographical, socio-demographic, or economic characteristics of a given place (The International Bank for Reconstruction and Development, 2011).

Many scientific studies (Akbari et al., 2016; Grimmond et al., 2016; Hajat et al., 2010) have shown how temperature is higher in urban areas, than in nearby rural areas. The annual mean air temperature of a metropolitan area can be 1–3 °C warmer than its surroundings (U.S. Environmental Protection Agency, 2010). This phenomenon, known as Urban Heat Island (UHI), can affect communities due to increasing urban discomfort and summertime peak energy demand resulting in increased costs for cooling, air and water pollution, greenhouse gas emissions, and incrementation in illnesses and heat-related mortality.

The local weather conditions (i.e., wind and cloud cover), the geographic location (i.e., climate and topography), not only the urban geometry but also properties of urban materials used to cover the ground and buildings surfaces, the reduced vegetative covers or absence of green infrastructures are key factors that influence UHI development. Concerning the urban geometry factor, the dimensions and spacing of buildings within a city can considerably affect wind flow, energy absorption, and thermal quality of the urban environment. Over the years, several research studies focused on the analysis of local microclimate conditions of historical "urban canyons," which are characterized by a downtown area that is surrounded by enclosed spaces and tall buildings (Georgakis et al., 2014). Castaldo et al. (2017) defined an urban canyon as "a space with a low sky view factor (SVF) value, closer to zero and with a limited surface heat re-emission capability, where the outdoor comfort is mainly affected by exposure to solar radiation and also street orientation and height/width ratio (H/W) have a considerable effect." Moreover, some recent Italian studies (Bassolino & Ambrosini, 2016; Evola et al., 2017; Lassandro et al., 2018) investigate the possibility to use novel materials and technologies to improve the outdoor comfort conditions in historical urban areas, where typical renovation strategies cannot be applied due to the presence of historical-landscape constraints. The objective is to analyze the impact of different mitigation strategies to reduce the UHI effect, adopting multiple scenarios based on a parametric design approach and comparing various configuration models mainly focused on trees and vegetation and properties of urban materials, in particular radiative (i.e., albedo and thermal emissivity) and thermal properties (i.e., heat capacity). Specifically, for paving materials placed at the ground level, the interest of researchers on innovative cold materials (i.e., cement-based materials and highly infrared-reflective stone) is growing, and as Dessì (2011) mentioned, an "emerging body of research and pilot projects are helping scientists and urban designers understand better the interactions between pavements and the urban climate."

Based on these considerations, this work investigates design approaches and solutions that support a design proposal of an urban transformation in Tuscany, Italy, which considers reducing exposure to climate risks (UHI, heatwaves, water, and flooding deficiencies), economic, and social sustainability. Furthermore, the paper presents analysis and evaluations operated in the frame of Post-graduate Master Course in Bio-ecologic Architecture and Technological Innovation for Environment (MSC ABITA) of the University of Florence, in order to improve the climate resilience of Florence's historical square Largo Annigoni. The design approach, based on microclimate simulation for urban modeling, was developed as a tool to stimulate the urban regeneration of the Italian historic districts, focusing on the effects of combining innovative climate mitigation and adaptation technologies.

2 Research Methodology

The research methodology, as described below, was articulated step by step to define a sustainable and resilient meta-design proposal for the urban regeneration of Largo Annigoni, from state of the art to evaluation of the design proposal. In detail, the scientific work was articulated as follows:

(1) Analysis of urban geometry factors and urban fabrics (buildings density and morphology) and climatic conditions (altitude, latitude, degree days, average temperature, prevailing wind, sun path diagram); (2) Analysis of urban open space uses, based on different patterns of spatial occupancy and considering specific users profile depending on the season and on the different time of the day; (3) Identification of some representative microclimate indicators for pedestrian comfort (mean radiant temperature, air temperature, relative humidity, wind speed) and urban features (solar radiation, sky view factor); (4) Identification of the urban and building features that mainly influence the local microclimate, such as: materials physical properties, urban fabric morphology, mitigating elements (e.g., water bodies, vegetation and integrated green systems as green walls and green roofs); (5) pre-processing of the geometric and physical model of Largo Annigoni, through ENVI-met; (6) UHI simulations of the square's urban climate before and after the renovation of 2019; (7) design of a suitable project scenario; (8) pre-processing of the geometric and physical features of the project scenario through ENVI-met; (9) simulation of the project scenario; (10) analysis of the simulation results and identification of the most effective technological strategies, in terms of mitigation of the urban heat island, overall improvement of thermal comfort and urban microclimate.

In detail, the transformation project shown in this paper was developed in the frame of MSC ABITA, involving students in the project-based learning experience through active exploration of a real case study.

The MSC ABITA, initiated in 2003, following EU directives aims to offer an advanced level of knowledge that gives new inputs and instruments for environmental projects in an eco-compatible perspective. In particular, it trains new professional figures capable of influencing the decision-making process to enhance territorial revitalization processes by defining intervention scenarios and comparing the different design solutions to build more sustainable and resilient buildings and cities. The topics dealt with a concern on environmental, economic, and social sustainability applied to the territory's management and governance at an urban scale. In the MSC Academic Year 2019–2020, as part of the practical experience in developing microclimatic simulations, students analyzed the outdoor comfort of the square Largo Annigoni using dedicated software, such as ENVI-met.

