Producing Project

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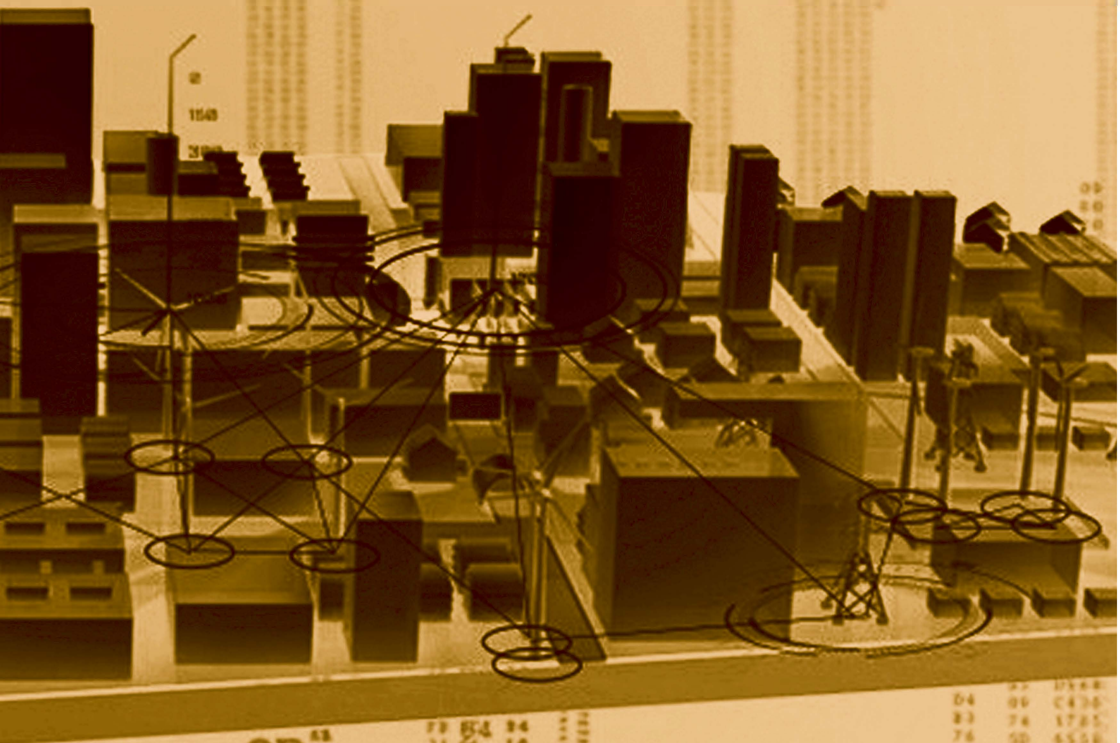
MASSIMO LAURIA
ELENA MUSSINELLI
FABRIZIO TUCCI



