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FUTURE SCENARIOS

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Design Technology Practice

FUTURE SCENARIOS

NOTE

PROLOGUE

DOSSIER edited by Andrea Campioli, Stefano Converso, Ingrid Paoletti

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CONTRIBUTIONS

ESSAYS AND VIEWPOINTS

RESEARCH AND EXPERIMENTATION

DIALOGUES edited by Ingrid Paoletti and Maria Pilar Vettori

NOTE

Maria Teresa Lucarelli, SITdA President,
Department of Architecture and Territory, Mediterranean University of Reggio Calabria, Italy
mtlucarelli@unirc.it

At the time, in the holder of this issue of TECHNE Future Scenarios, no one could certainly imagine the serious incidents of public health emergencies that have invested nations and peoples, heavily engulfing the global economy. 'What is to come'– future scenarios -is not a new question": this was the incipit of the call of the number, challenging and purposeful, certainly assertive as can be the thought of those who look to the future with positivity and optimism: «[...] As humans, we always have adapted our being in the world through artifacts, tools, built spaces to give a (precise) shape to the image of the future environment in which we will live»[1].
However, how will the future be? What environments we will live in and use? The current dramatic events necessarily require some reflection, albeit brief one. The pandemic that has taken the world by surprise, is removing optimism and security by highlighting a profound weakness in dealing with an event that, although announced over the years by other similar forms but underestimated by most people, has caught politics and science unprepared to give comprehensive answers and propose acceptable solutions even in the emergency. It is precisely the unpredictability of virulence that makes difficult the control if not through social distancing and confinement. A solution that can only be temporary.
It is inevitable, however, to wonder why the many possible dangers and risks that have long been linked to health problems (ebola, sars, etc.), environmental (climate change, disruptions, earthquakes, etc.) and, socio-economic (poverty, ghettoization, immigration, etc.) have not been addressed with the necessary attention. There are no convincing answers, also because in many cases the events appear unintentional but, almost always, they refer to serious human responsibility in not knowing how to prevent the event and, above all, not knowing how to deal with it. A lot of debate is going on, answers are being sought that science and politics have to mediate even in the face of an economic default that seems unstoppable. So the deep concern for physical health is associated with the psychological fear for the future resulting from the traumatic event that – as S. Freud says «[...]not being predictable makes any form of defence impossible»[2].
It is, therefore, legitimate to ask oneself what will be the future scenarios – possible, probable, preferable – with the awareness that at the moment there are no exhaustive answers. In fact, many of the certainties acquired during the last decades have disappeared, first of all, the deep conviction of being able and knowing how to control nature by serving its own needs.
If, therefore, the pandemic is creating an inevitable disorientation and a consequent slowdown of life in all its expressions, it cannot be denied that the environmental crisis that has characterized the last 50 years, and the economic crisis that occurred between 2007 and 2013, second only to the great depression of the early twentieth century, have long imposed on humanity a change of pace with effects, especially on the social level, not easy to solve.
Architecture, in front of the multiple challenges and their complexity, has to be able to relate to a multicultural society, in rapid change, increasingly forced to deal with the unpredictability of events. Therefore, the attention to the new scenarios, which are already prefigured in this issue, can provide adequate answers from the world of research and architectural culture, having in itself the ability to «[...]to develop a synthesis of scientific, social, political and cultural points of view at a time when the anthropocentric perspective has radically changed our approach to the environment, construction, technology and materials[...]» [3].
Numerous and diversified papers contained in the text – 27 selected by double blind review among the 104 received – that through the development of the five topics[4] proposed in the call, focus the issues on possible future arrangements.
It is, in fact, evident that with the wide diffusion of digital technologies, the culture of the project is undergoing significant transformations. On the one hand, by obtaining greater design and implementation performance. On the other hand – in the transition from a traditional, linear and sequential approach to an integrated and interactive one – modifying the ideation and expressive methods that will necessarily require a change in the management of the relationship between human creativity and artificial intelligence.
The result is an appropriate and profound transformation of the approach to the "project" of cities and for cities that will increasingly face urbanization and population growth, energy problems, land consumption, climate change and possible serious health events, associated with significant social problems already present in large urbanized areas. There are many simulations in worldwide to predict the extent of the phenomena, especially climate phenomena. There are also many backcasting processes done for the construction of future development scenarios and different approaches that, starting from ecological thinking, talk about Collaborative Design, Nature Based Solution, Circular Economics in which the production and consumption processes promote a circular logic "from cradle to cradle". Certainly, the architectural and urban design, with greater attention to the metabolism of cities, will have to focus on new structures in which a renewed vision of sustainability reviews the relationship between anthropized and natural systems to contribute to their resilience as a stable condition, albeit dynamic, and not as an emergency solution.
This will be possible if there is a real cooperation between the world of design and that of industrial experimentation/production in which technological innovation – technical, material and design – associated with knowledge innovation, will make it possible to govern complexity, identifying transdisciplinary and interdisciplinary ways, even with immaterial collaborative forms, to respond to the main challenges of the future[5].
It will be fundamental to re-think the figure of the Architect, his training and his new or renewed skills. For some time now, the

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growing needs of the world of design and construction, increasingly aimed at a global market, require knowledge and ability to manage digital tools and skills in process and project management. It follows the need to form a new figure of architect, able to govern the various phases with greater knowledge of the potential that lies ahead and full awareness of a future with many uncertainties. A transformation that requires, together with the ability to adapt, new skills and abilities to manage the relationship between human creativity and artificial intelligence. Therefore, there is the need for a revision of training models that are not only based on the use of platforms, even if they are useful facilitating tools, but that identify new and diversified fields of knowledge capable of renewing the figure of the Architect and projecting him into the future, starting from the places of training, in particular the University.

Problems, all of which find interesting answers in this Special Issue of Techne.

NOTES

[1] Campioli, A., Converso, S. and Paoletti, I. (2019), *Call for paper Techne Special Issue n. 2,* Firenze University Press, Florence.

[2] Recalcati, M. (2020), "La Repubblica", *Newspaper of 16.03.2020.*

[3] Campioli, A., Converso, S. and Paoletti, I (2019), op. *cit.*

[4] Topics: «1. Architecture and change management: theory, criticism, vision» «2. Cities in transformation: environmental and social design and large scale perspective» «3. Project for climate change: policy and technology for adaptation and mitigation» «4. New challenges for technical innovation: production, techniques and materials» 5. Architect of tomorrow: knowledge, education, pedagogy».

[5] Lucarelli, M.T. (2019), "I nuovi scenari della Progettazione tecnologica", Lauria, M., Mussinelli, E. and Tucci, F. (Eds.), *La produzione del Progetto*, Collana Politecnica, Maggioli Editore, Sant'Arcangelo di Romagna (RN), Italy..

BUILT EXPERIENCES.
History as a barometer of contemporaneity

Emilio Faroldi, emilio.faroldi@polimi.it
Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Italy

Architecture is both a means and an end. Tending towards it allows the designer, and whoever takes part in the design activity, to make an ambitious attempt at defining an evolving entity.
Deciding today what will be tomorrow – or, even, forever – is an extraordinary action that carries with it a high degree of responsibility: before being created, everything we see today in our built environment – public spaces, buildings, materials – were first of all imagined, and even dreamed.
It is a question of accepting imagination as an instrument of creativity, as a primary element of evolution, allowing man to change and adapt to the spaces in which he lives. Dream, foresight, anticipation, invention and creativity – in other words, the overcoming of the sensitive side of our existence – represent the highest expression of man's responsibility towards the world.
By definition, a designer's imagination is akin to the ability to anticipate: the environment, the city, the habitat of man; the urban and non-urban landscape of the future; the transformations we can impose and those we must endure.
The act of designing means constantly pondering such aspects, cultivating the exercise of doubt as a primary prerogative of developing architecture. Designing means trying to never lose sight of the value of the many "maybes" that man faces every day, with courage but also with uncertainty. For architectural designers, use of the conditional is a desirable practice, given their constant battle with weak, alleged certainties and infinite unknown variables.
Our responsibility, as designers, is to take consistent and structured architectural decisions promoting the construction of buildings and such use of the environment and landscape as to anticipate new scenarios, drawing on our past yet projecting ourselves into the future based on evolving scientific criteria.
Taking these assumptions as our starting point, I wish to dwell on the relationship between history and contemporaneity, in order to outline plausible prospects for our geographical area, based on an autochthonous and original reading of the Italian and European contexts in particular. A vision that takes its cue from the purposely provocative wish to elevate history to a barometer of contemporaneity[1].
This interpretation relies on the assumption that ours is an urban world. While it is true that cities occupy less than 3% of the planet's surface, people, the inhabitants of the world, live and circulate mainly in cities, and the tendency is to reaffirm this dynamic. This cultural attitude has inevitably resulted in their growth, in number and size, in a variety of ways mirroring our different lifestyles.
The built environment constitutes the theatre of our lives, that physical context, hosting the life of man, readily identifiable with the concept of city. There can be no proper planning of our world, of our reality – whether natural or relating to man's *habitat* – without constantly referring to the history of places and cultures.
Great masters have always been unanimous in reiterating the need to be familiar with history so as to be able to draw on such knowledge and adapt it to the new era. A civilization with no memory is destined to repeat its mistakes. Studying our past, instead, favours the contemporaneous experience, whether it be permanent or temporary, in continuity or in discontinuity with our past. In this dialogue between past and present resides the sequential and evolutionary value of the moment we are living.
In the world's heterogeneous urban structures, there are contexts for which a genuine history has not yet been written, and others, which, on the contrary, are strongly characterised by their urban experience.
The city is everywhere, it permeates every anthropized interstice, concentrating in magnetic form and making it seem that our fate has already been written: we *will* live in megalopolises. By 2050, the world's population is expected to increase from 7.6 billion to 10 billion people. Currently, 54% of the total population lives in cities and, again by 2050, this percentage is due to rise to 70%, with the world having over 40 megalopoles – cities with more than ten million people – by 2030.
On the other end of the spectrum, however, it is worth noting that in the countries of the European Community, Italy among them, almost two-thirds of the population currently live in small and medium-sized urban centres.
For us, history is both a constant and inescapable liability, but also an enormous asset to be protected and valued. As a result, the European city, and the Italian one in particular, is going through a dynamic, non-static age nourished by the relationship of accord and discord between these two factors. It is constantly being enlarged and modified over time, opening itself up to the territory in a widespread manner and altering the urban behaviour of its inhabitants, its visitors, its designers.
The city can no longer be measured, as it used to be, in terms of density, continuity, variety: the current urban scenario is discontinuous and enfolds considerable differences in terms of housing and functional density.
It is also increasingly difficult to determine where the countryside begins and where the city ends: new ingredients linked to the concept of free time change our set ups and habits, and contexts connected with historical tradition show signs both of development and of contraction. This phenomenon takes its place among dynamics linked with the concepts of metropolisation and urban shrinkage, i.e. an increase in the mass and a decrease in the weight of the city.
This development, mainly associated with a population decline, involves much more than just a falling demographic trend. It is viewed, instead, as a phenomenological and unplanned result