The design proposal was inspired by a holistic approach finalized to improve the Florentine square's resilience, starting from a first analysis carried out on the identification of its social and environmental features. Attention was paid to preserve its historical urban configuration and its relations with the surrounding areas whilst increasing its responsiveness to the effects of climate change, in particular to the UHI. Moreover, with the aim to transform both the psychological perception by users, in particular university students and elderly people, the design strategies were focused to maintain its functional and aesthetic appearance. Simulations were performed using ENVI-met software to calculate and compare the leading indicators of the UHI's impacts on the urban environment. In detail, to determine the value of the Mean Radiant Temperature (PMV Index, °C) and outdoor thermal comfort (PET Index) of a specific user (including sex, age, height, and weight data), the ENVI-met's application "Biomet" was used. Moreover, in this phase of analysis, only climatic conditions of the UHI and the PMV index that exceeds [−3/+3] range value were taken into account to identify the thermal discomfort for the older people that represent the case study's target group.

3 The Case Study

3.1 Largo Annigoni Before and After the 2019 Renovation

Largo Annigoni (Fig. 1 and 2) is a large public square realized in 2005 as the roof of underground parking in the Sant'Ambrogio neighborhood, located in the historical center of Florence. The recovery project, by Florentine studio Natalini Architetti, provided the total demolition of the former municipal warehouses giving way to a parking and a new pedestrian square for the Sant'Ambrogio neighborhood. On the west side of the new court, paved in "pietra serena" (a typical Tuscany stone), two pavilions are located to allow the parking entrance and exit as well as the access to its technical rooms. Recently, 28 modular and prefabricated boxes were built in the northern part of the urban space to realize the new city's antique market. Since the renovations, citizens spend much time in the square during the whole year, particularly during the summertime, despite the inadequate comfort conditions due to the absence of shading or green surfaces and the lack of urban furniture to increase their livability.

Currently (Fig. 2), the square presents a complexity of physical and morphological conditions due to the simultaneous presence of historical and modern buildings surrounding the space, market activities, and restoring spaces.

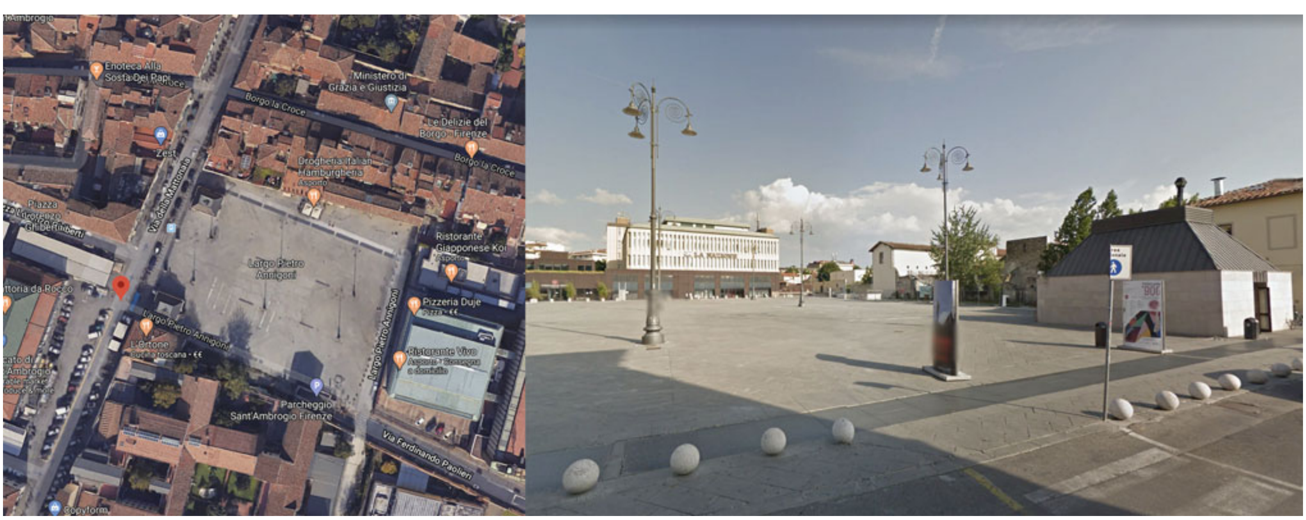


Fig. 1 Largo Annigoni square before the 2019 renovation (Base case)

