# NEW COGNITIVE MODELS IN THE PRE-DESIGN PHASE OF COMPLEX ENVELOPE SYSTEMS

# Producing Project

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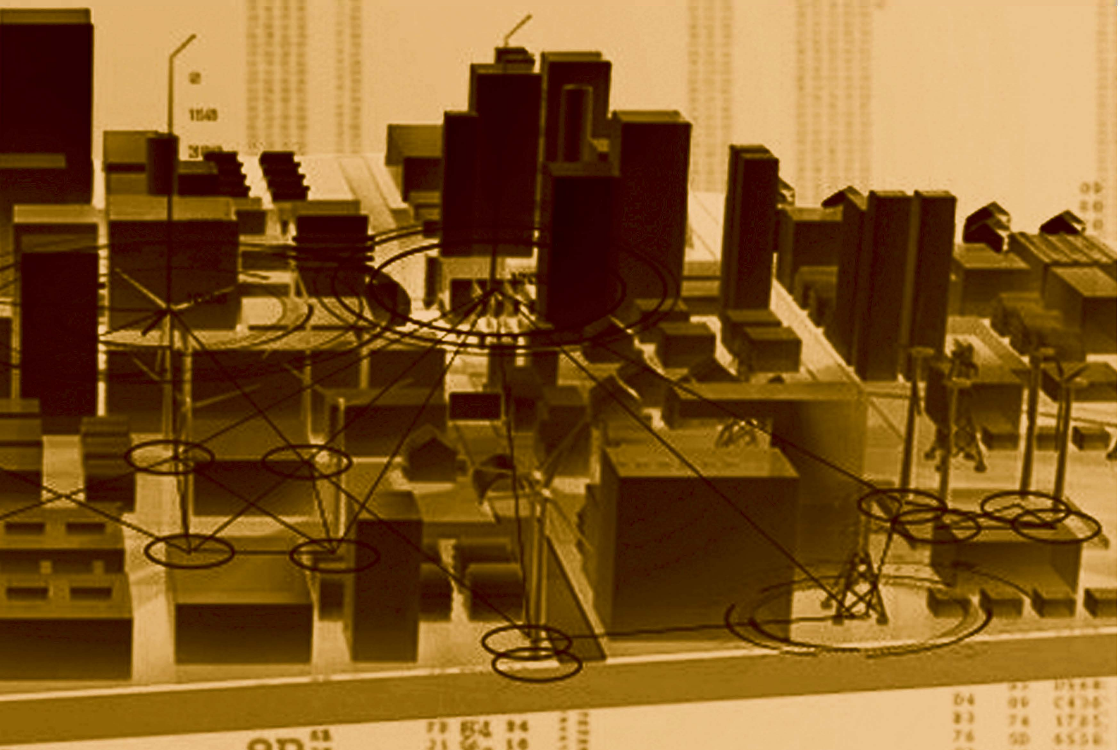
MASSIMO LAURIA
ELENA MUSSINELLI
FABRIZIO TUCCI