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of economic and political decisions resulting in excessive urban spaces, buildings and obsolete properties. Consequently, while some realities grow culturally, physically and economically, others experience deindustrialisation, economic crises, demographic nosedives that result in a redundancy of empty and abandoned buildings.
The housing heritage passed on to posterity, often unused and obsolete, represents a serious challenge for the community in terms of dealing with the existing scenario and with the built city. "New" settings exist, and make sense, even where man has already carried out transformations: in the European context, there is no need to design a "new city", but rather to identify new development strategies in line with the existing reality.
This concept has been universally accepted as the primary means of giving whole parts of the city a new lease of life: the act of making *urban regeneration* a driver for the rebirth of areas that have lost their identity. In the case of Italy, the idea is to regenerate neighbourhoods springing from a historical design but that have in fact lost the population that originally defined and nurtured it.
Regenerating means restoring a state of dignity and grandeur by reconstructing the injured or lost parts of an urban organism. More specifically, it means tackling the new demands of contemporary living within historical fabrics, adapting the forms that the city has taken on over time to the changed needs of new urban populations. Building in an existing, on an existing, within an existing context: this is the challenge our generation must face.
«The underlying theory», writes Paolo Portoghesi, «is that architecture, every architecture, is born from other architecture, from a non-fortuitous convergence of a series of precedents, combined by a synergistic process of individual thought and collective memory»[2].
The Italian landscape owes its survival to the fact of giving attention to local cultures and rejecting standardised developments, because it in is such "differences" that beauty, continuity and harmony lie. Every urban context is inevitably the result of multiple stratifications, and as such can be referred to as *historical*. Contemporary designing continues this historical process based on an inescapable rationale of continuity.
The juxtapositions of *continuity-discontinuity* and *assonance-dissonance* lie at the epicentre of the dialogue between the past and the future. It is for these and other principles that we must live the city, we must preserve it and value it, not as antiquarians or museum managers, but as citizens-architects with a highly developed sense of civic duty. We need to leverage the best of our past and of our experience and adapt it to our present and our future. This is because life – and, even more so, the work of an architect – is the sum of experiences, in the very same way as the city is, too.
As Italian singer-songwriter Francesco De Gregori sings in a beautiful song from the 1980s, "we are history" (*La storia siamo noi*)[3]: history, therefore, is not about buildings, or rather, it is not just about buildings and spaces; history is made by the men and women who live and interpret them.
The dialectic relationship between memory and contemporaneity, in every discipline, sums up the ambiguities and difficulties we are going through. Consequently, the relationship between expressions of contemporaneity and traces of our past directly involves the debate on the range of action of design and constructive practice. Since modernity-related phenomena often tend to weaken the natural, historical and cultural environment, in Italy it is inconceivable to have an idea of architecture that disregards the concepts of memory and identity, also in relation to topical modern-day environmental problems.
The process of creating our contemporary world must also serve as a fundamental instrument of analysis, elevating the critique and study of history to a constructive filter of new trends. Utterly inadequate, therefore, would Frank Lloyd Wright's alleged dig at Siegfried Giedion be today: "we both deal with history, the difference being that you write about it while I make it".
Critical action, an awareness of the past, an understanding of the present and an inclination towards the future are strategic and synergic factors for the dissemination of knowledge, since every age must represent itself: it must leave a trace, through the built and the unbuilt environment, of its style and tenets. We must, therefore, counter an idea of the *past* as a phenomenon in itself, as something that is over and done with, separated by an irreparable fracture from the present.
This is an attitude that the younger generations tend to adopt: for them, the past is obsolete and the here and now advanced and progressive. Our young people's growing ease with the use of electronic instruments should be set against a growing weakening of their critical ability.
Contrast, hybridisation, fusion, allegory, reference: in contemporary urban architecture, these factors are elevated to legitimate and desirable processes. The *vexata quaestio* regarding the logical connection between *contemporary architecture* and *historical contexts* sums up the daily relationship between the old and the new, with the concept of *historical continuity* – in functional, semantic and technological terms – being the constant element of the equation.
Here, then, is the paradigm: architecture is the *barometer of an era*, while the consolidated city sets the *stage for comparing different eras*. There is no single road to be followed, but multiple approaches, which can be mutually contradictory or complementary.
Man was born to be a builder and modifier of the world he lives in: a child left alone on a beach will show his instinct as a builder as he plays with the sand. Hence the human mind's faculty to

preserve and call up memories and experiences that represent a founding element of the individual and collective identity of the city. Memory, in this cultural context, is an essential requirement for the birth and development of a people's culture.

Man simply adds to or subtracts from this memory, seeking a dialogue with pre-existing frameworks within which new designs can outline the transition from past to future. We channel the passage from before to after, without ever being extraneous to either.

Aldo Rossi believed that the question of *ancient-new*, of *conservation-innovation* «can no longer be seen only from the viewpoint of the relationship between the old and the new [...]but from that of the necessary modifications that are produced with every work»[4].

Architecture is such when it favours its usability, in line with the idea of an entire community. The hope is that, in a thousand years' time, when future archaeologists find our ruins, they can easily date our buildings and our cities due to the forms, the materials, the technological and construction systems used.

Buildings, like men, are living, pulsating beings in continuous evolution; and the city, to use an oxymoron, is their natural environment. Moving beyond the metaphor of architecture – referred to by Goethe's as "petrified music" – and widening our horizons, it is worth noting that every human sphere regards the history of society as the engine of contemporary design.

The relationship between memory and contemporaneity is the barometer of all the elements that make up our existence – society, work, well-being, health, interpersonal relationships, lifestyles – and of our relationships with them. Every transformation can be positively experienced when it is welded to its own past, not in opposition but in continuity with same.

Every day we are reminded by the experts that global warming is progressing faster than expected; every action connected with altering the built and the natural environment must necessarily be carried out with this in mind.

In order to try to outline some future scenarios, paraphrasing the context in which this paper is placed, and acting within that paradigm, I would like to reiterate certain concepts on which future strategies should be based.

The historical city is a more resilient entity than others are because, having had to confront that very historical aspect, it has had resilience imprinted in its very DNA. The city is where most of the world's infrastructure is concentrated - a vital element for quality of life and always a critical factor within the Italian scene; it is the primary place and a democratic instrument of inclusion, integration and enhancement of differences through the plurality of its configurations; it represents the framework and a paradigm of acceptance and reception of inhabitants from rich and poor lands alike, who have decided or have been forced to leave their native home; the city and its spaces, its forms, play an educational role in the behaviour and habits of people.

Three actions are consequently essential for our modern-day reality, incorporating a strategic significance for the future of our contexts and landscapes.

It will become increasingly necessary to invest in urban regeneration, both in a material (space) and an immaterial (society) sense, without ever forgetting that cities are the people and not the containers that house them.

It will become increasingly important to foster and promote dialogue with the built city and not to interpret the two entities as diametrically opposed, drawing on the concepts of valorisation and use, and not of simply preserving and treating cities like a museum - because the city only survives if it lives.

It will become increasingly useful to consider the city as a living being, developing new formulas to graft and transplant "new organs" through micro and macro urban surgery operations on the city's living body. And there is no doubt that the citizen is the city's best possible doctor.

We are the outcome of the experiences that have formed us. Each of us preserves his or her own memory of the past, and this will emerge subconsciously when facing anything new, combining rational reason with subjective need.

The city is the sum of many architectures. Likewise, architecture – and history – are the sum of many stories.

We are history.

NOTES

[1] The text refers to Emilio Faroldi's talk at TEDx Parma "Della Città e Del mondo", held on 25 November 2018 at *Workout Pasubio*, Parma, entitled: "Built experiences. History as a barometer of contemporaneity".

[2] Portoghesi, P. (2016), "Combinando cose lontane (Combining distant things), Techne, *Journal of Technology for Architecture and Environment*, Vol. 12, Firenze University Press, Florence, p. 40.

[3] De Gregori, F. (1985), *La storia (siamo noi)*, from the album "Scacchi e tarocchi".

[4] Rossi, A. (1972), "Architettura e città: pasato e presente", in Rossi, A. (Ed.), *Scritti scelti sull'architettura e la città 1956-1972*, edited by Bonicalzi, R., Edizioni Clup, Milan, Italy.

BACKCASTING THE XXI CENTURY
Digital culture and tacit knowledge for the future of Architecture

Andrea Campioli[a], Stefano Converso[b], Ingrid Paoletti[a],
[a] Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Italy
[b] Department of Architecture, Roma Tre University, Italy
andrea.campioli@polimi.it
stefano.converso@uniroma3.it
ingrid.paoletti@polimi.it

Introduction

Technological change and its social implications have in recent years become a topic of intense interest and fierce debate. Human actions are driven by cultural, economic and political forces that have unforeseen consequences and side-effects, as we have recently noticed.

Climate related risks for natural and human systems (drought and precipitation deficits; sea level rise; species loss and extinction; health risks, livelihoods, food security, water supply, human security, and economic growth) are reaching higher and higher levels (IPCC, 2019) and we are asked to rethink and redesign ourselves as users of life in close and interrelated familiarity with the environment.