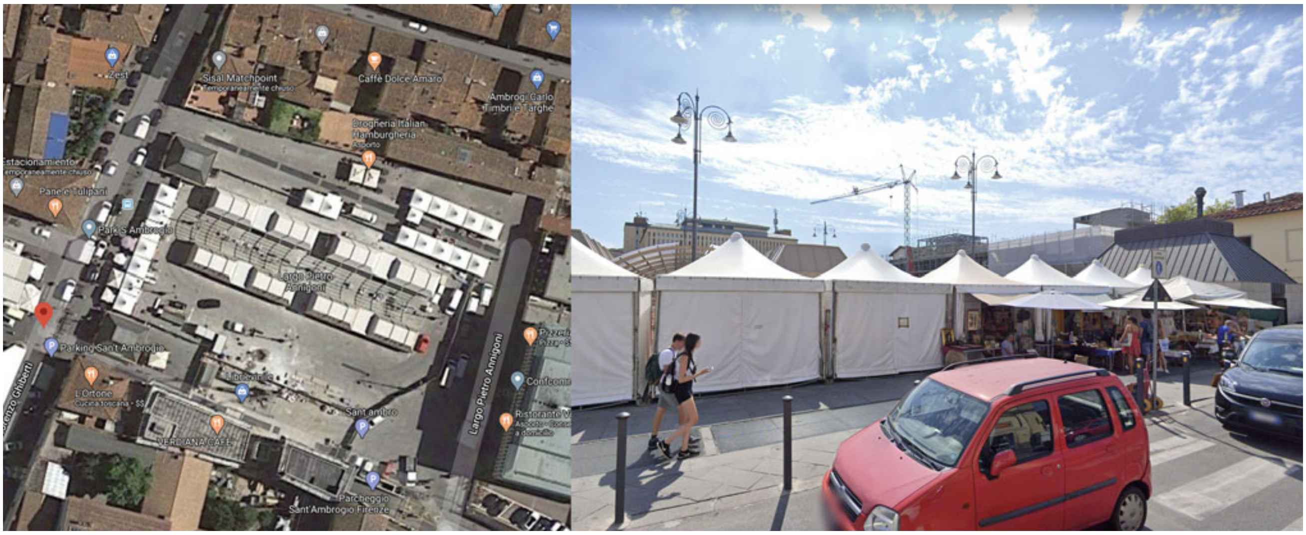


Fig. 2 Largo Annigoni square after the 2019 renovation (Scenario 1)

On the east border, the headquarter of the Nazione magazine is located, while the new access to the School of Architecture of the University of Florence is under construction along the southern border; on the west edge, Via Mattonaia divides the square Annigoni from Sant'Ambrogio market.

3.2 Master Students Design Proposal

The square is surrounded by buildings with irregular shapes in a fragmented composition; its pavement is realized with dark pedestrian materials, while the adjacent roads are paved with asphalt. The absence of trees and vegetation, water elements, semi-permeable and permeable green areas, shading elements, seats, and other street furniture elements are evident.

For this reason, the MSC students' regeneration design proposals (Figs. 3 and 4) were focused on the definition of new urban spaces, where a new antique market and other social infrastructures were located to improve the outdoor comfort and the environmental performances of the urban district and to increase its social potential as aggregative space.

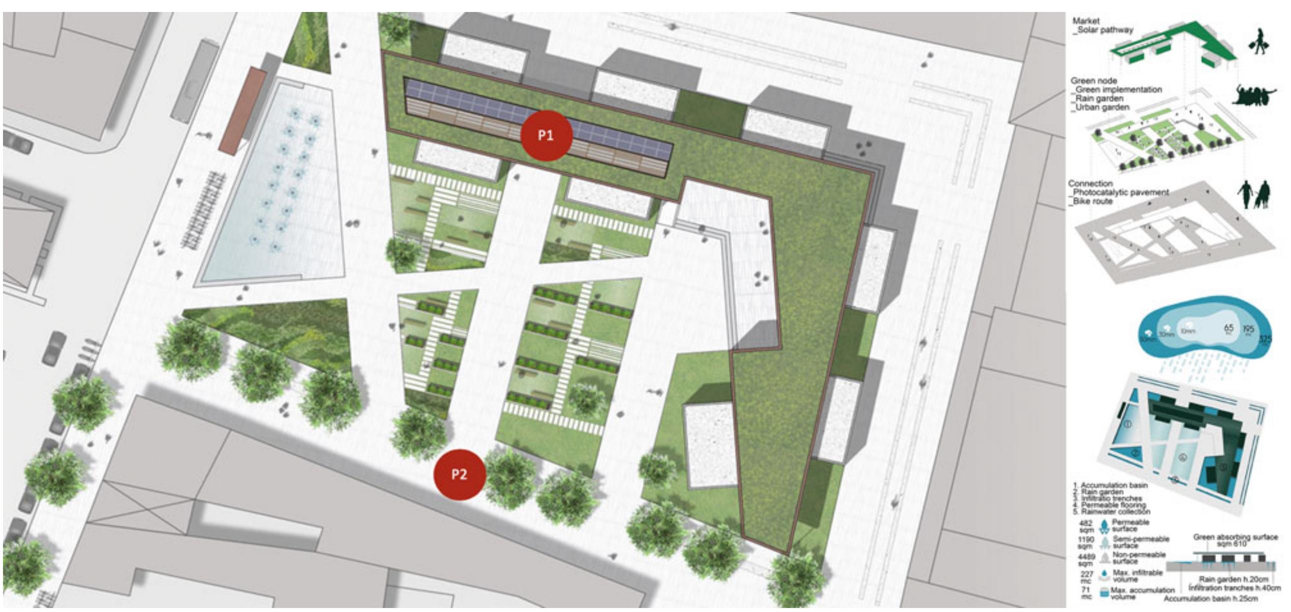


Fig. 3 Design proposal (Scenario 2): **a** Plant layout: P1, solar wood shading, P2, south border near the new entrance of the Architecture School; **b** Green infrastructures design scheme; **c** Water infrastructure design scheme

Fig. 4 Rendering of the design proposal (Scenario 2)

In detail, the project of Master students was focused on: (1) the re-paving of the square; (2) the construction of new market buildings with integrated renewable technologies for the energy production and water storage in a wooden solar shading structure; (3) the retraining of the nearby streets, transformed into green corridors; (4) the design of water elements, like fountains, to increase the outdoor comfort, especially during the summertime; and (5) the realization of a rain garden for water collection to prevent and treat the local stormwater run-offs.