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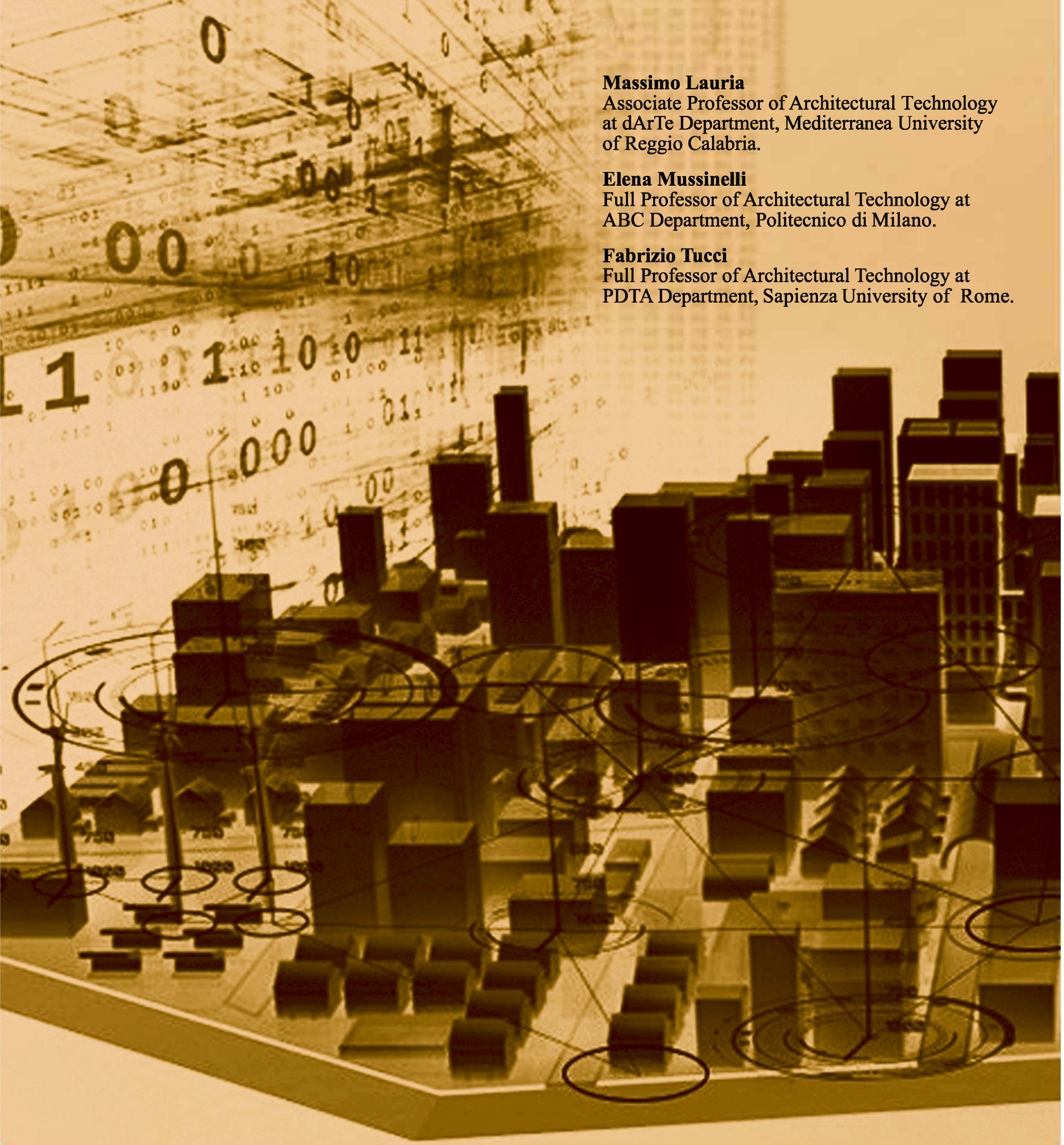

Massimo Lauria
Associate Professor of Architectural Technology at dArTe Department, Mediterranea University of Reggio Calabria.

Elena Mussinelli
Full Professor of Architectural Technology at ABC Department, Politecnico di Milano.

Fabrizio Tucci
Full Professor of Architectural Technology at PDTA Department, Sapienza University of Rome.

The transformations created about the design activity by the several challenges started by the economic crisis, climate change and environmental emergencies, together with the impact of the Web and ICT on social and productive systems, highlight many critical issues, but also significant prospects for updating concerning places, forms, contents and operating methods of “making architecture”, at all levels and scales.
In this context, the cultural tradition and disciplinary identity of Architectural Technology provide visions and effective operating practices characterized by new ways of managing and controlling the process with the definition of roles, skills and contents related to the production chains of the circular economy/green and to real and virtual performance simulations.
The volume collects the results of the remarks and research and experimentation work of members of SIT*d*A - Italian Society of Architectural Technology, outlining scenarios of change useful for orienting the future of research concerning the raising of the quality of the project and of the construction.

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edited by
Massimo Lauria
Elena Mussinelli
Fabrizio Tucci

editing, collection and supervision of texts by
Maria Azzalin

proofreading by
Filedelfja Musteqja
Francesca Pandolfi

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www.maggiolieditore.it
e-mail: clienti.editore@maggioli.it

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2.9 NATURAL VENTILATION AND CFD IN THE SPACE OF THE HISTORIC CITY: THE QUALITY OF URBAN DESIGN

*Gaia Turchetti**

Abstract

Attention to the design process must necessarily include the living space at different scales, not only the individual building, but the entire urban space. In this process, which goes from the design phase to the construction, use and disposal phases, the climatic theme must also be included, in order to achieve a condition of balance between situations of comfort and discomfort. Starting from the porosity of the architectural organism, the focus has therefore been on natural ventilation as one of the factors that affect the urban climate, opening a parenthesis on the potential and limitations in the use of CFD, for the diagnosis and prognosis of the urban project in a specific field of investigation: the historic city.