This scenario overwhelms us with a sensation of uncertainty, of accelerated times, of technological transformation and rapid social changes that create concern and profound expectations at the same time.

This paper will focus on the architectural project as the center of a new debate, able to build complex scientific, social, political and cultural point of views, in a period where the downturn of anthropocentric perspective is radically changing our approach to design, technology and materials given their impact on resources.

The question we will try to answer along this paper is mainly: How can we direct our knowledge today so that – as designers – we can re-balance our impact on the planet and literally 'build' our future?

Of course, there's no linear and obvious answer.

Backcasting XXI century: the European Green Deal

"What is to come" is not a new question. As humans, we've always adapted our being in the world through artifacts and tools, building spaces to give a (precise) shape to the image of the future environment in which we will live.

In the field of futuristic studies, the traditional forecasting approach is still dominant, where the idea is to make previsions on mainstream trends.

However, in complex systems like the human habitat, this approach will hardly generate solutions that could be long lasting: the premises change fast and subjectivity of action doesn't allow a unique direction.

In Architecture, a more interesting approach is backcasting, intended as a method to analyze the future with the focus on a preferable scenario.

The fundamentals of this approach were outlined by John B. Robinson in the nineties in his famous paper Unlearning and backcasting (Robinson, 1988), where he stated that to change the present it's hard to use forecasting previsions, as their success depends on the correctness of the hypothesis, which usually are present related. Backcasting deals with the implications of a specific scenario, and thus does not rely only on the accuracy of the prevision but more on the policy and path that can be set in order to reach a preferable scenario.

This approach is still meaningful today as it is less concerned with a possible, plausible or probable future (as futurists are) and more with the construction of a progressive knowledge, a set of skills and policies for a feasible scenario that runs from a future end-point to the present (thus 'backcasting').

In this perspective, Architecture can give a real contribution to the debate on cities and dwellings in a variable and multi-cultural fast-changing society. The question is not to anticipate the future but to build socio-technical scenarios that are relevant and have the capacity to shape our built environment.

In a backcasting perspective, new processes, production methods, construction systems, advanced materials and experimental technologies have to consider environmental protection, social equality and people's health and well-being as priority goals. In this domain, the European Commission presented at the end of 2019 the "The European Green Deal" for a fair economic transition, which is expected to help facilitate the path to climate neutrality by 2050.

The objective is to protect, conserve and enhance the EU's natural capital and mitigate environmental risks at the same time, while making this transition just and inclusive. Moreover, construction is considered one of the resource-intensive sectors, like textiles, electronics and plastics (The European Green Deal, 2019).

In the document, at least three aspects should be underlined in a backcasting perspective as they have a peculiar relevance for architecture and the built environment.

The first is the consciousness that there are no borders. The recent events are very clear in this direction: it is not possible to think that environmental impact can be bound to a European context only.

If buildings are efficient only for some specific northern cities in Europe, the risk is to have carbon leakage, meaning just shifting carbon production somewhere else.

And somewhere else means in countries where environmental regulations are loose or not respected. The fatal mistake is widening the "waste divide" between rich "clean" countries and poor or unregulated 'dirty' ones. This is not acceptable from the point of view of a collective responsibility.

The second is the growing relevance of circular design and waste management.

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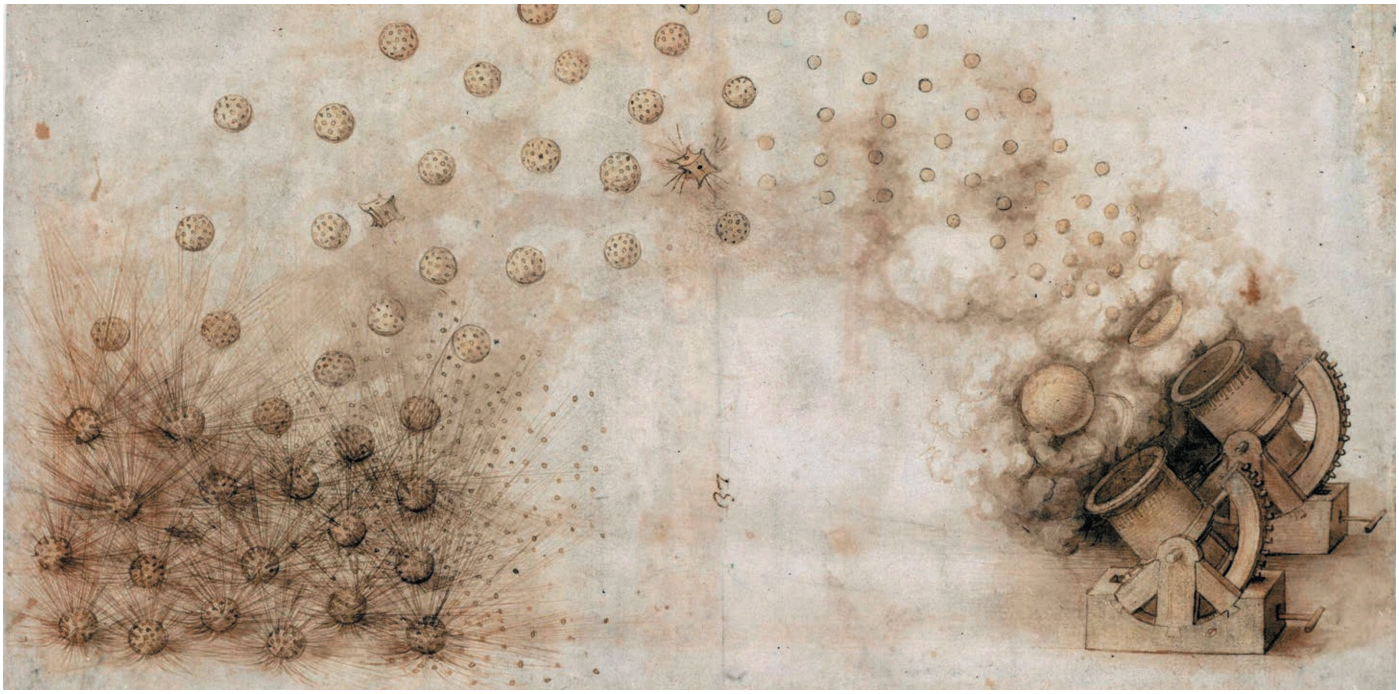


01 | Leonardo da Vinci drawing
This drawing expresses the tentative to fix the lines of movement, striving to see the network of forces that arise from a bomb blast. As the world is rapidly changing, increasingly interconnected and linked through networks, this image is evocative of the constant correlation of cause and effect, we should never forget
Marini, P. (2009), *Fortezze, bastioni e cannoni: disegni di Leonardo dal Codice Atlantico,* De Agostini, Novara, p. 58

One of the targets related to construction is to reduce potential waste significantly, and where waste cannot be avoided, its economic value must be recovered and its impact on the environment and on climate change minimized.
«More specifically, waste in architecture is simultaneously the interhuman fabrication of the absence of value, a misreading of the laws of nature, and a condition which denotes worth, isomorphically, by means of both its own existence and nonoccurrence. The idea that something can be worthless» (Osseo-Asare *et al.*, 2019).
Here is a first suggestion for our 'backcasting approach'. Thomas Rau has written a 'material universal right chart' focusing on the idea that waste is nothing other than a material without identity (Rau, 2018). If we can keep value as long as possible, we can avoid any material system being left behind. In this scenario, circular design can become a common methodology and guidance principle to prioritize reducing and reusing materials before they become waste (if any).
The aim of the Green New Deal is to try to give possible scenarios of cooperation among different figures that can really foster a roadmap to change, thinking about who, what and how. Designing buildings and spaces is more and more an activity that involves different figures, including – from end to end – final users and policy makers.
So here stands the third important aspect: the need to identify forerunners.
The Deal is quite attentive in trying to identify forerunners that could bear the economic, cultural and social responsibility of innovating with its high risk and low initial revenues. This is a critical issue: if the socio-economic environment has no advantages to foster innovation, all the action will remain on paper. Who are the forerunners in architecture?
Two entangled aspects will be touched on, before giving an answer, to enable the change we are looking for: how digital tools will impact design and its way of pushing creativity and how tacit knowledge, a crucial part of design research and practice, can boost a novel visionary ability to direct transformation.

Digital culture and design

The introduction of digital technology in practice has allowed contemporary architects to work embedded in a speed, scale, and level of complexity previously only dreamed of. While traditional demands of real estate placed on practice have remained relatively constant, the means by which those expectations are fulfilled, and the conditions they play out within have changed. Contemporary collective assets of information technology, artificial intelligence and computational tools however allow an unprecedented background knowledge.
Algorithmic advancements enable designers to perform multiple configurations in a relatively short time without iteratively requiring changes until they satisfy all the relevant criteria and are economically efficient. A proliferation of expertise has been facilitated by many tools that render this array of knowledge operational. Developed primarily for purposes of efficiency and accountability, these work platforms slowly become a space and possibility for self-reflection, judgment and design.
In a world going towards a higher degree of automation, algorithms are already replacing repetitive tasks and augmenting human creativity in the design process. The human-machine collaboration is reducing the time spent on routine work, enabling designers to focus on more complex tasks that require more cultural and technological skills.

But at the same time, automation, especially when linked to optimization can become a "soft cage". Even if the risk of degenerating into aesthetics (as the sixties 'Debord's sharp idea of "Society of Spectacle") is already outdated, a true data connection between phases should be pursued – intended as information passing along models without any need for rebuilding – generating unexpected connections and breaking boundaries where new competences arise (Cache, 1999).
Thus rooting form generation into decision making processes seems to be a key in the networked society of information, where the time needed for architectural design to arise can suffer from a difficult pace of change typical of many contemporary processes. It seems that while data evidence is increasing, it is crucial to set the boundaries of its use and responsibility. How much are we favorable to sharing information where it has crucial economical value? If open access is a preferable path, the management of data becomes even more important where artificial intelligence, and in particular machine learning, enters the field of Architecture.
Filtering and shaping data ethically becomes the crucial issue.
These suggestions come from a scenario where designers work with data coming from a digital environment interacting in a network of relations that is not explicit and not only individual. The digital affects each decision we make as a new 'invisible' but not immaterial environment with which to implement research and practice.
Machine learning, with its neural networks, has so far introduced a new form of "distributed" knowledge founded on the collective experience represented by big data. Floridi states the boundaries between life online and offline break down, and we become seamlessly connected to each other and surrounded by smart, responsive objects; we are all becoming integrated into an "infosphere" (Floridi, 2014). The enormous 'cloud' to which we gift our precious data and memories is a new habitat with no friction and limits.

