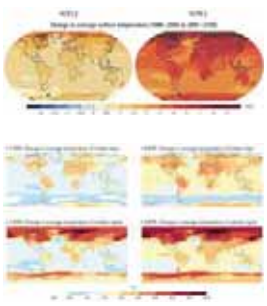
Innovative methods of design simulation for urban resilience in climate change

R. Bologna[1], M. V. Arnetoli[1], G. Guerri[1], G. Hasanaj[1]
[1]DIDA Architecture Department, Florence University, Florence, Italy

National Research Project of Relevant Interest
"Adaptive design and innovation technology for resilient regeneration of urban district depending on climate change"

Challenges

Climate change is one of the hugest challenges of our age, as proved by the **World Meteorological Organization** (WMO). The most significant emergencies related to climate change are mainly **rising temperatures** and increasing extreme rainfall events. WMO states 2015-2018 were the four warmest years on record as the long-term warming trend continues. So climate change represents an urgent and potentially irreversible threat to human societies and the planet.
In view of this, the majority of countries around the world adopted the **Paris Agreement** in December 2015, with the aim of limiting the increase in global temperature to **1. 5°C**. Moreover through the United Nations Framework Convention on Climate Change, the **Intergovernamental Panel of Climate Change** (IPCC) has been invited to present a special report on the **impacts of global warming of 1. 5°C above pre-industrial levels** and the associated global greenhouse gas emission pathways. IPCC proves global warming of 1. 5°C implies **higher average temperatures** than pre-industrial times in almost all places, both on land and in the oceans. IPCC shows change in average surface temperature comparing two **Representative Concentration Pathways** (RCP). Relative to 1850-1900, global surface temperature change for the end of the 21st century (2081-2100) is projected to likely exceed **2°C** if high emissions will continue to rise (**RCP 8.5 business as usual scenario**), while it's unlikely to exceed 2°C if there will be high emissions reduction (**RCP 2.6 mitigation scenario**).
This theme has been considered so urgent that "**Climate action**" was included as one of the SDGs **Sustainable Development Goals** in the **2030 Agenda of the United Nations**. Facing the impacts of climate change is today fundamental by **adapting our cities** and developing **urban resilient strategies** for sustainable communities.
The **Mediterranean area** is one of the most affected regions by warming and urban heat island, as demonstrate by the **European Environmental Agency**. Several world institutions have stated climate change will **amplify existing risks** and create new risks for natural and human systems, especially for **disadvantaged people and communities** in countries at all levels of development. So climate change is expected to be a **multiplier of poverty**, which means that its effects should make the poor poorer and the total number of people living in poverty more numerous. The warming trends raise alarm bells for **public health** as extreme temperature events are observed to be increasing in their intensity, frequency and duration.
Implementing methods and tools for the **Adaptive design** of urban environment is the objective of the Research Project of Relevant National Interest *"Adaptive design and innovative technology for resilient regeneration of urban district depending on climate change"* developed from the Universities of Reggio Calabria, Naples, Rome, Milan and Florence.
The work exposed is focused on the application of **innovative technological solutions** able to reduce the **effects of the UHI** improving the resilience and the architectural quality of the **open public space** experimented in **peripheral districts** of the Metropolitan area of Florence.



Sources: IPCC, Special Report 2018; IPCC, Climate Change 2014.

UHI Urban heat island
The impact of climate change is more evident on **cities** that is the most vulnerable to the **Urban Heat Island** (UHI). This phenomenon occurs when an area experiences much warmer temperature than nearby rural areas, this difference is usually larger at night than during the day; the UHI is linked to **human activities and urban morphology**, due to the ability of surfaces to absorb and retain heat in any environment.

Case study

Overview of the studied area and the urban district of Scandicci

Ortophoto of Piazza Togliatti

The research has identified as a **study area** a vast peripheral portion of the **Metropolitan City of Florence**, located in the west of the capital. In this area the urban agglomeration of **Scandicci** was identified as the **intervention district** for its high level of **vulnerability** to extreme climatic events. At the architectural scale the research has investigated the scope of the **public spaces** and **Piazza togliatti** was identified as the survey area; currently the square is a vast degraded urban space where are located a playground and a market area used also as a parking, is characterized by a **negative degree of climatic resilience** and many critical issues related to sociality, liveability and accessibility as an aggregative space.