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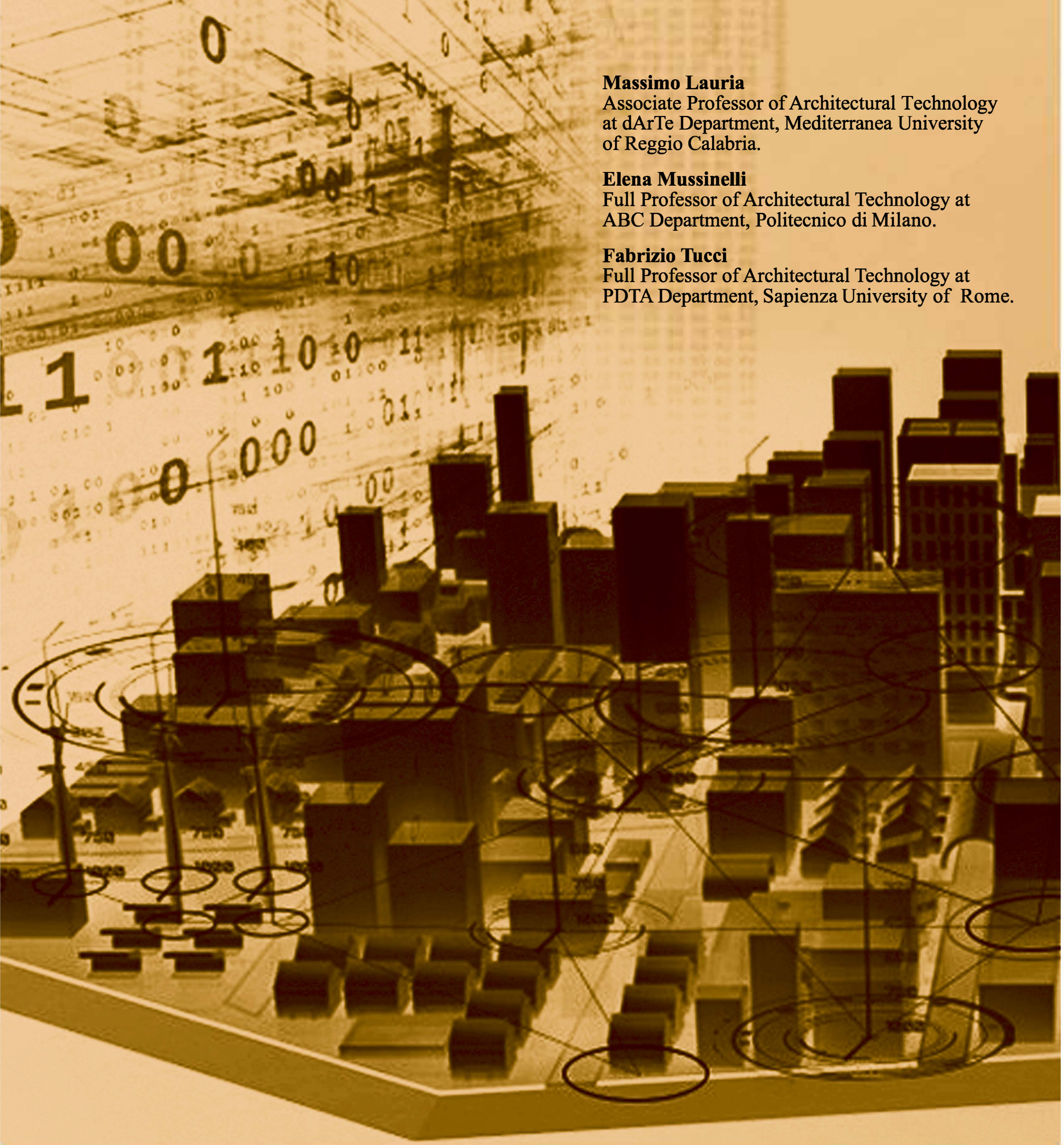
**Massimo Lauria**
Associate Professor of Architectural Technology at dArTe Department, Mediterranea University of Reggio Calabria.

**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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e-mail: clienti.editore@maggioli.it

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# 3.15 New cognitive models in the pre-design phase of complex envelope systems

*Paola Gallo*, Rosa Romano**

***Abstract***
*The paper is focused on the description of innovative research that are aimed to define new cognitive, experiential and design-based models connected with new forms of collective intelligence and capable of responding to the main challenges of the future. In particular, it will analyse the issue of the envelope systems production, in order to define innovative models capable of responding to continuously changing scenarios in the frame of environmental sustainability and energy efficiency of the built environment, through the ability to use simulation tools capable of predicting, anticipating and optimising the results of the design phase.*

*Keywords: Energy simulations, Design thinking, Sensitive Analysis, Envelope systems, Environmental sustainability*

## Introduction

The identity features linked to the innovation of forms of knowledge and the cognitive theoretical foundations of design require new vision capacities that is an effort to build the future.

It will be necessary to work not only to find answers to concrete problems, but above all, to define and expand the problem itself. A vision for everything now deserves commitment: one that tells of a future in which the environmental issue, in its broadest sense, is central.