Tacit knowledge as an anticipatory (creative) tool

Tacit knowledge is typical of the individual construction of experience. Theorized by Polanyi in the 1960s in the text *The Tacit Dimension* (Polanyi, 1983), it describes human knowledge not only as verbalized and theorized, but also as intuitive, experiential and physiological.
It is important to emphasize that tacit doesn't mean only "implicit" but has more complex implications, such as the physical implication of gestures, the link with materiality and intentionality of behavior, the relation with the environment through body language.
The typical example is the apprentice who observes the carpenter and by watching his hands internalizes the fine knowledge and expertise.
In Architecture, tacit knowledge refers to what is called 'research by practice' or the ability to develop innovative content through design activity. The project is understood in its pro-iecto etymology, which means to throw forward, allowing to imagine innumerable possibilities.
Many argue that tacit knowledge is linked to personal practice – praxis, that is to say a mix of experience and expertise acquired in one's own cultural context, and to habitus as Alain Bourdieu stated, the way in which individuals perceive and react to the social world that surrounds them (Bourdieu, 2010).
However, the contemporary socio-technical scenario has blurred borders. Already in the seventies the idea was that: «technology/biology, pure/applied, internal/external, subject/object and technical/social are some of the dichotomies that were foreign to the integrating inventors, engineers and managers of the system- and network-building era. [...] the dichotomies would promptly evaporate» (Bijker *et al.*, 1987).
We can build our path to the future thanks to an instinctive approach that goes beyond the spoken and beyond the mere practice activity, and enhances the designer's anticipatory capacity. This capacity is fostered by different tools overlapping: hand sketching, digital or physical modeling, imagining, making, in an entanglement of means and meanings.
This direction defines a new typology of tacit knowledge today in Architecture.
This tacit knowledge is not something outside us, not only a way of interiorizing some knowledge from practice, but it is literally "through" us: thanks to the pervasive digital culture and it prosthesis (tools to design, data set, "clouds" of our memory everywhere) a new way of learning and creating is being shaped. We are nearer to competence without comprehension, in a similar way to the ubiquitous life of bacteria, hunting and animals than to a structured rational reaction to the environment.
Gestures here are intended as "reflection-in-action" not only through imitation but through novel cooperation between analog and digital technologies. Matter is no longer the primary wellspring of creativity where a form is applied but it is extended by its immaterial twin, which increases its power.
Our mimicking movements in a digital realm allow a non-verbal rise of knowledge that influences us at an unbelievable level.
As an example we can take the case of google glasses: if we start looking at the built environment with such a device, or even, design it, which images will come back to us? As creativity comes from the imaginario we have inside ourselves, this breaking new process starts, stops, ebbs and flows dynamically and continually.

02 | Leonardo da Vinci drawing

A complex mix of representation of reality, of visionary ideas, of techniques and disciplines, of lines moving one into another without interruption. There is no waste, no discard, nothing to exclude to build a common responsibility. Saggio delle opere di Leonardo da Vinci, tratti dal Codice Atlantico, Ricordi, Milan, 1872, tavola XVIII

03 | Leonardo da Vinci drawing

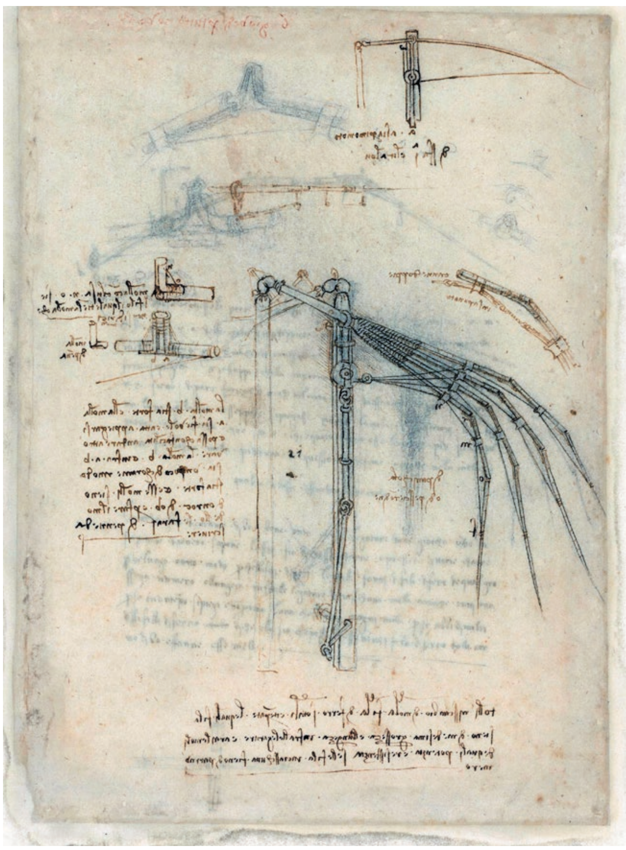
This drawing has different languages in the same paper domain. It reminds us that imagination, nature, artificial and language are an unicuum able to really build unexpected scenarios opening paths for innovations to come. Il codice di Leonardo da Vinci nella biblioteca del Principe Trivulzio di Milano, Angelo della Croce, Milan, 1891, tavola 3A

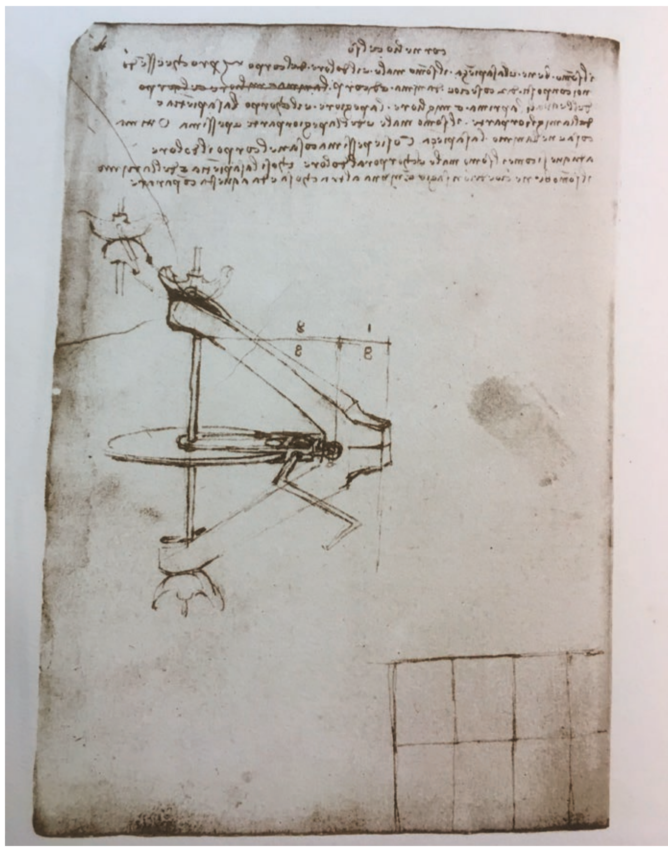
It can be banal, but if we think of it, everything that is built around has been first imagined.
'How then can tacit knowledge, and with that digital continuum, gain a degree of command while remaining open and free within the medium being worked? (Bardt, 2017).
One more step. "Tacit knowledge is not only influenced by moral, cultural and scientific authorities, but is also first realized within the social boundaries generated by them" (Mareis, 2012).
This means that creativity and innovation have to incorporate our vision of present and future and orient our purpose in the backcasting perspective of an equal society with a carbon-neutral, sustainable and clean environment. This scenario needs a collective engagement, which becomes the new way of acquiring knowledge and incorporating social issues. The worrying times request a common ground of values that can support a sovereignty that walks on crutches (Bauman, 2016).

Forerunners

So what is the roadmap to reach the scenario we have drawn in a backcasting perspective for a sustainable society and environment?
We think that it is the construction of a socio-economic context that allows the experimentation of new design practices, innovative data driven processes, experimental material systems as a privileged way to take the risk of innovations.
This challenge should not be frightening. Recognizing culture and creativity as assets for our future desire, and at the same time sustainable and inclusive growth, the conclusions we address are linked to design for different expressions of cultural enhancement, opening critical reflections on the role of architecture.
The recent events show us how vulnerable we are: viruses frighten us, climate change hits us and pollution requires us to change our habits and habitat. A habitat that is near to a novel Umwelt, which is a German word that means at the same time "environment" or "surroundings", defining a domain of the space that is simultaneously material and immaterial.
At the same time, we are facing immense horizons of new knowledge that, while continuously influencing the rate of change, is the result of the new technologies and methods of information production and collation.
How can we thus be forerunners as this period is asking?

02 |





| 03

04 | Leonardo da Vinci drawing.