The vegetative species integrated into the green areas of the new square were selected from native species according to the phytoclimatic and bioclimatic characteristics of the study area considering the following: mild and non-allergenic species; a balanced use of evergreen and deciduous trees to improve seasonal water regulation; permeability of foliage for radiation control; seasonal adaptability and maintenance.

The project proposal was also characterized by using the local materials for the urban paving with a high albedo and a low Solar Reflectance Index (SRI).

4 Simulation Model

The proposed method analyzed microclimate conditions and thermal behavior of the square Largo Annigoni (before and after the realization of the flea market in 2019) using environmental simulation modeling performed through the ENVI-met, a holistic three-dimensional software that allows the developing predictive models based on the fundamental laws of hydrodynamic and thermodynamic at an urban micro-scale.

Indeed, ENVI-met can fulfil detailed microclimatic analysis starting from the climatic data, (including wind speed and direction, hourly air temperature, and humidity), the interactions between several environmental factors (such as the surface materials, buildings, and vegetation), and their influence on the urban microclimate. Moreover, it evaluates Fanger's indices based on the modified heat balance equation for outdoor conditions developed by Jendritzky and Nubler (1981).

In detail, to evaluate the main design strategies, to develop appropriate project proposals for a future requalification of the square based on their impact, and to reduce the UHI effects, the atmospheric temperature (°C) and the outdoor thermal comfort (PMV and PET indexes) were calculated, analyzing the energy performances of three different scenarios: Base case, before the renovation (Base case); Base case, after the 2019 renovation (Scenario 1); and Design proposal (Scenario 2).

The study starts from a reference simulation model, the Base case before the renovation, in which the square was generated editing the area with a rotation of −20° from the North. The grid size of the rendered model was $60 \times 60 \times 30$ (x-y-z) with three-dimensional spacing of dx = 3.00 m; dy = 3.00 m; and dz = 2.00 m. The buildings included in the model have a height between 6 and 24 m. For the modeling of the vegetation modeling related to Scenario 2, three different tree types were employed (Table 1).

Table 1 Principal characteristics of trees integrated into the model simulation

Characteristics of the trees	Acer negundo	Tilia platyphyllos (t)
Height (m)	11	25
Width (m)	9	15
Albedo	0.5	0.18

Moreover, the simulation model was developed mainly on radiative properties of surface materials of the three different design scenarios (Table 2). Finally, a part of the urban context surrounding the square was included in the model, as the software struggles in producing precise results near the edges of the simulation area.

The input setting of input climatic data in ENVI-met simulations refers to the hottest day expected in the climate file: the August 1, 2017 (Minimum Temperature 20.0 °C at 4:00 a.m.; Maximum Temperature 41 °C at 04:00 p.m.; Minimum relative Humidity 15% at 01:00 p.m.; Maximum relative Humidity 70% at 6:00 a.m.; and 0.2 m/s wind speed from south direction).

The results associated with the atmospheric temperature and Predicted Mean Vote (PMV) and Physiologically Equivalent Temperature (PET) were derived from the least favorable microclimatic conditions (04:00 p.m.) and in the relation to the most disadvantaged users, represented by older men (Age: 75 years, Height: 1.75 m, Weight: 75 kg, Clo: 0.90, Met: 1.35).

The analysis of solar radiation and sun path diagrams (Table 3) for the Base case was performed in a 3D model generated with Sketchup using Florence's meteorological data in .epw format (Energy Plus Weather Data format).

Three different scenarios (Fig. 5), listed below, were analyzed by the students of the MSC ABITA to compare different design strategies to minimize the impact of the UHI effect on urban area:

- Base case. The model was extrapolated/generated by analyzing the Largo Annigoni urban environment before the 2019 renovation, as described in detail in Sect. 3.1.
- Scenario 1. The model created had the same characteristics as the Base case model with the addition of prefabricated modules located on the north side of the square from Florence's municipality in 2019.
- Scenario 2. The model was realized in order to analyze the impact of the technological solutions adopted for the urban area regeneration, improve its microclimate and thermal comfort, and increase the quality of users' urban life, as described in Sect. 3.2. The same Input files of the Base case were analyzed in ENVI-Met software, modifying only the Configuration File with the new urban materials and elements added in the design scenarios.

5 Results

5.1 Atmospheric Temperature, PMV, and PET Index

Simulations for all three scenarios were measured on August 1, 2017 within the 24 h range. Figure 6 shows Thermal and PMV maps of the three scenarios analyzed during the warmest period of the day (04:00 p.m.).

The plan views (x-y) show the data at pedestrian eye-level height (z = 1.75 m, representing perceived thermal comfort of the users).