Photos of Piazza Togliatti: playground (left), market area (right)

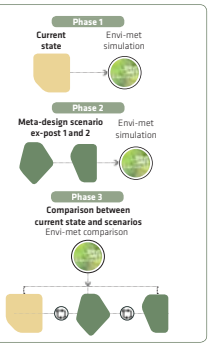
Method and tool

The exposed research has used the **Envi-met software** in the case study of Piazza Togliatti as a support tool to develop a **design methodology** that has as objective the construction, evaluation and comparison of multiple **meta-design scenarios of urban regeneration** declined in the fraim of **adapting cities to climate change**, in particular against the **UHI**.
Envi-met is a **three-dimensional software** of holistic imprint that allows to simulate and reproduce the **micro-climate behavior of urban areas**, evaluating the interactions between the morphological, material and physical characteristics of surfaces, vegetation, air and energy flows, of a portion of an urban area stressed by the specific climatic conditions of the geographical context of reference.
In this context the Envi-met software has been used to **simulate climatic conditions** related to the extreme phenomenon of the UHI analysing the performance related to the **climatic and social resilience** of the **public open spaces** of Piazza Togliatti located in the urban district of Scandicci, identified as the case study by urban scale analyses.
In the design methodology developed by the research, the Envi-met software has been a **fundamental support** for analyzing the current state of Piazza togliatti and, starting from the findings, to **orient design strategies towards results of effectiveness**.

The software has been used in **three phases of the design process**:
- **Phase 1 ex-ante status analysis**: simulations of the studied area of Piazza togliatti in its current shape have been carried out, allowing the identification of major **criticalities**, due to the presence of hot materials, the scarcity and fragmentation of vegetation, the absence of shading elements and water elements;

- **Phase 2 analysis of meta-design scenarios**: simulations of the two intervention scenarios have been carried out, in which the square has been redesigned applying **adaptive design technology solutions** related to the insertion of cool materials, increased vegetation, prediction of shading systems and insertion of water elements, in a **holistic perspective of intervention** that plans to increase the degree of climate resilience but also to improve the square as a place of social aggregation;

- **Phase 3 comparison of the benefits obtained**: the software was used to make comparisons between the behavior of the square in the current state and that in the two intervention scenarios, enabling the **environmental benefits** obtained in the two scenarios to be highlighted and which of the two is most advantageous against both the increase in the degree of climatic resilience and the urban regeneration of the public open spaces of Piazza Togliatti as an aggreative and social space for the urban agglomeration.



Simulation details

Input data

The **Envi-met** software used in the research has a complex **structure** that can be articulated in input and output phases.

The input data are:

1. Size of the study area: the characterization of the simulation area of Piazza Togliatti is defined into **Spaces** interface through a grid of 300x300 m, composed from square cells of 3x3 m.

2. Urban surface modeling: the geometries of the urban components of the area are defined into **Spaces** interface with the following information:
- **Buildings**: 10 buildings were included in the model with a height between 6 and 24 m, 15 m being the mean value;
- **Trees**: in this case study are inserted simple plant and also 3D plant with the following specific species: *Pinus Pinea, Acer Negundo, Cypress, Populus Alba, Tilia, Populus Nigra, Privet*;
- **Permeable surfaces**: green areas 25 cm average, loamy soil;
- **Impervious surfaces**: asphalt, concrete pavement, brick, beaten earth.

3. Climate data: into **Envi-guide** interface the insertion of the initial parameters of calculation and the boundary conditions of the simulation is required.
The climatic data were provided by a collaboration with the IBIMET - National Council of the Research of Florence. The input data examined refer to the the hottest day recorded on 11th August 2011 representative of the **extra-ordinary condition of the UHI** with the following parameters:
- **Temperature**: T_{min} 20. 7°C at 6 am, T_{max} 41°C at 4 pm;
- **Humidity**: H_{min} 14% at 1 pm, H_{max} 66% at 6 am;
- **Wind speed and direction**: 0. 2 m/s, direction South.