The city in plan and its blurring borders and interconnected relations are for Leonardo the most powerful tool we have, as humans, that is imagination. Imagination is – somehow – already, a way to build

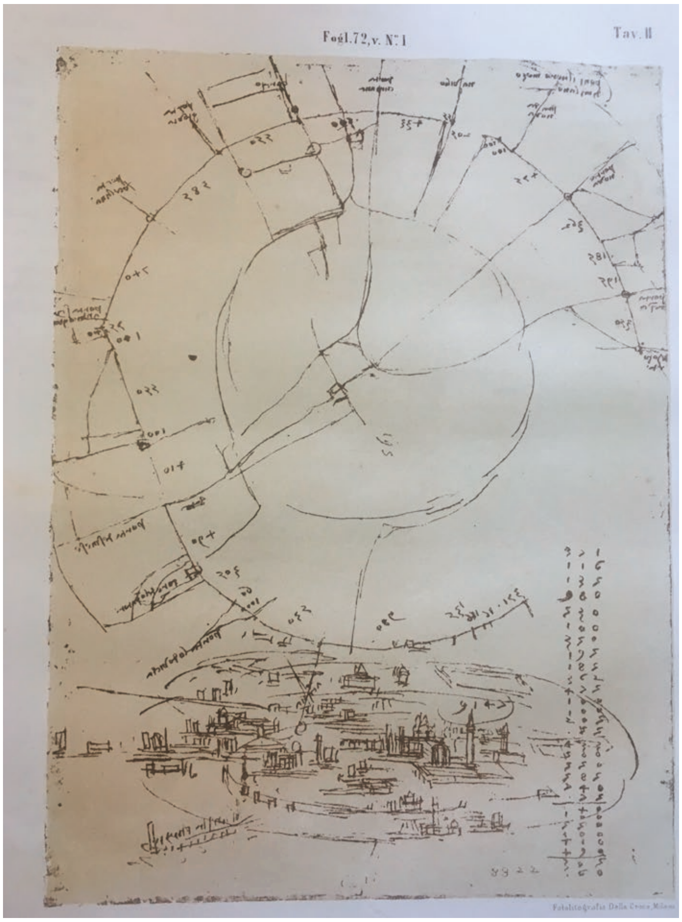
Saggio delle opere di Leonardo da Vinci, tratti dal Codice Atlantico, Ricordi, Milan, 1872, tavola II

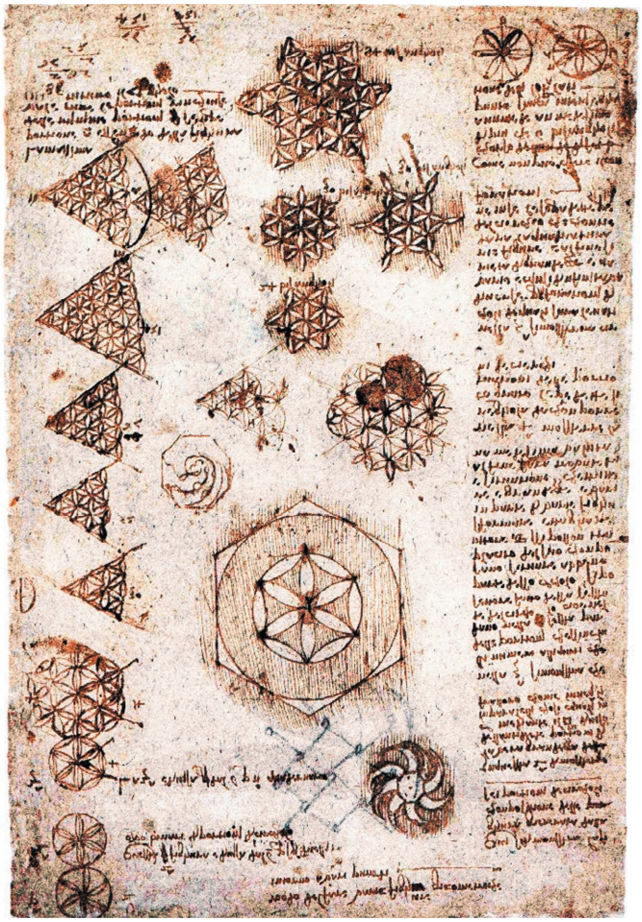
05 | Leonardo da Vinci drawing

In the geometrical structures related to the ornamental structure named today "Flower of Life", bottom and top are reversible and parameters become a pattern. A contemporary way of composing and computing form and meaning

Codice Atlantico, folio 459r. - https://commons.wikimedia.org/wiki/File:Leonardo_da_Vinci_%E2%80%93_Codex_Atlanticus_folio_459r.jpg

04 |





| 05

«Designers are, by nature, an opportunistic species. They work with and on problems, finding or creating openings from which to make things» suggests Ann Pendleton-Juliann.

The convincing hypothesis is that designers can drive forces and be effective in negotiating change. The entanglement between imagination and action can be the driver of new practices that are both responsible for, and a product of our emerging global society.

Agency becomes the deep understanding of an environment where the two ends (imagination and action) are not mutually exclusive and are both engaged in a mixed reality of digital and analog.

Within this dynamic, dialectical or polarized positions are not as productive as they once were. The paradigms of edge versus core, 'learning about' versus 'experimenting with', or, in our case, research versus practice blurs in the concept of overlap, transition or gradient. Consequently, architectural designs are the result of complex and occasionally conflicting sets of requirements that can only be reconciled through processes of negotiation between different disciplines and different fields of knowledge.

Every activity of a designer, like sketching, drawing and model making, merges imagination, techniques, languages – either physical or digital – in a unicum able to really build unexpected scenarios and open paths for innovations to come. It's a renewed collective tacit knowledge that empowers architects, as forerunners, of a bigger responsibility towards societal changes and environmental issues.

«In this zone of entanglement – this meshwork of interwoven lines – there are no insides or outsides, only openings and ways through. An ecology of life, in short, must be one of threads and traces, not of nodes and connectors. And its subject of inquiry must consist not of the relations between organisms and their external environments but of the relations along their severally enmeshed ways of life. Ecology, in short, is the study of the life of lines» (Ingold, 2007).

REFERENCES

Bardt, C. (2017), *Material and Mind*, Mit Press, Cambridge, USA.

Bourdieu, P. (2010), *Outline of a Theory of Practice*, Cambridge University Press, Cambridge, United Kingdom.

Cache, B. (1999) *Projectile*, AA Publications.

Debord, G. (1967), *Society of the Spectacle*, Bread and Circuses PUblishing ,U.S.

Floridi, L. (2014), *The Fourth Revolution - How the Infosphere is Reshaping Human Reality*, Oxford Press.

European Commission (2019), *The European Green Deal, Communication from the Commission to the European Parliament, the European Council, The Council, The European Economic and Social Committee and the Committee of the Regions, COM (2019)*, Bruxelles.

Ingold, T. (2007), *Lines a brief history*, Routledge, London, United Kingdom.

Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield, T. (2018), "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", in IPCC (Ed.), *Global Warming of 1,5°C*, Geneva, Italy.

Mareis, C. (2012) T*he Epistemology of the Unspoken: On the Concept of Tacit Knowledge in Contemporary Design Research*, Design Issues, Vol. 2, Mit Press, pp. 61-71.

Pendleton-Jullian, A. (2009), *Design Education and Innovation Ecotones*.

Polanyi, M. (1983), *The Tacit Dimension,* MA Peter Smith, Gloucester.

Osseo-Asare, D. K. and Abbas, Y., (2019), *Files 76 - Waste*., AA Files.

Rau, T. and Oberhuber, S. (2018), *Material Matters*, Edizioni Ambiente, Milan, Italy.

Robison, J.B. (1988), "Unlearning and backcasting: Rethinking Some of the Questions we Ask about the Future", T*echnological Forecasting and Social Change*, Vol. 33, pp. 325-338.

Bijker, W.E., Hughes, T.P. and Pinch, T. (1987), T*he social construction of Technological Systems*, Mit Press, Massachusetts, USA.

Telmo Pievani,
Department of Biology, University of Padova, Italy
contact-pievani@elastica.eu

Material cultures are the result of human ingenuity and aim at a purpose: a very basic notion of "technology". They have surrounded the birth of human babies for more than three million years, much earlier than previously thought. In 2015, the discovery of an enigmatic lithic industry was announced at the Lomekwi 3 site on the western shore of Lake Turkana in Kenya, surprisingly dated to 3.3 million years ago, that is, more than half a million years older than the first known fossil belonging to the genus *Homo.* We have to rewrite the textbooks because it is unlikely that *Homo habilis* was the first human to build and manipulate tools (Harmand *et al.*, 2015). He no longer deserves his surname. Lomekwi's tools are rudimentary and often unfinished, but already diversified: they are a lithic "industry" in all respects, not a failed experiment of occasional creativity. We do not know which technologist hominin made them: in those regions in Africa, at that time, australopithecines of the *A. afarensis* species (like Lucy) and their *Kenyanthropus* cousins circulated. They had a brain that was a third of ours.

Our brains develop for two thirds after birth. Thus, the experiences, the care we receive, the family and social context in which we grow, the encounters that happen to us, the games with friends, what we learn by social imitation, and so on, literally carve our brains (Dehaene *et al.*, 2015). Therefore, in the past, the tools and technological (bodily and mental) prostheses that we learned to use, that surrounded us since we were born and that perhaps we ourselves contributed to invent or improve, shaped our brains (Wrangham, 2009). Fire, cooking food, group life have transformed the environment around us, making it more permissive, relaxing natural selection, so allowing the affirmation of costly adaptations such as neoteny (the retention of juvenile traits in adults, our developmental secret) and articulated language.

Long after, when the last glaciation ended 11.700 years ago, after a long period of trials and errors (intuitive selection of plants for feeding and self-medication, flour production, and so on), some populations of *Homo sapiens* learned to systematically domesticate plants and animals in several regions of the globe. Today, we think of agriculture as the domain of the "natural", but actually it was the largest technological experiment in the engineering of terrestrial ecosystems ever done. Some plant and animal species started to produce goods useful to humanity, as of course they would never have done. Artificial selection has radically transformed them, morphologically and genetically. Nevertheless, from their point of view, domesticated plants and animals have cleverly used us humans as vehicles of diffusion. As a result, ecologically and geologically speaking, the Earth has never been the same via technologies. The Anthropocene is an old story.

We change the world, and the world changes us

What do we learn from these discoveries about the long natural history of technologies? Firstly, that the different human species (five human species inhabited the planet up to 50.000 years ago – Pievani, 2018) have been immersed in eco-cultural and technological niches for a long time, for more than three million years. We took advantage of the natural phenomena that surrounded us: the properties of minerals, fire, flesh and bones of the preys, then of domesticated plants and animals, and then metals, water, wind, and coal in the last two centuries. We invented technologies (including writing) that have filled our ecological niches and our babies have become "native" from time to time with new technologies. Therefore, technologies have contributed to sculpt their brains differently. The eco-cultural niches so modified fed back, retroactively, on human populations modifying them on the social, cognitive but also genetic level. In short, the genus *Homo* evolved in symbiosis with its technologies. It is no longer correct to say that there has been an "evolution of technologies", as if they have changed on their own. Technologies intrinsically and closely co-evolved with us, and the process is still going on.