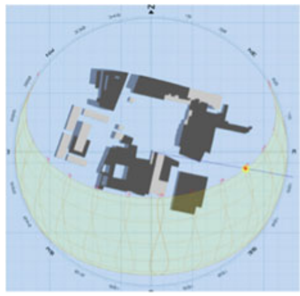
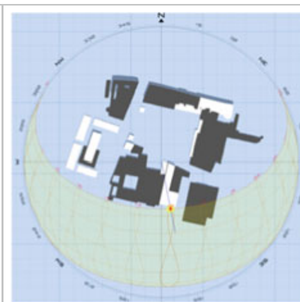
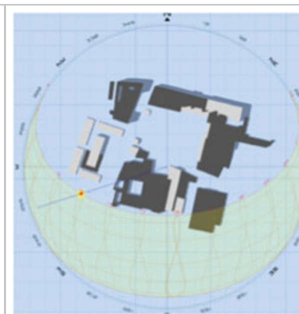
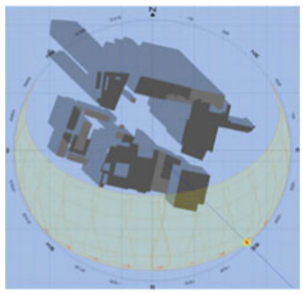
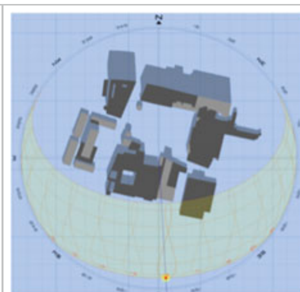
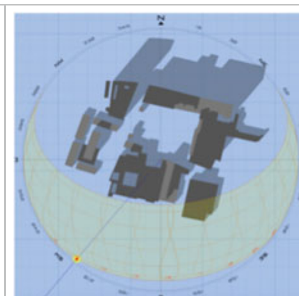
The simulations results achieved can be summarized as follows:

- *Base case*. The square shows a general discomfort throughout the day due to the lack of trees, vegetation, and shaded areas with a temperature range from the maximum of 38.87 °C to the minimum of 36.40 °C in the south part of the square. Climatic comfort indicators delineate a condition of high stress due to the summer overheating (PMVmax = 6.52 equivalent to PETmax = 79.70 °C). The buildings' shadow on the southern border creates an area with a minimum PMV index value of 5.52.
- *Scenario 1*. Compared to the Base case, this scenario shows no significant improvement over the whole square's urban comfort, with the permanence of extreme

Table 2 Radiative properties of surface materials integrated into two design scenarios

Materials	Albedo	Emissivity	Base case	Scenario 1	Scenario 2
1 Asphalt	0.2	0.93	✓	✓	✓
2. Asphalt with red coating	0.5	0.93			✓
3. Dark granite pavement	0.2	0.63	✓	✓	
4. Reflective concrete light	0,7	0.93			✓
5. Loamy soil	0.15	0.90	✓	✓	✓
6. Grass	0.2	0.97			✓

Table 3 Solar radiation analysis and sun path diagrams for the Base case

Summer Solstice 21 June		
 09:00 a.m Azimuth: 100,41°, Altitude: 45,09°	 12:00 p.m Azimuth: 169,01°, Altitude: 69,38°	 03:00 p.m Azimuth: −107,87°, Altitude: 50,97°
Winter Solstice 21 December		
 03:00 p.m Azimuth: −141,21°, Altitude: 12,72°	 12:00 p.m Azimuth: 176,79°, Altitude: 22,77°	 09:00 a.m Azimuth: 136,06°, Altitude: 9,66°

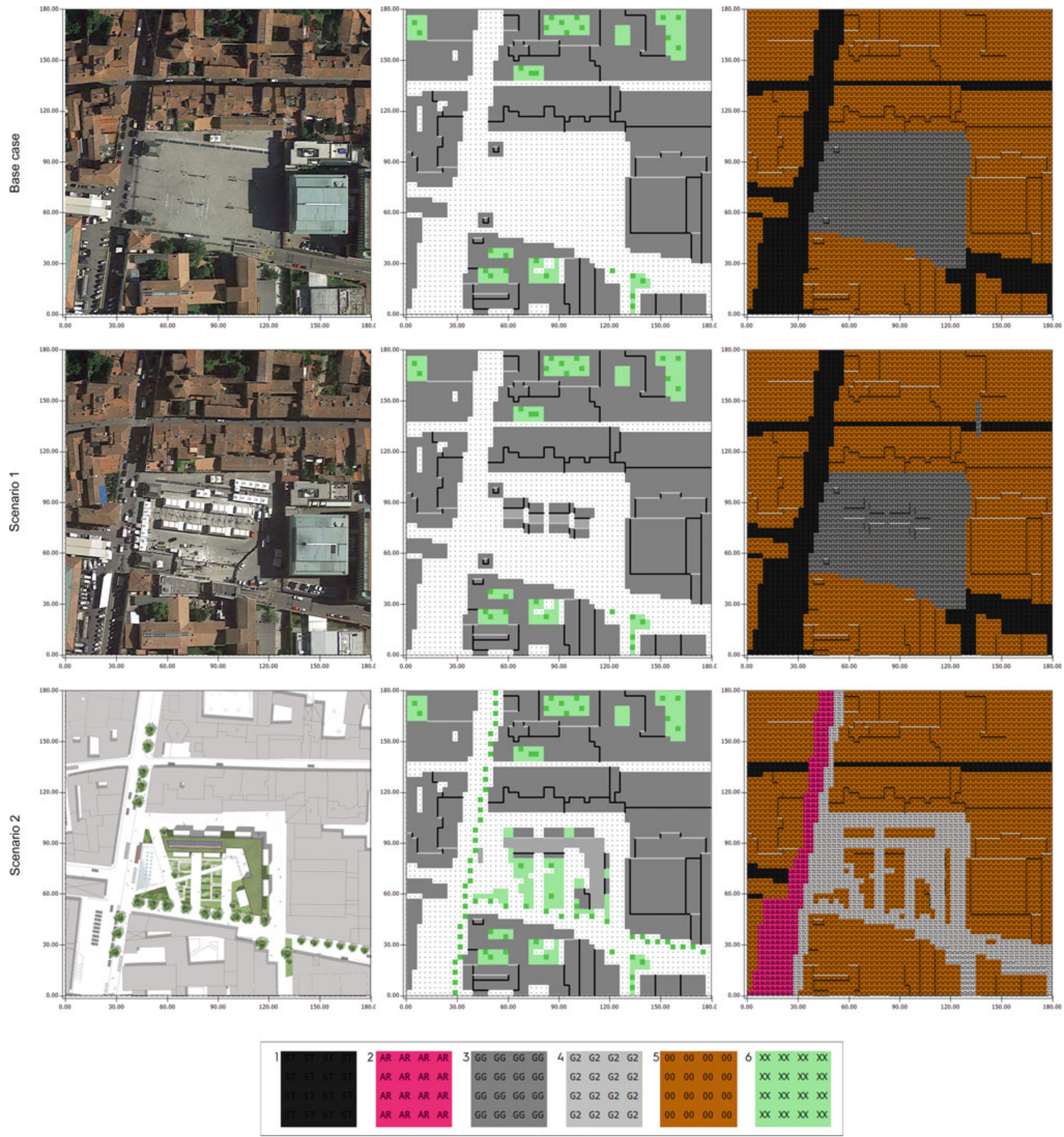
microclimatic conditions. Radiant and air temperature reduction is achieved only in the northern area of the square, in correspondence with the shading formed by the market roof, with a PMV of 4.45; however, it is below the comfort threshold. Also, the gallery area between the two rows of new market buildings shows a slight improvement compared to the reference case (atmospheric temperature of 36.33 °C), due to the shading generated by the volumes, but also in this case, the PMV is 4.40. In other words, the addition of new prefabricated buildings connected by a covered gallery does not guarantee to achieve good comfort performance inside the square, with overheating phenomena detected in summer days also inside the new flea