In the next years we will be called on to create a deep crisis in a research tradition entirely located within a culture based on concepts of growth and development and to guide technology towards generating effective solutions that are capable of resolving problems. These innovative building technologies should be energy efficient, and environmentally compatible as early as the preliminary phase of the project (Campioli, 2016).

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* Paola Gallo is an Associate Professor at the Department of Architecture, Florence University, Italy, paola.gallo@unifi.it.

* Rosa Romano is a Research Fellow at the Department of Architecture, Florence University, Italy, rosa.romano@unifi.it.

In this scenario, the future research challenges and themes in the technology area must necessarily refer to the pillars identified from Horizon 2020, linked to the topics proposed by the European Construction Technology Platform and the International Council for Building (CIB). The challenges must be related to neuralgic and transdisciplinary aspects (concerning quality, creativity, sustainability, competitiveness) and connected to the priority issues of operational research in the architectural technology area (such as housing, innovation, the environment, development).

With respect to the critical nature of the current situation, challenges that focus on the proliferation of information technologies and the now appropriate applications of sustainable practices pop up. The process of renewing the construction sector implies the adoption of strategies to transition from the construction industry to the built environment industry, based on digital economies and extended to the urban and infrastructural scale. The design of construction products processes, favoured by information processing systems with advanced efficiency, becomes the real goal to strive for, to achieve real future proofing sustainability results. As a consequence, the modelling shifts from the architectural object towards preoptimisation of behaviour and use models, stimulated and encouraged by suitable interrelated design solutions. (Del Nord, 2016).

In this period, we are witnessing the advent and affirmation of new production models connoted by Industry 4.0.

Within the scope of these futuristic scenarios, the possibility of connecting to the Internet all the objects that populate the environment we live in, the availability of production systems and technologies with a high level of automation, and the spread of digitisation within design and production processes, will bring about unprecedented development opportunities for the manufacturing industry (Campioli, 2017).

## New parametric design and environmental simulation tools

The energy efficient buildings simulations, like that of complex envelopes, increasingly requires the use of parametric analysis tools. These are configured as virtual workspaces, where interactions between interdisciplinary knowledge occur with the aim of assessing, from the metadesign phase, the performances of the object, be it a material, a complex technological system, a building or even an urban context of broad dimensions.

All this why today, the science of sustainability opens up new technological areas in design and requires us to look beyond and not simply at the useful life of products, their direct users and the local context. Therefore, digital technologies lead us to rethink the design process in terms of the creative aspects, the management of information and knowledge, production and implementation (Astbury, 2016).

The ongoing digitisation of the design process actually makes it ever easier to analyse the performances of a building right from the preliminary phase of the design and increasingly often in the presence of specific expertise; this analytical ability is even more interesting when it involves technological solutions from the environment compartment. In this sense the simulation tools allow us to simultaneously assess the geometric-formal characteristics of the architectural work and the energy-environmental performances, together with issues linked to its cost and the building management, from the implementation phase to the use phase. This analysis and assessment process is even more appropriate if transferred to the scale of defining adaptive envelope systems linked to industrial innovation.

In fact, in the last decade, in the building design area, Building Information Modeling (BIM) tools have inexorably changed the procedures for defining operating models of architectural practice. These are indeed new methodological approaches to creative space, and not just simple operating tools comparable to the vector-based ones used in the past.

The term BIM in fact identifies an integrated process involving different applications capable of interacting with each other and sharing the same informative logic and structure (Ridolfi, 2018).

The need to adapt the operating structure of these complex tools to the operating situation of the construction sector, and above all to the design phase and therefore the validation and analysis of building systems and the technological solutions, has led in the last decade to the development of new BIM functionalities. These can be identified as the Performative BIM, concerning the exploratory and simulation activities typical of the idea-based phases traditionally ascribed to the figure of the architect (Marsh, 2016).

The performative model is no longer a mere geometric entity but it represents a complex system made up of families, types and elements that allow us to spread the updating of various attributes to all components of the design in a dynamic and interactive way and to modify an entire building by changing even just one of the parameters that define it (Attia, Gratiaa, De Herdea, Hensenb, 2012). This gives rise to Building Performance Simulation (BPS) and Building Performance Optimisation (BPO) tools within the context of research pertaining to Performance Based Design (PBD).