The expansion of Middle Eastern farmers towards Europe began around 9 thousand years ago: first in Anatolia, then in the Balkan Peninsula, then again in Central and Western Europe. Together, grain cultivation and the domestication of animals obviously arrived in Europe. That is, both humans with unprecedented behaviours and new technologies arrived (Cavalli-Sforza, Pievani, 2011). The European ecological niche changed because many animals that produce meat and milk, and interact with humans, were now around. Molecular biologists have recently discovered that 7500 years ago – perhaps in the Hungarian plains or in northern Europe – a genetic mutation spread in some groups of shepherds and farmers, which delayed the shutdown of the lactase enzyme used by babies to break down and digest milk. The mutation allowed carriers to digest first the milk derivatives (which contain less lactose) and then directly the nourishing fresh milk even in adulthood, offering them considerable adaptive advantages. The mutation spread successfully, although there is always a percentage of the population that does not possess it (still today).

What happened exactly in evolutionary terms? A cultural and technological change (that is, breeding animals) modified the human ecological niche, altering the selective pressures that acted on the human groups of the time, so favouring the success of a certain genetic mutation. Technology came first, then genetics. It seems evolution upside down: a cultural change led to a genetic change, and not vice versa as we usually think. The phenomenon

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repeated elsewhere, in West Africa and the Arabian Peninsula, with similar effects. In some regions (for example in the Far East, Australia, and the Americas), quite no one in the native populations is able to digest milk. The mutation never came. A planetary map of lactase enzyme activation clearly shows that what we are today, even at the genetic level, depends on our long coevolution with technologies (Curry, 2013).

Between biological evolution and technological (cultural) evolution, there are many analogies and differences in terms of mutations (innovations), strategies of diffusion (fashions) and inheritance (traditions), and selective processes (Cavalli-Sforza, Feldman, 1981). However, it is in the constructive relationships between individuals and environments that a strong connection between the two emerges. Cultural changes can feed back on our biology and modify our genome (Laland, 2010). This also applies to alcohol metabolism after the invention of fermentation technologies for producing beer and wine; to the recent, continuous availability of fatty and sugary food in relation to the epidemic diffusion of obesity; to the maladaptive effects on our immune system and microbiotas of our daily lives in industrial and urbanized environments. The domestication of fire itself (a new technology) induced humans to adapt to eat cooked food, recursively. Now our digestive system depends on cooking. Genetic changes having cultural changes as drivers are defined *gene-culture coevolution* (Fisher and Ridley, 2013), but it is easy to see that in all the cases mentioned above specific technologies are involved, so the gene-culture coevolution is also, and more precisely, a *gene-technology coevolution.*

Humans, the great builders of their niche

"Niche construction" is the general term for the co-evolutionary pattern in which organisms do not just respond to selective pressures imposed by the environment, but also actively contribute to modify the environment itself, therefore modifying the frame of selective pressures that then feedback on them (Odling-Smee et al., 2003). Niche construction is an ambivalent process: it has given us great evolutionary successes and prosperity (even if not for everyone), but it can turn into an evolutionary trap if the environment is transformed and altered too quickly. Being builders of your own ecological niche (eco-technological in our case) means altering the ecological niche of others. Some much known human technological activities (namely five: deforestation; spread of invasive species; agricultural and industrial pollution; overpopulation; intensive hunting and fishing) are causing the Sixth Mass Extinction of biodiversity, as serious as the five major catastrophes in the paleontological records (Pievani, 2015). This time *we* are the asteroid.

Only a mixture of greed, short-sightedness and insipidity can explain a behaviour that is counterproductive even on a purely economic and anthropocentric level. The depletion of ecosystems guarantees immediate profits to a predatory market but will present us with a very expensive bill when we have to pay the "ecosystem services" that we receive for free today (water cycle, air cleaning, soil fertility, pollination, and so on). What is climate change if not a global (and risky) niche construction process? Technologically, we bring fossil fuels to the surface, refine and burn them. We produce tons of carbon dioxide per capita by heating houses and using old-fashioned means of transport. We alter the composition of the atmosphere and the extent of the greenhouse effect. We pollute the waters and change the acidity of the oceans. We empty mountains and divert the course of rivers.

In other words, climate change on the evolutionary scale is a global niche construction process in which a single species alters the ecological parameters and biogeochemical cycles of the biosphere by obliging the other species to adapt in the short term. However, we are also obliging ourselves to re-adapt on the medium term to higher average temperatures, to more energy in the planetary networks, higher levels of the seas, with growing masses of environmental refugees forced to move from their homeland. Not surprisingly, "adaptation" (an evolutionary term) has become the key word of the recent International statements on climate warming. Furthermore, many observers point out that facts and numbers are not enough to be truly convincing of what is happening: climate change is a counter-intuitive phenomenon (too large, slow, non-linear) for our minds and we could be embroiled also in a cognitive trap (Diamond, 2005; Pievani, Meneganzin, 2020).

Climate change natives

Niche construction also maps very well the processes of biotechnological "symbioses": cyborg grafting (neuro-chips); biomimetic technologies; synthetic biology (borrowing a technological metaphor to produce microorganisms with computer-engineered genomes); expanded DNA (De Biase and Pievani, 2016). Niche construction processes also involve the integration of heterogeneous dynamics with unpredictable loops of interdependence. For example, converting large portions of territory to produce bio-fuels (new technology, apparently green) initially seemed a good idea; actually, it was bad for environmental impact, land use and global price dynamics. Side effects and interconnections generate unexpected problems, to which Homo sapiens responds with new technological research (i.e. production of biofuels without land consumption, for example using algae).

These recursive dynamics clearly show how, despite the possible evolutionary and cognitive trap, any catastrophic techno-skepticism is inconclusive. If the nineteenth-twentieth-century technologies are at the origin of most of the aforementioned problems, the damages are not inherent to technology itself but to its uses. Technology itself is and will be an essential part of the solutions thanks to innovation, energy efficiency, and all the eco-sustainable alternatives that will come to mind for the humans of the future.

Those humans of the future will be "climate change natives". Niche construction processes also explain particularly well the phenomenon of being "native to a technology". The technological ecosystem in which we are born provides the basic selective pressures (cultural and social) that influence cognitive and social development. The human brain always seems the same, but growing in a new technological landscape is like being born in a different environment that redefines our relationships with reality. Our technologically re-alphabetized brains are biologically – not just culturally – different from those of the previous generations (Pagel, 2012).

Thus, we can hope that "climate change natives" will find solutions that we, as "climate change immigrants", cannot even imagine. Right now, all over the world, a swarm of creative girls and boys, engineers, designers, investors and entrepreneurs, inventors and researchers is building the next horizon of the technosphere, which is still unknown to us. Who could have imagined the serendipic discovery of gene editing ten years ago? Now, who can predict what we will do with these biotechnologies in ten years?

In evolutionary terms, the so-called "post-human" is a nonsense: evolution teaches us that what will come after the human will still be something human, something still invented by the same *Homo sapiens* the African. Old dichotomies lose their meaning: uncritical techno-enthusiasts VS unlimited techno-sceptics; naturalness VS artificiality; revolution VS continuity; individuality VS collective superorganism. Co-evolution means responsibility: we are actors who, with their choices, actually build the eco-technological niche of the future, which will then transform us and into which our grandchildren will be "native".

Unpredictable tinkering

We invent technologies, which change the eco-cultural niche (social, economic, of the imaginary), which again changes us through new selective pressures. Technology arises from a need or an opportunity, but then generates other desires and opportunities (think about the auxiliary needs induced by the automotive or digital industry) (Basalla, 1988). Technology calls technology, and in some respects we are its productive and reproductive organs (Kelly, 2010; 2016). Small frequent changes can have apparently negligible but cumulative niche construction effects; others have intermediate effects; others have perhaps a modest onset, and then explode in rare large-scale eco-technological upheavals. The technological ecosystem evolves together with its actors. We need an "ecological theory" of techno-evolution, not only in the sense of preserving the natural environment, which is also a crucial component of the model, but in the sense of understanding the ecological dynamics in terms of inter-dependencies and co-evolutions among artefacts, inventions, projects and human societies.

Technologies arise from a request, from a material or immaterial need, but their exuberant diversity is not reducible to the needs of the moment: it goes further and transcends them. Technological innovation never starts from nothing, but existing technologies are recombined and hybridized, reorganizing them through new design and usage principles (Brian Arthur, 2009). Natural selection works in the same way, struggling and finding trade-offs with the constraints of the previous structures. We start from the available material and recombine it, we move from pre-existing constraints and modules, in a continuity of change fuelled by the creative and sometimes revolutionary reuse of what already exists. This evolutionary tinkering is the basis of both biological evolution and human techno-evolution (Pievani, 2019). The historical origin and current function of an organ (as well as an artefact) do not necessarily coincide.

We call "exaptations" those functional shifts. In the history of technologies, it is rare to find an invention that maintained the same uses and functions originally envisaged by its creator (Gould, 2002). Thomas Edison designed the phonograph for anything but playing recorded music. The same is true for radio, transistor, laser, internet, and GPS. Not to mention the multiple reuses and extensions that mobile phone technology is having, invading our days with its trills. Every technology, when it is born, enters into an ecology of other already existing technologies and changes the pattern of relationships among them (Kauffman, 2000).

Our brain is a compendium of exaptations: its neural components, more or less ancient, were born in relation to certain survival functions and then were co-opted to do something else. Hence, with a brain born 200 thousand years ago in Africa, but unusually plastic, today we learn to read and write, that is, to produce technologies and to carry out tasks for which certainly our brains have not evolved (Tattersall, 2013). For a mobile and expansive species like ours used to living in unstable and heterogeneous ecosystems, as well as to constantly migrate in search of new possibilities, flexibility, adaptability and plasticity are the primary survival strategies. Such a plastic brain is able to establish a dynamic of close co-evolution with the technologies it produces, and that fill its eco-cultural niche.