- *Scenario 2*. The covered area of the flea market designed by Master students in this scenario is realized in wood and covered with a mobile roof structure with adaptive shading devices. This design choice favors the temperature reduction of −3.33 °C with a temperature range from a maximum of 38.39 °C to a minimum of 35.37 °C (Fig. 7). The PMV index shows a minimum value of 4.45 and a maximum of 6.52, with a maximum reduction of −2.06 (Fig. 8) corresponding to the central area of the new flea market located in the northeast side of the square, where the existing dark pavement was replaced with reflective concrete, and a wood shading device was built. Furthermore, the new nine trees located on the south side of Largo Annigoni, close to the main pedestrian path, generated additional shading areas to benefit the square users.

5.2 Detailed Analysis of Hourly Temperature Profile

To better understand the comfort conditions and the temperature oscillation in different areas of the square, two different spot points were selected: near the wooden solar shading (Fig. 1) and on the south border of the Largo Annigoni close to the new entrance of the Architecture School (Fig. 1).

Regarding the UHI phenomenon, the analysis (Figs. 9 and 10) shows that Scenario 2 guarantees good results in both the analyzed spots. Furthermore, it is interesting to note the decreased atmospheric temperature in the southern



1 Asphalt, 2 Asphalt with red coating, 3 Dark granite pavement, 4 Reflective concrete light, 5 Loamy soil, 6 Grass

Fig. 5 Surface vegetation and soil analysis in the three simulation models: Base case, Scenario 1, Scenario 2

border area (P2) in comparison to the Base case and Scenario 1, despite limited changes (repaving and to planting new trees) proposed by design for this zone.

In other words, the ENVI-met simulations show that the design choice to integrate shading device, green and reflective surface, allowed reducing the atmospheric temperature in a historical urban contest, which improves the urban microclimate comfort also in the inadequately ventilated and not directly affected by the effect of shading systems.