Keywords: Natural ventilation, CFD Computational Fluid Dynamic, Urban microclimate, Historic city

The quality of the urban organism

As Ciribini writes (Bosia, 2013), in a gestaltic vision of everything, "every phase of the building process is a project", the quality of which is to be found in every level and at every scale of the living space, from the single building to the "urban space", the place of urban sociality. A "cyclical" process, therefore, in which it is necessary to include also the climatic problem that, at an urban level, is more relevant to the central fabrics of cities, today the most vulnerable ones as a result of continuous processes of urbanisation.

Starting, therefore, from the porosity of the architectural organism, we wanted to focus the attention on the potentiality and limits of natural ventilation as the engine of the process of "microclimatic mending" at the base of every transformation, analysing with a critical eye possible design effects in relation to a specific field of investigation: the historic city.

Obviously, the choice of this field of investigation has involved not only a critical rereading of already consolidated knowledge on the theme of ventilation in urban areas - which is mainly different from other disciplinary areas - but has also revealed the dual need to calibrate existing instruments and, in

* Gaia Turchetti is a PhD at the Sapienza University of Rome, Italy, gturchetti.arch@yahoo.it.

some cases, to define new ones that, unlike the former, are better suited to describe the considered urban reality, wondering how much the specificity and methods of use of these instruments affect the correspondence to the real data, what is their reliability degree and how they relate to the project timelines.

It is clear that for an exhaustive picture the difficulty is in taking into consideration several competing factors both at a climatic and morphological level - not only in relation to the air masses - which are closely connected and often difficult to calculate, and translate them into useful data at a practical level, i.e. aimed at improving the encountered crisis situations.

Historic city: fluid-dynamic computation in complex space

Investigating the physical phenomena related to urban ventilation is an extremely complex operation. Today, however, the use of microscopic CFD (Computational Fluid Dynamic) models allows us to discretise the real data on increasingly smaller and more precise geometric meshes, based on the subdivision of space into control volumes (cells) and on the application of fluid motion equations for each cell. The term "micro" precisely depends on the construction of these basic elements, the size of which is such as to consider, within each cell, the constant value of the examined quantity (De Santoli, 2011). Their structuring into more or less complex meshes (structured, unstructured or hybrid/adaptive) allows us to shape the model according to different spatial definitions.

Nevertheless, these tools, although they undoubtedly help to speed up and economise the calculation processes of the microclimatic aspects related to ventilation - offering us, if integrated in complex models, a holistic reading of the environmental problem -, on the other hand present some pitfalls.

The accuracy of the model, in fact, must be calibrated according to the results that are to be obtained taking into account that there is a directly proportional relationship between the size of the cell and the complexity of the calculation of the model, poised between the risk of simplifying or complicating too much the calculation, where you want to define grids as dense as more accurately responding to the real data. The operation is, therefore, delicate and involves, first of all, the identification of the answers that are sought through this process, keeping in mind the simulation objectives in the data setting, and aware that if the question is not well formulated, the answer will not provide useful terms to elaborate reasoning (Calcerano, 2014).

The whole procedure is a "process in a process" that, in order to reach the desired quality, must be guided by a critical evaluation of the results that the tool - as such - offers, results that must necessarily be compared and validated in the various steps and scales of the project.

The experience of the operator in evaluating the spatial definition of the model, the choice of an appropriate accuracy level, and not least the collection and use of input data to be entered, is therefore fundamental.

However, by analysing in detail all sides of the city, we could easily ask ourselves how and to what extent these limitations derived from instrumental and functional needs affect the correspondence of the model to the real data and what is the maximum degree of simplification that can be achieved without compromising the reliability of the answer, a question that acquires a greater emphasis if we approach the analysis of historical fabrics, which draw their strength from the complexity of their development. Starting, therefore, from a review of the main scientific results on the use of CFD models in the urban environment, the research briefly presented here, wanted to critically reread them in relation to the needs of investigation of particular urban areas, those of the historic city, assessing their potential and limitations, aware that a CFD analysis cannot be detached from a morphometric investigation or even less from a direct data examination, by virtue of a necessary knowledge of the fabric and the trend of flows, fundamental to implement those simplifications necessary to the computational process. The first step was to select the most appropriate calculation model for the survey needs, capable of providing information not only on the individual building but on a larger urban scale. The choice fell on the Envi-Met[1] software which, according to a survey conducted by Y. Toparlar, B. Bloken, B.Maiheu, G.J.F. van Heijst (2017), is one of the most used software in the investigation of the urban microclimate, because - although in the evaluation of some factors, such as ventilation, the accuracy of the model (unlike dedicated CFD software) is in the order of one metre - allows an organic reading of all the competing factors, necessary to intervene in a space, the urban one, where it is precisely the confluence of flows of different nature (anemometric but also radiative, anthropogenic, etc.) to define the comfort. On the side of scientific research on the specific theme, it is also revealed in parallel that there are few, albeit interesting, international studies that pose these questions, and that investigate the different responses that the computational model provides in relation to different types of building density. A study conducted on the city of Bilbao by Juan A. Acero and Karmele Herranz-Pascual (2015), using the Envi-Met program as the software of reference, has shown that there are differences between simulated data and data measured in situ, recording values of wind speed underestimated in the fabrics of the city's historic centre and overestimated in the expansion areas of the nineteenth and twentieth centuries[2].