Output data

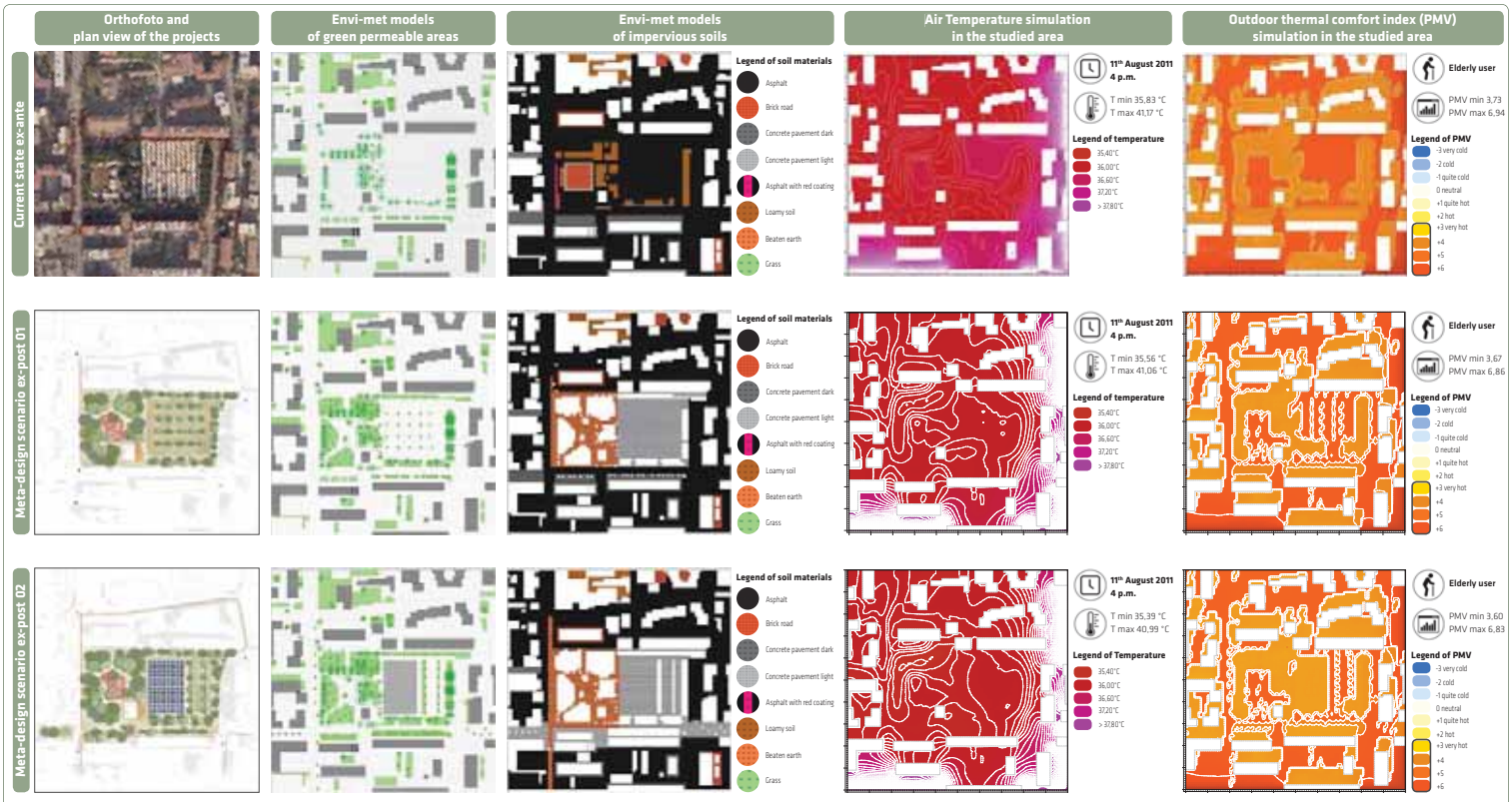
This type of data is obtained after the simulation phase where **fluiddynamic equations** are calculated. This process can take several days and depends on the size and complexity of the model.