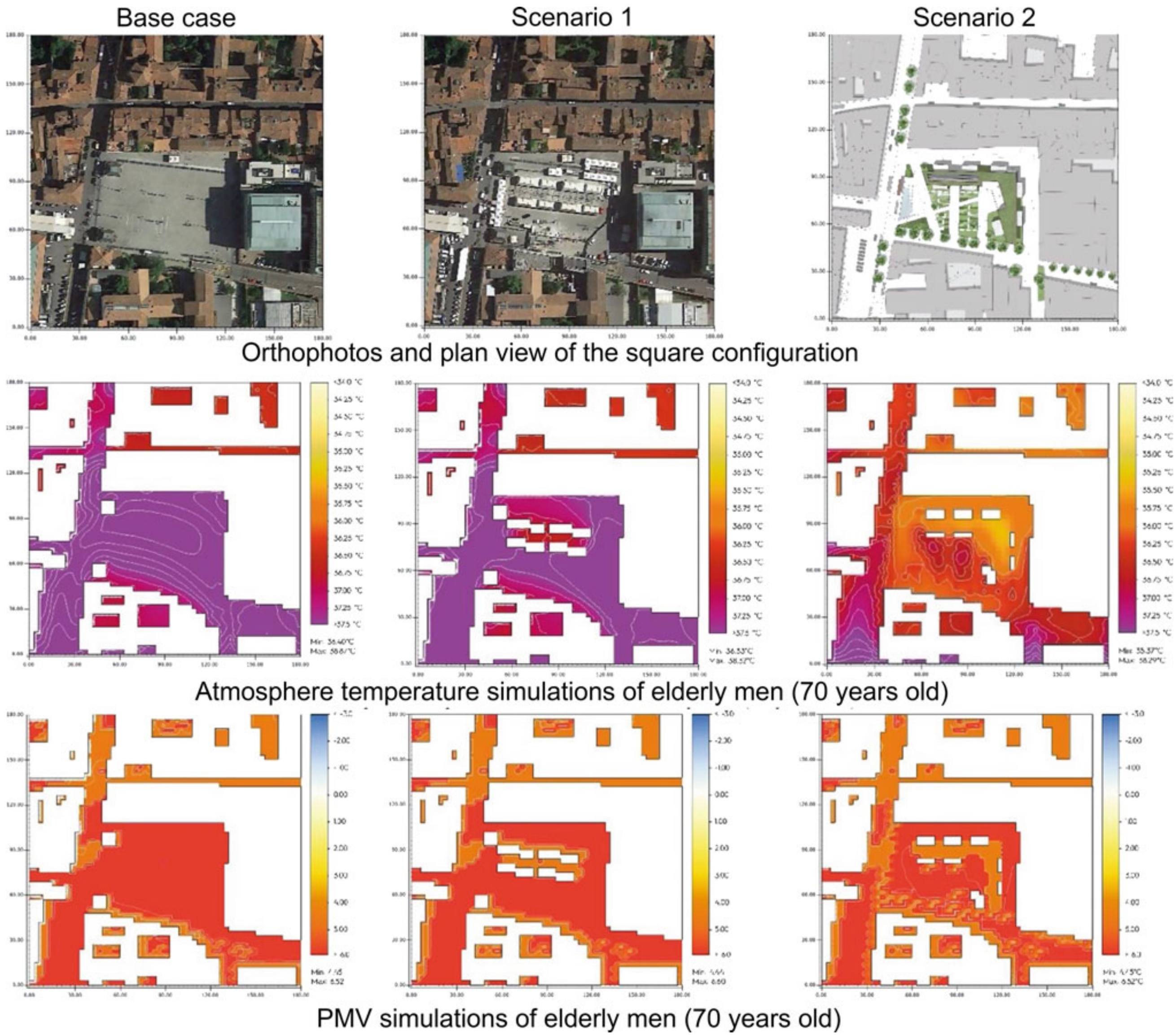
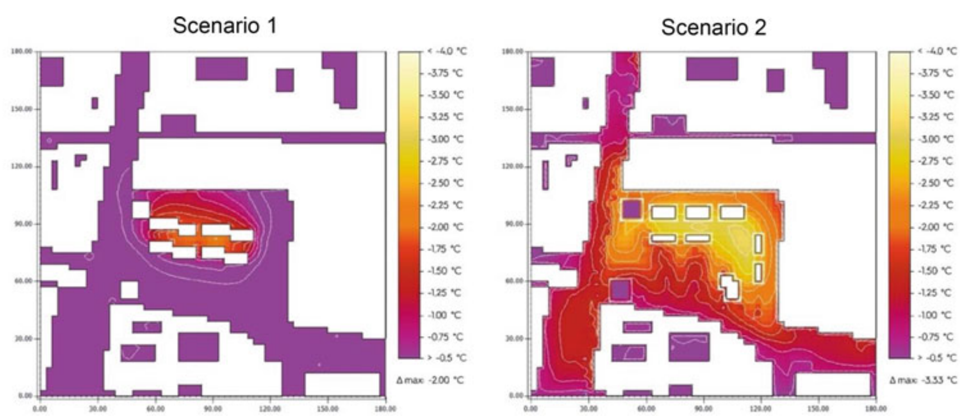


Fig. 6 Thermal and PMV maps of the three scenarios analysed

Fig. 7 ENVI-Met® comparisons of the decreasing of atmospheric temperature in the scenario 1 and 2, x–y view at z = 1.75 m, at 04:00 p.m., 1 August 2017



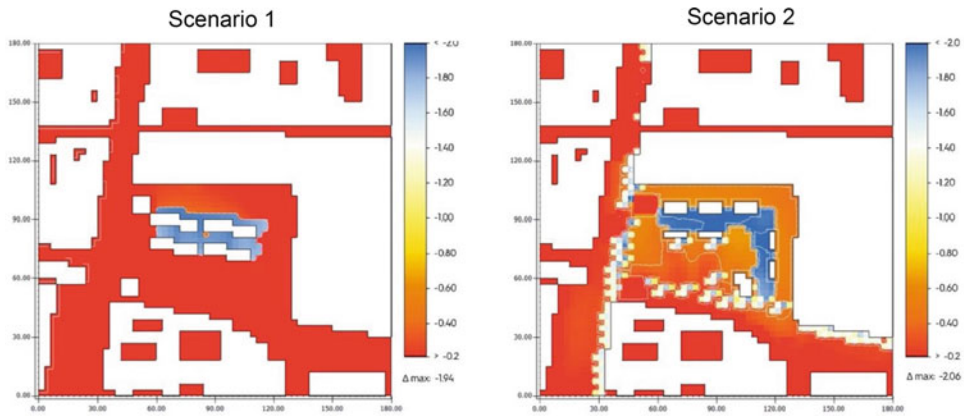


Fig. 8 ENVI-Met® comparisons of the decreasing of PMV in the scenario 1 and 2, x–y view at z = 1.75 m, at 04:00 p.m., 1 August 2017