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1 Created in 1993 by Prof. Michael Bruse, Envimet is an environmental and microclimatic simulation software that is based on a three-dimensional model and is able to reproduce the microclimatic and physical behaviour of urban areas.

2 «In this study, modelling techniques have been compared with micrometeorological measurements in Bilbao carried out during three days covering typical summertime weather conditions (overcast, partly covered and clear sky days)» (Acero, Herranz-Pascual, 2015).

The comparison carried out on the city of Bilbao has shown that in the calculation of the wind speed and the average radiant temperature there may be significant differences that will affect the reliability of the simulated model and the definition of the various parameters and indices. Specifically, the researchers indicate three main problems, the first related to the difficulty of forcing the simulation with data such as wind speed and radiation, which take into account the daily variations of the phenomenon, the second concerns the inaccuracies in the calculation of radiant flows, relevant for the estimates of the average radiant temperature, the third refers to the spatial resolution of the model which may in some cases be a limitation for a detailed definition of the morphological aspect of urban elements and therefore their influence in climatic variables. The study then assessed what the recorded difference between real and simulated measurements could be in the specific case of the city of Bilbao, warning the future user of the recorded deviations. The findings of the three previous points are also confirmed in the studies of B. Blocken (Blocken et al. 2012), in which it is revealed the need to evaluate ventilation on the basis of different directions and not only with the use of a single parameter. Similar studies were also conducted with comparable results on different urban realities, including the area of Nanaimo[3] in Canada and Changtown in South Korea (Park, Tuller, Jo 2014), as also reported in Salata, Golasi, de Lieto Vollaro, de Lieto Vollaro (2016).

Starting, therefore, from the above mentioned researches, where we can see a difficulty in calculating the software related both to the spatial conformation of the model and to a definition of flow direction and intensity, we have chosen to analyse these specific problems in relation to complex fabrics of the Italian city, taking as a case study the historic city of Rome.

The first and fundamental phase of this survey involved the comparison between the results of the first simulations[4] and the data recorded in situ thanks to a series of measurement campaigns carried out in selected areas of the capital during the spring-summer periods of 2016[5].

From the numerous simulation tests carried out on five[6] of the selected areas it was revealed - in line with the other investigations mentioned - an underestimation of the intensity parameter of the flow, which varies between 0.1 and 1.3 m/s, with an average value of 0.8 m/s.

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3 Taking into consideration the study carried out on the Canadian settlement of Nanaimo, an average value of -0.52 m/s was estimated as the difference between the actual data and the data simulated by the Envimet software.

4 Also, for the research presented here was used the software Envimet version Pro V4.2.

5 The measurement campaigns were carried out under the supervision of the CNR-IDASC "Orso Mario Corbino" Institute of Acoustics and Sensors, where a period of functional research training was carried out.

6 The selected areas are: the site of Piazza Borghese, Rione Campo Marzio; the site of Piazza dell'Immacolata, Quartiere San Lorenzo; the sites of Via Boncompagni and Via Piave, Rione Ludovisi; the site of Piazza delle Cinque Scole, Rione Angelico/Regola.