Alongside the rapid evolution of indicators and legislation on the buildings energy efficiency new computer models for evaluating the design were developed: the Building Energy Modelling/Models (BEM), which were quickly disseminated in the construction sector and evolved rapidly within a decade. They have the capacity to assess the behaviours of the built environment from the static to the dynamic situation.

These tools are capable of developing models in which descriptive data related to geometric aspects is associated with data characterising the thermophysical aspect of the technological solutions adopted.

With the introduction of BIMs, the BEMs transform into interoperable tools often integrated into the interfaces of more complex modelling products. These are plugins and addons dedicated to specific aspects of the energy and environmental simulation, demonstrating that no software is capable of resolving all aspects of the energy simulation (Ridolfi, 2018).

The complexity of BIMs and BEMs means there is a need to develop specialist knowledge, above all when BPS and BPO tools are used, as the indicators concerning the energy performance of the technological system or the indoor and outdoor comfort parameters of the building are numerous and often require detailed assessments. The calculation and simulated display of the heat and humidity characteristics of the construction elements, the forecasting and simulation of the environmental parameters (such as ventilation, sunshine, shade, the diffusion of natural light in rooms), new material production techniques, 3D printing, as far as robotic architecture, are changing the forms that we design (and can built) (Neuckermans, 2017).

## Energy simulation in the concept design phase of complex envelope

The preliminary phase of designing the environmental component of complex envelope systems is characterised by the need to assess different alternatives capable of satisfying the client's requirements in terms of ensuring maximum energy efficiency and, at the same time, guaranteeing the economic sustainability of the project. Therefore, this degree of creative approximation requires the designer to quickly and accurately assess the performance scenarios with respect to which the project will be developed, also and above all within the scope of the definition of detailed technological solutions that guarantee achievement of the nearly Zero Energy Building (nZEB) standards.

The new operating paradigm, necessarily linked to the designer's forecasting capacity as early as the concept design phase of envelope systems, suggests a high degree of interdisciplinary knowledge aimed at the use of assessment tools. These tools are able to work in a dynamic regime that can help to define the project performance requirements necessary to achieve the energy efficiency objective and reduce environmental impact connected to its meaning of sustainability. In this sense the use of BPS is essential even in this first phase aimed in particular at analysing the energy flows passing through the architectural envelope (e.g.: solar radiation, thermal resistance capacity of the materials, air flows, etc.) (Charron et al., 2006; Hayter et al., 2001). The designer can use this software to analyse morphological and material choices in scientific detail, directing the design of the envelope's technological system towards its creation through prefabrication in highly innovative production environments, also characterised by the use of advanced tools connoted by the production processes typical of the fourth industrial revolution, the socalled Industry 4.0.

Thanks to datadriven strategies and the possibility of interconnecting design and production in a single work flow, customisation of the form can, in fact, be linked to a responsive interpretation with respect to local characteristics and regional variations (Figliola, 2017). Therefore, within the scope to design adaptive envelope systems, it is essential to develop a performance analysis by constructing a virtual model that allows us to assess its behaviour in relation to the materials (traditional or innovative) and the integrated technological subsystems (active and passive actuators, systems for the accumulation and production of energy, etc.) up to the need to optimize the performances based on the external climatic conditions and indoor comfort. For these reasons, the virtual model is tested in terms of contribution (positive or negative) to the energy requirements (for heating; cooling, electricity, etc.) of the built environment, also and above all in relation to the climate area in which it will be used. This evaluation phase, conducted with increasingly sophisticated BPS and BPO tools and imagining the system integrated with elements that, in terms of characteristics and form, are similar to the "test cells" used in the prototying phase, allows us to optimise the geometric, material and formal choices for the façade system. Software such as Grasshopper[1] for instance, even in this phase allows us to cross the energy-environmental analyses with the geometric-formal, as well as economic and performance-based ones. In this way all players in the process are able to assess, from the preliminary phase, the project variables that can be implemented at technological detail scale with the aim of optimizing the performances in a broad sense. Finally, it is important to remember that the simulation phase must always be accompanied by a testing phase carried out in a real environment which enables (through monitoring campaigns conducted at set time intervals and protocol applications and test procedures recognized internationally) the assessment of specific thermophysical parameters such as thermal transmittance and thermal capacity of the materials used. The thermophysical characterisation of a system by means of a "test cell" and the dynamic analysis of the output data obtained from monitoring the energy simulations under a dynamic regime allow us to obtain accurate and realistic models representative of the physical system investigated, providing a significant contribution to overcoming the limits met in the case of a simplified analysis. They also allow us to develop empirical models that can be applied to the monitoring data obtained from test campaigns on entire buildings and under conditions of use, in order to quantify the energy savings that can be achieved through the application of the devised technological component.