The cemetery of wrong predictions is expanding. Today we are less and less plunged into the category of necessity, and increasingly into that of possibility. Imagining a future scenario already means influencing the future. The same large bipedal mammal, with the same brain size, that 100.000 years ago scrambled with sticks and chipped stones, today drives a spaceship, builds robots that explore Mars' surface and invents nano-technological wonders such as graphene. This residual African twig of the genus *Homo* has walked a long way, presumptuously giving itself the surname "sapiens". 100 thousand years seem a lot, but actually, it is a little more than 4000 human generations. Human techno-evolution is only in its infancy.

REFERENCES

Basalla, G. (1988), *The Evolution of Technology*, Cambridge University Press, Cambridge, United Kingdom.

Brian Arthur, W. (2009), *The Nature of Technology*, The Free Press, New York.

Cavalli-Sforza, L.L. and Feldman, M. (1981), *Cultural Transmission and Evolution*, Princeton University Press, Princeton (Nj).

Cavalli-Sforza, L.L. and Pievani, T. (2011), *Homo sapiens. The great history of human diversity,* Codice Editions, Turin.

Curry, A. (2013), "The milk revolution", *Nature*, Vol. 500, pp. 20-22.

De Biase, L and Pievani, T. (2016), *Come saremo. Storie di umanità tecnologicamente modificata*, Codice Editions, Turin ("How we will be. Stories of technologically modified humanity").

Dehaene, S. *et al.* (2015), "Illiterate to literate: behavioural and cerebral changes induced by reading acquisition", *Nature Reviews Neuroscience*, Vol. 16, pp. 234-244.

Diamond, J. (2005), *Collapse. How Societies Choose to Fail or Succeed*, Penguin Books, New York, USA.

Fisher, S.E. and Ridley, M. (2013), "Culture, Genes, and the Human Revolution", *Science*, Vol. 340, pp. 929-930.

Gould, S.J. (2002), *The Structure of Evolutionary Theory*, Belknap Press-Harvard, Cambridge, Massachusetts , USA.

Harmand, S. *et al.*, (2015), "3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya", *Nature*, Vol. 521, pp. 310-316.

Kauffman, S. (2000), *Investigations*, Oxford University Press, Oxford.

Kelly, K. (2010), *What Technology Wants*, Penguin Group, New York, USA.

Kelly, K. (2016), *The Inevitable: Understanding the 12 Technological Forces That Will Shape Our Future*, Viking, New York.

Laland, K.N. *et al.* (2010), "How culture shaped the human genome: bringing genetics and the human sciences together", *Nature Reviews Genetics*, Vol. 11, pp. 137-148.

Odling-Smee, J., Laland, K.N and Feldman, M.W. (2003), *Niche Construction. The Neglected Process in Evolution*, Princeton University Press, Princeton (NJ).

Pagel, M. (2012), *Wired for Culture*, Norton, New York, USA.

Pievani, T. (2015), "Earth's Sixth Mass-Extinction Event", in "Science Direct", *Elsevier - Online Reference Database: Earth Systems and Environmental Sciences*, online 9 November 2015.

Pievani, T. (2019), *Imperfezione. Una storia naturale*, Raffaello Cortina Editore, Milano ("Imperfection. A Natural History").

Pievani, T. and Menaganzin, A. (2020), "Homo sapiens: the first self-endangered species", in Roque, A.C. Brito, C. and Veracini, C. (Eds.), eds., *Peoples, Nature and Environments: Learning to Live Together*, Cambridge Scholars Publ., Newcastle upon Tyne (UK), pp. 10-24.

Tattersall, I. (2013), *Masters of the Planet*, Griffin Publ., New York, USA.

Wrangham, R. (2009), *Catching Fire: How Cooking Made Us Human*, Basic Books, New York, USA.

ENTOMOLOGY AND INFORMATION TECHNOLOGY

Federico Leoni,
Department of Human Sciences, University of Verona, Italy
federico.leoni@univr.it

Insects

At some point, philosophy started talking about insects. Insects became a recurrent conceptual character. Bergson writes beautiful pages about wasps (1907), Heidegger (1929) about bees, Henri Maldiney (1991) and Gilles Deleuze (1995) about ticks.
Philosophy is a kind of laboratory. The output of that laboratory is concepts. And what is a concept? It is a concentrated experience, something that happens in the world summarized in an extremely economic form. A crystal of events.
So, at some point, the activities of that laboratory change perspective. The main characters are no longer God, Being, Good and Evil, or not only and not always. We should ask what happened, what kind of transformation is going on. Not so much in philosophy, but in our world.

Instinct and intelligence

Let's consider Bergson. One of his great books is *The creative evolution* (Bergson, 1907). We find here many pages about wasps and their preys: caterpillars. He does not only speak about wasps and caterpillars since the author is a great admirer of Darwin, a philosopher who wants to construct something like a philosophy of biology.
In which context does Bergson introduce this new philosophical character, the wasp? When we answer this question, we begin to understand. The wasp is introduced in a chapter where Bergson reasons about technology, about the instruments we use and the tools every form of life uses. His book is the book of a Darwinian thinker, as said. So, the first thing Bergson carefully avoids is to split the field of his enquiry. Nature and artifice, biology and technology, body and instruments. Bergson holds together the two regions and establishes a perfect continuity among them. Every form of life uses technologies. Not only man. Not only primates, as it would be easy to say. The argument would be again a dualist one. Primates would play the role of a prudent exception. Every form of life uses instruments, says Bergson. Or, more precisely, every form of life is a technology. His chapter provides a sort of natural history of technology. We should, if anything, describe the structure of these different technologies, the peculiarity of their specific functioning. In the second chapter, Bergson proposes two definitions that help us to proceed in this direction. We call intelligence, he says, the capacity to use an instrument from the outside, not as a part of our body, but through a sort of fundamental distance. And we call instinct, he adds, the capacity to use an instrument from the inside, in a sort of fundamental continuity, in a way that includes the instrument within the space of our body, in the field of its functioning.

Amoeba, and momentary organs

One of Bergson's examples (1907) is the amoeba. The amoeba is a mass of protoplasm, he says. In some sense, it doesn't have organs. But when it encounters food, the membrane which envelops the mass opens in a sort of mouth. That mouth is an organ which lasts the time of its function. Once the food has been swallowed, the mouth becomes an internal bubble, which englobes and digests the bite, a kind of momentary stomach. Then the bubble reaches the surface, the membrane opens again, and even this new organ of expulsion lasts the time of the expulsion, a sort of temporary anus.
What is interesting in Bergson's example (Leoni, 2019)? The idea that there are organs that are in such a profound continuity with the organism, that not only can't they be classified as external instruments, like a hammer or a bicycle, but neither as internal organs such as our heart or our lungs. Heart and lungs are stable organs, stably characterised by a certain physiology, stably engaged in a certain function. Amoeba organs, on the contrary, are the organism itself, temporarily declined, temporarily folded on itself, in a sort of doubling or difference which is differentiating but also and always undifferentiated in those differentiations. Moment by moment, every fold unfolds, and recreates itself in another point, responding to another occasion, developing another function. Amoeba organs coincide with the time of their operation, and in a sense they are nothing different from their actual operation.

Hearts and bicycles

The question of time is always instructive. Let's try to extend Bergson's suggestion. Let's interrogate our instruments in the perspective of his example. All our instruments are stable objects. After their use, they continue to exist, they remain identical to themselves, they are at our disposal for the next time.
We could classify instruments on the basis of their duration. Do they last the time of their operation? Do they last longer than their operation? How much longer? Our heart is not a momentary organ, it is a heart from the beginning to the end of our life. My bicycle is an even less momentary organ, it continues being a bicycle all my life and more. It will be a bicycle for my son, and for those who will eventually buy it in some flea market. Also death is always an instructive anthropological indicator.
What does this stability of the instrument imply? What happens when this stability increases to the point that the instrument lasts longer than the moment of its operation, or more than the time of the life of the living being it had to assist? What happens when the instrument becomes so stable, so self-identical, so resistant

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to every kind of change, that every organism encounters it as something completely external and other? We could answer in one word: Culture is born. Old instruments remain for new subjects, and the new subjects will share with old generations something which is more stable, more binding than them, something which sets the law to which the organism or the subject must respond.

As we can see, time is the great operator of all these differentiations. The different duration establishes the great difference between what we usually call organ, and what we usually call instrument. It is not a difference of nature but of grade. It is not a difference among two fields but the differentiation of the one and only field. The different temporalities determine the variable geometry of the use. The more the instrument lasts, the more the organism appears used by it. The less the instrument lasts, the more we tend to see the instrument as an organ, and the organism as the subject which uses the organ. The Greek knew something about this continuity, and Bergson takes advantage of their wisdom when he plays on the threshold of the Greek word "organon", which is at the same time the biological and internal instrument and the technological and external organ.

Wasps, and scale errors

Let's go back to wasps. Bergson underlines one or two things which assume great importance in his analysis (Bergson, 1907, chapter 2). The wasp, he says, always knows where to sting the prey, typically the caterpillar. The wasp, he adds, always knows when to sting the caterpillar.

We could say that, within this landscape, there is no space to hesitate, nor to formulate a question. Where should I sting it, when should I sting it? The answer comes immediately. So we must understand the nature of this odd thing, an answer which comes immediately. This is the pure concept implied in the conceptual character of the wasp. There is no time to cross, no space to cross in order to act. In a way, all is already present. But what is an answer if it is not an answer to a question, what is an action, if it doesn't follow another distinct action? We may say, what is an answer which answers itself?