Analysing where and with what possible logic the peaks of lower and higher intensity in the model are recorded and comparing these values with the real ones, it can be noticed that it is not only the dimensional ratio of the building that is affected, but also, and in some cases - primarily - the direction of the flow set in the model and the fabric orientation with respect to the point of entry of the flow itself, which is more evident - although not constantly and with many irregularities - for fabrics with a more regular mesh (referred to as type B fabrics, i.e. areas of urban renewal/expansion of the nineteenth and twentieth centuries more or less compact). In type A fabrics, on the other hand, (i.e. areas of medieval origin or of Renaissance expansion and modern pre-unification) it is more difficult to define a general criterion justifying this discrepancy in the intensity value. This depends mainly on a combination of factors - not least the thermal factor[7] - which vary from fabric to fabric, and the potential of the software to simulate a flow in a given urban fabric and with relatively low intensities. However, it appears as a general data an underestimation of the intensity value in both type A and type B fabrics, given that this does not conflict with what was reported in the study on the city of Bilbao, mentioned earlier, because, if we stop to analyse the nineteenth and twentieth centuries expansion fabric of the Spanish city, in relation to the points selected by scholars, we realise that it corresponds more to an image of urban suburbs and not to the image of the consolidated districts of “our” historic city. Therefore, the underestimation of the intensity data for the historic city is confirmed, while in order to confirm or not its overestimation we should extend the measurements to peripheral areas of the Capital, where the dimensional relationships and especially the continuity of the built fronts present other characteristics compared to the fabrics analysed so far. Including the limits and potential of this computational tool, and testing it in relation to the specific urban fabric of the Capital, we have come to the definition of a calibration factor that - by implementing the above mentioned studies and working on the entire process of the model construction - allows to reduce as much as possible the discrepancy between real data and simulated data recorded for historic fabrics, obtaining in many cases an average improvement of the response in terms of 20-30%. Although we are aware that the calibration factor in its current state of definition needs further refinement, which is possible with a subsequent work on the algorithms underlying the calculation processes, we are nevertheless certain of the importance of its definition. A difference in the estimation of the ventilation factor - and not only -, which can reach, as estimated, very high values, can compromise a correct reading and understanding of the possible benefits of the anemometric factor both in the condition prior to the project and in the definition of intervention

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7 It should be noted that, considering how the movement of flows is influenced by the thermal balance of the urban reservoir, some parameters relating to the prevailing materials have been calibrated, to render them more in line with the real data, without this, however, resulting in a sufficient variation of the parameter sought.

scenarios (always due to the fact that even a wind in a gust or breeze regime can determine interesting microclimatic improvements of the analysed reservoir) as well as altering the comfort indices calculation (Santamouris, 2007).

Conclusions

This brief discussion is not intended to and cannot provide but a brief overview of part of the conducted research, with the aim of activating, even in the Italian landscape, an interesting debate on the use of computational simulators in the complex field of urban fabric. The aim is to underline how an indirect analysis such as the CFD cannot be released from a direct evaluation of the site and the real data. Just the necessary knowledge of the fabric and of the changes in the trend of the flows deriving from its variations, is a fundamental step of that process of simplification, necessary to optimise the computational analysis, which is and remains a useful tool for the comparison between several scenarios of intervention, in a systematised process of the "in progress" project production knowledge.

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References

Acero, J.A., Herranz-Pascual, K. (2015), "A comparison of thermal comfort conditions in four urban spaces by means of measurements and modelling techniques", *Build.and Envir.* vol. 93, pp. 245-257.
Blocken, B., Janssen, W.D. et alii (2012), "CFD simulation for pedestrian wind comfort and wind safety in urban areas: General decision framework and case study for the Einhoven University Campus", *Envir. Mod. and Software*, vol. 30, pp. 15-34.
Bosia, D. (2013), *L'opera di Giuseppe Ciribi*ni, Franco Angeli, Milano.
Calcerano, F. (2014), *Technological design for bioclimatic architecture. Strategies and natural ventilation systems for passive cooling in environmental and energy retrofit in the Mediterranean climate*, PhD Tesis PDTA. Sapienza Università di Roma.
De Santoli, L. (2011), *La ventilazione naturale: il moto naturale dell'aria per il controllo delle condizioni ambientali*, Flaccovio, Palermo.
Park, S., Tuller, S.E. et alii (2014), "Application of Universal Thermal Climate Index (UTCI) for microclimatic analysis in urban thermal environments", *Lands.and Urban Plan*., vol. 125, pp. 146-155.

Salata, F., Golasi, I. et alii (2016), “Urban microclimate and outdoor thermal comfort. A proper procedure to fit ENVI-met simulation outputs to exerimental data”, *Sust.Cities and Society*, vol. 26, pp. 318-343.
Santamouris, M. (2007), “Heat Island Research in Europe: The State of the Art”. *Advances in Building Energy Res.*, vol. 1 (1), pp. 123-150.
Toparlar, Y., Bloken, B. et alii (2017), “A review on the CFD analysis of urban microclimate”, *Renew.and Sust. Energy Rev.*, vol. 80, pp. 1613-1640.
Tucci, F. (2012), *Atlante dei Sistemi Tecnologici per l’Architettura Bioclimatica. Ventilazione naturale negli edifici / Atlas of Technological Systems for Bioclimatic Architecture. Natural Building Ventilation*, Alinea Editrice, Firenze.