1 This is a modelling investigation and theoretical experimentation tool, that can organise projects into parametric systems, based on the logic of the relationships between the parties, offering the possibility of altering the overall configuration of the system by acting on the variables set as the basis of the design process (Tedeschi, 2010). Developed in 2007 by David Rutten and Robert McNeel & Associates, Grasshopper, was largely disseminated as a plug in to Rhino software in the context of virtual modelling linked to the architecture and design sectors.

## Conclusions

It is clear how even the sector of the design of complex envelope systems is required to evolve from collective intelligence into connective intelligence made up of physical and virtual networks in which researchers and/or designers become the bearers of knowledge linked to operational and decision-making processes, involving horizontal skills (Raiteri, 2014).

The analysis of this type of adaptive technological solutions requires the use of multiple BPS tools that often produce interoperable outputs in the context of BIM environments. Therefore, it is essential that designers learn to define simulation strategies from the perspective of the design objectives more than the use of single analysis tools (Loonen et al., 2016).

The fates of Technological and Environmental Design and those of the so-called anticipation disciplines seem to cross, not only because convergent regarding some theoretic positions on postmodernity, but also because they are solicited by the needs of the real world and by some important looming reforms (Fanzini et al., 2017).

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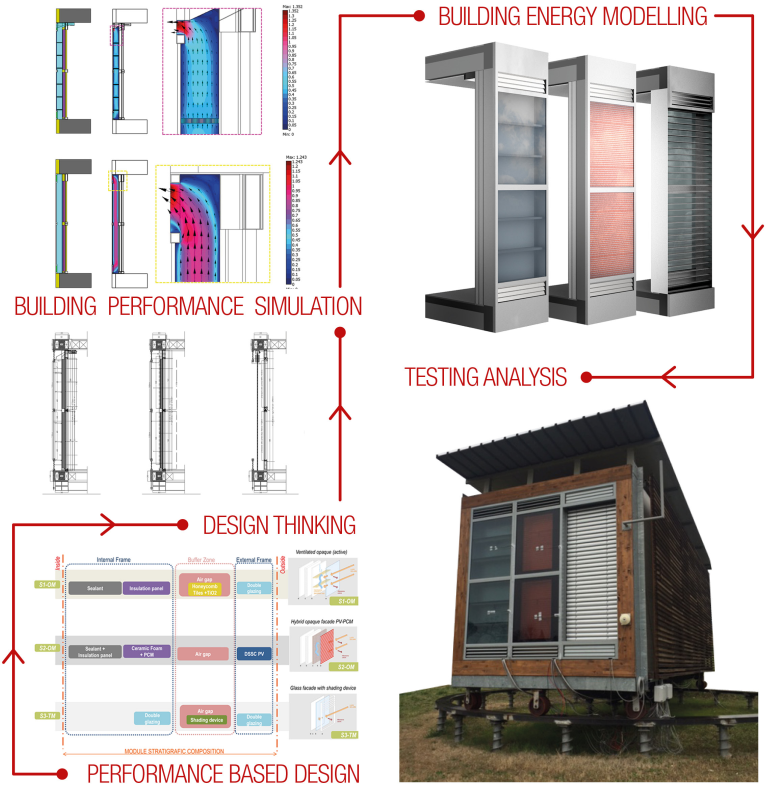


*Fig. 1 - From metadesign to verification with BPS and BPO tools of the energy performance of adaptive envelope systems: the SELFIE facade system*