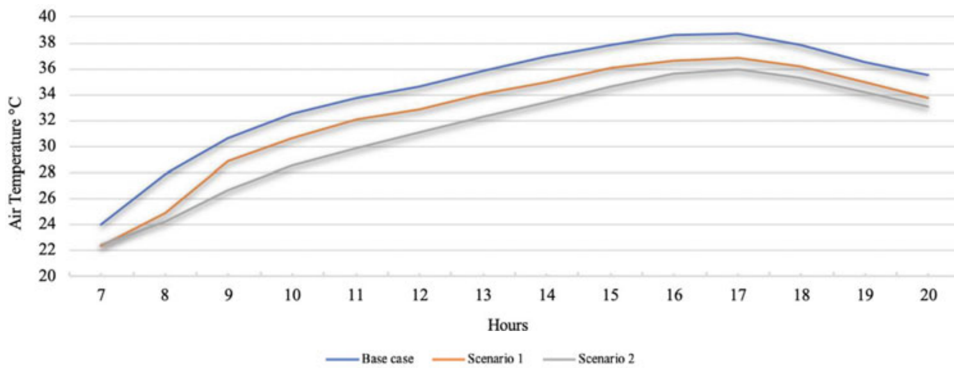


Fig. 9 Hourly temperature profile of the selected spot situated under the wooden solar shading, at z = 1.75 m, at 04:00 p.m., 1 August 2017

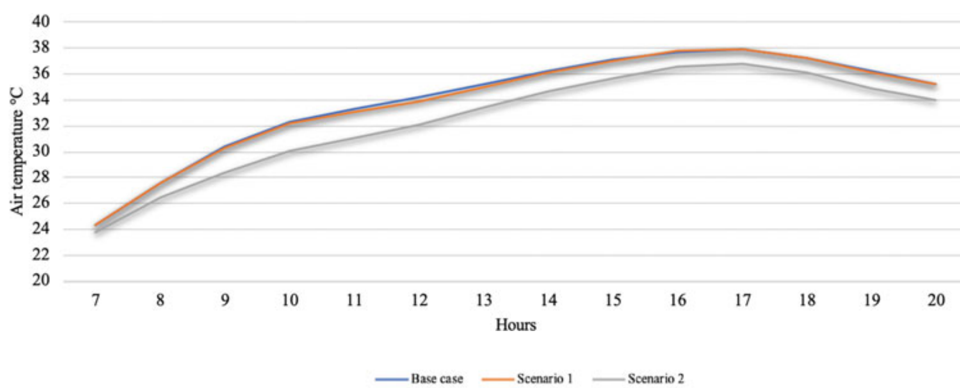


Fig. 10 Hourly temperature profile of the selected spot situated in the south border, at z = 1.75 m, at 04:00 p.m., August 1, 2017

6 Conclusions

Climate change adaptation in an urban area and city resilience requires collaborative problem-solving and useful integrated methods for the evaluation of different strategies at the urban micro-level concerning the climatic characteristics of the site and to the purposes of urban planning. The public space needs to be renovated to promote the city's image and contribute to advancing the social, physical, or economic life-quality of its citizens. Furthermore, urban environmental quality depends on microclimate conditions and the Urban Heat Island effect, which can affect communities by incrementing the urban discomfort, energy needs due to summertime peak, heat-related illness, mortality, etc.

Therefore, as confirmed by an EU report in 2015 (EU Expert Group, 2015), "UHI mitigation strategies have been implemented in various sustainable cities around the world. These strategies include urban greening through the use of simple technological solutions as green and blue infrastructures, replacement of standard materials with highly-reflective ones, simple shading devices; all strategies that can be implemented consistently and stand a good chance of reducing the ill effects attendant upon the occurrence of UHI in the built environment."

Accordingly, the presented study shows how the architectural value of public spaces can be considered an appropriate strategy for improving urban outdoor comfort also in the historical center of the cities located in southern Europe, where frequently typical retrofit solutions cannot be applied due to the preservation constraints. In addition, the simulation results confirm the thermal benefits in terms of outdoor thermal comfort for pedestrians generated by the application of the proposed materials with particular radiative properties (i.e., albedo and thermal emissivity) and thermal properties (i.e., heat capacity).

Furthermore, the workflow of the design process together with the use of simulation software to predict the effect of the application of such strategies on a case study to improve the microclimate behavior can become a useful method for designers and the Public Administrations to know exactly the achievable results of these strategies in order to choose the best solutions to redevelop an urban space and to improve its environmental comfort (Romano et al., 2019).

Finally, the quality of the results achieved from the students of the Master ABITA in the frame of this practical exercise demonstrates the validity of teaching methods chosen, which has contributed to increasing the cognitive maturity of the young architects linked to the technological and environmental options made at the urban scale. A choice that requires an increasing degree of specialization and cares at the scale of technological detail for the integrated project, but especially of responsibility toward professional assessments that can have irreversible effects on our future and on that of following generations.

Acknowledgements The research work shown in this paper was developed within the framework of the ABITA Master's Degree Course of the University of Florence in the Academic Year 2019–2020. The authors thank all the teachers and students involved in Module 1 of the MSC ABITA. A special thanks to the students: Federico Bocchini, Luca Della Rosa, and Marco Salvatore Santone, who designed the urban regeneration solution presented in this paper.

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