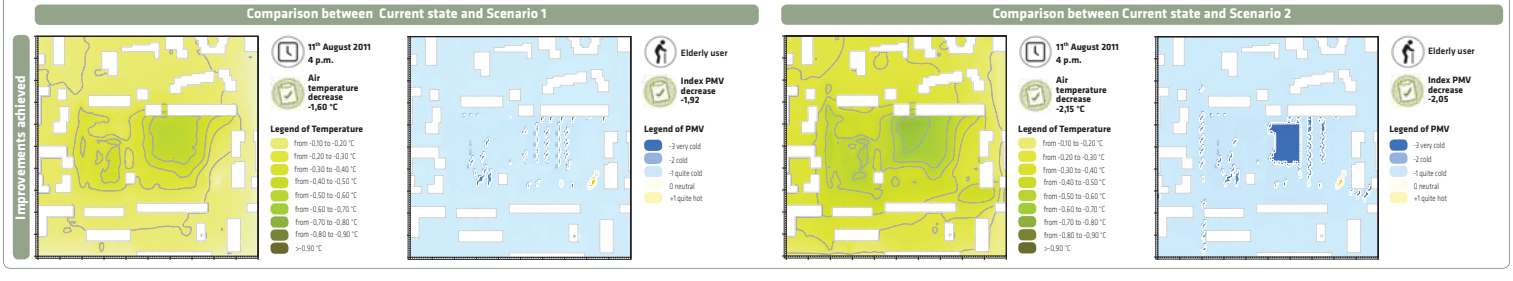
- **Outdoor thermal comfort**
The **Biomet** section allows to describe through some physical parameters (sex, age, height, weight) the type of **users** according to which calculate the indices of outdoor comfort.
This research has selected the point of view of the **elderly** because they are recognized as the **most vulnerable citizens** to the extreme heat events and also because of the high density of population over 75 that live in Scandicci.

- **Reading of output data**
Into **Leonardo** interface Envi-met allows to obtain **2D and 3D maps** with the spatial trend of multiple values concerning the distribution of physical variables and perception of the thermal comfort of the simulated area.
The output data generated by the software used in this research work are:
- **Air temperature** (°C)
- **Wind speed** (m/s)
- **Predicted Mean Vote PMV**
The Predicted Mean Vote (PMV) is an index of outdoor thermal comfort that takes into account the physical variables related to the environment (listed above) and the characteristics of the individual (metabolism, activity, clothing).

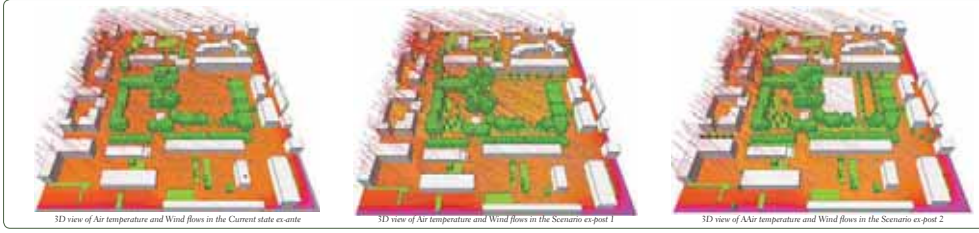
In the following **Results** section the output obtained by the application of the Envi-met software are showed, regarding the Adaptive design method developed by the research.

Results





Conclusions



3D view of Air temperature and Wind flows in the Current state ex-ante

3D view of Air temperature and Wind flows in the Scenario ex-post 1

3D view of AAir temperature and Wind flows in the Scenario ex-post 2

The **design method** developed by the research is aimed at the **resilience regeneration of public spaces in vulnerable urban districts**. It was applied in the case study of Piazza Togliatti in Scandicci to verify its validity. This application represents an innovative experimentation that demonstrates how it is possible to obtain important benefits in terms of **adaptation to the climatic criticality of the UHI** through the application in the open spaces of the city of **adaptive technological solutions**.
The use of **Envi-met software** during the analytic and design phases has proved essential to perform **predictive simulations** capable of directing design actions towards **high levels of effectiveness**.

The simulations that this tool allows to obtain bring a double advantage to the designer:
- make it possible to understand how an urban area behaves in its **current state** in relation to the trend of temperatures, through the characterization of surfaces, buildingns and vegetation, highlighting the major criticalities;
- allow design choices to be directed on the basis of numerical evidence data (**Evidence based design**) describing the urban resilience aspects of the **design scenario proposed**, which can thus be modified and improved during the preliminary design phase.

This tool is therefore a valuable help especially in the field of **public space action**, helping to ensure the effectiveness in the use of scarce public economic resources available to the **Public Administration**.
Research is now continuing through the application of the methodology presented on **urban sectors** that define multiple systems of public spaces, using the Software to simulate the benefits of the design strategies identified through an operational collaboration with the Municipality of Scandicci.