If we follow these questions, we are forced to an utter disconcerting conclusion. The wasp and the caterpillar are a one and only thing. If anything, we must consider the caterpillar as a momentary organ of the wasp, a temporary extension of its body, or the wasp as a momentary organ of the caterpillar since we know that organs don't always peacefully cooperate. In other words, the hostility of the two is not an argument against the idea that they are a one and only thing. More exactly, we must consider the wasp and the caterpillar as momentary organs, as temporary foldings, coordinated because they differentiate out of a larger but unitary organism, which in some ways has no definite time borders and no definite space dimensions.

As long as we keep on describing two separate organisms, we don't understand what's happening and how it can happen. How can the wasp never fail? What gives her the knowledge about the right place to sting, the right time to attack? When we study them as a unique organism, many problems fade away. It is no longer a question of knowing or not knowing the right time or place. It is no longer a question of choosing among many times and many places, or which one would be the right one. There is a one and only organism, a one and only time, which must be the right one because there is no other time, no succession of separate instants. A one and only place, which must be the right one because it doesn't involve an extension of points external to each other. A one and only action, which is not the juxtaposition of two partial actions, stinging and being stung. A one and only event.

Let's briefly meditate on this thing we call event. It must be an impersonal event, which passes through its various parts and elements and characters. An event which is wasp and caterpillar, a wasp which encounters itself as a caterpillar, or a caterpillar which encounters itself as a wasp. Or a third thing without a name, which encounters itself and which evolves, in each encounter, into two or more different directions that we can call, for example, the wasp and the caterpillar. The scene was described with a scale error (Leoni, 2019). We must not think in terms of single elements, or organisms, or species, but in terms of blocks, couplings, concatenations, coevolution (Thompson, 1994). We have to think in terms of differentiations in progress, not of already differentiated and separated differences (Deleuze, 1967). And we should say that the more each difference pushes its differentiation forward, the more it finds at the bottom of its difference the other differences, the other differentiations, the other apparently extraneous lines. The more the wasp becomes the wasp, the more it becomes the caterpillar and all other beings which are implied in the caterpillar's life, evolution, differentiation. The more one thing becomes that thing, the more it realizes in its perspective all other things. That's what we call an impersonal event or process: a generality, but also absolutely singular; an omnidirectional totalisation, centered around an event which is always absolutely unique.

Chimpanzee and externalized organs

Let's consider some classic observations about chimpanzees (Kohler, 1925). When they want to reach a banana that is fixed up too high, they know they can use a stick to reach it. They search for the stick, they hit the banana, they eat it. And then what do they do? They abandon the stick. a presence for him even when it is still absent from his perceptual field. But the stick has no general presence, it doesn't gain a presence that is really independent from the actual situation. The day after, the primate will search for another stick, it will use it, and will forget it again. From this point of view, the primate hasn't emerged from that dimension of temporary technologies, which has its greatest paradigm in the amoeba. From another point of view, the primate knows so well that those momentary organs are instruments, that he can search for them, he can anticipate their presence in his surroundings, he can imagine those functions externalized and projected in a somewhat objective field of possibilities. The organ is becoming an external instrument, it will become a sediment in the external space. Or, better said, space is becoming for the first time something external. And the subject is becoming something internal and properly subjective.

It is on this line of externalization of internal and temporary organs, that we find *homo sapiens.* At one moment man coopted some less aggressive wolves and integrated them in the human herd (Shipman, 2015). He learned to trust them in various situations, hunting for example. His nose became less and less sensitive, but his hunting became more and more efficient. Should we say that man has lost the sense of smell? No, it is exactly the opposite. He increased it by coopting and integrating in a kind of extended and collective organism those new external organs called dogs (Ruyer, 1952). The history of the coevolution of this human-canine concatenation is the history of the externalization of the human nose, at least when we tell the story from the human point of view. The case of the hammer or the bicycle is not so different. They are externalized hands and legs. The mark of this complete externalization is the trivial fact that when we are done with them, we put them on a shelf or in a garage. We should meditate the extraordinary power of the invention of the shelf (Giedion, 1948), the space of the available instruments, the instrument which maintains, within the frame of an infinite presence, all our absent instruments. The shelf frees our instruments from every temporary character, detaches them once and for all from our body and from its ongoing operations. The shelf is the invention of future, the matrix of the possible, the condition of every human chronology, the transcendental space which gives presence to the absence by making absent from now on any kind of presence.

Entomology and information technology

Yet something new happened since the hammer and the bicycle appeared. What kind of instruments have we built in the last fifty years? Are our technologies more of the "hammer and bicycle" type, or are they more like the "momentary mouth and stomach" type? Didn't we realize something new, something we are thinking of in terms of technology, but we should understand in terms of organology?

We begin to realize the value of that strange symptomatology of contemporary philosophy. Bergson talking about wasps, Heidegger about bees, Maldiney and Deleuze about ticks, and many others we could cite. Consider information technologies. As we all know, they are everywhere, none of our activities happen without intertwining some form of informatic support. Having a coffee, shopping at the supermarket, working at the office or at home, dating or going to the cinema, every daily gesture is faithfully accompanied by what has been called the celestial providence of the algorithm (Alizart, 2017). Laptop computers and mobile phones are the materialization of this unceasing informatic companionship. All of our operations converge in those little tabernacles, and from those little tabernacles our operations restart towards many devices and operations.

But we must not be fooled by their humble dimensions. The fact we can hold them in the palm of our hand or keep them on the small surface of our desk doesn't mean much. Since they minutely encode every gesture within their grids, since they monitor every action moment by moment, they provide us with a sort of environment. This tireless operativity of the algorithm is the factor that converts an instrument into an environment and commutes this environment from an external and inertial container into an active space within which all events must take place. The subtle rain of questions it addresses towards us is the factor that constitutes all our behaviours as a repertoire of answers minutely and immediately adapted to the questions, so that the questions cannot find within the answers anything but themselves. Algorithms are talking to themselves through us.

The continuous character of this monitoring profoundly recalculates the nature of the actions of those subjects we used to be. Our actions were a set of instruments disposed on the shelf of the possibles. We were subjects because of the distance we had with respect to those objects of our questioning. The time of the hesitation among the possibles was the time of the subjectivation of these actions and the root of the illusion of our freedom (Bergson, 1907). All of this is now recalculated in terms of a process within which the time of the question increasingly coincides with the instantaneous time of the answer, so that the form of the subjective decision increasingly resolves into the form of a continuous and imperceptible autoregulation of the system. We don't decide on an action, but we participate in an impersonal operation. This operativity without a subject performs by itself by recalculating in every instant its motionless movement through our bodies and minds.

This kind of technological regime is an organological regime.

The sphere of the information technology is something of an organism. Users are its momentary organs. Our activities are its offshoots, moment by moment aroused and dismissed, instant by instant shaped out of precedent applications and abandoned to forthcoming applications. We are the momentary mouths, the temporary stomachs of an extensive and translucid informatic amoeba, hence the feelings of solitude and hyperconnection which coexist so typically in our time and anthropological type. But those who suffer from this contradictory affect suffer from the hesitations of every half-breed being. We are going towards the operativity of a wasp's nest, but we are also forged by old instruments that continue to breed old feelings of subjectivity. If we look forward, we see that the mixture will resolve by itself. The subject-form will decline more and more, and the entomological paradigm will absorb ever higher quotes of our experience.

Bergson is the great symptomatologist of this organological mutation of our technologies. He talks about wasps and caterpillars, but he is speaking about us. We could repeat what was said about them. Until we describe certain phenomena by distinguishing two things, for example nature and technology, bodies and instruments, subjects and environments, we don't understand what is happening and how it is possible for it to happen. How can the wasp always know the right place to sting, the right time to attack? When we assume there is a unique organism which folds upon itself, which doubles and differentiates itself in each fold, and which, for this very reason, perfectly coordinates and corresponds with itself in every fiber, a whole series of enigmas fade away. It is no longer a question of knowing or not knowing, or of choosing the right time and place among many times and places. There is a one and only organism. There is a one and only time which must be the right time because it is the only time, a vast present pulsating everywhere. There is a one and only place which must be the right place because it is the only place, a unique space pulsating of many inner spaces. There is, in one word, a one and only event, a one and only complex which is completely natural or completely artificial, the difference between natural and artificial being the effect of a class of instruments which are no longer our prevailing instruments. This third thing is what encounters itself in every instant and in every encounter diverges, sediments in points that keep on becoming into different directions, breeding within their unique bubble wasps and caterpillars, bodies and instruments, inner spaces and outer spaces. Our technologies are organologies and our experience has been minutely described not by our modern psychological disciplines but by our eternal and changeless mystic tradition (Bergson, 1932).

REFERENCES

Alizart, M. (2017), *Informatique céleste*, P.U.F., Paris, France.

Bergson, H. (1959), *L'Évolution créatrice* (1907), Oeuvres, P.U.F., Paris, France.

Bergson, H. (1959), *Les Deux sources de la morale et de la religion* (1932), in Oeuvres, P.U.F., Paris, France.

Deleuze, G. (1967), *Différence et répétition*, P.U.F., Paris, France.

Deleuze, G. and Guattari, F. (1995), *Qu'est-ce que la philosophie?*, Paris Minuit.

Giedion, S. (1948), *Mechanization Takes Command. A Contribution to Anonymous History*, Oxford University Press, Oxford.

Heidegger, M. (1983), *Welt - Endlichkeit - Einsamkeit. Die Grundbegriffe der Metaphysik* (1929-1930), Klostermann, Frankfurt a.M.

Koehler, W. (1925.), *The Mentality of the Apes*, Kegan Paul,London, United Kingdom.

Leoni, F. (2019), *L'automa. Leibniz*, Bergson, Mimesis, Milan, Italy.

Maldiney, H. (1991), *De la transpassibilité, in Penser l'homme et la folie*, Millon, Grenoble.

Ruyer, R. (1952), *Néofinalisme*, Gallimard, Paris, France.

Shipman, P. (2015), T*he Invaders. How Humans and their Dogs drove Neanderthals to Extinction*, Harvard University Press, Harvard.

Thompson, J.N. (1994), *The Coevolutionary Process*, University of Chicago Press, Chicago.

FUTURE SCENARIOS. A cinematic perspective

François Penz,
Cambridge University, United Kingdom
fp12@cam.ac.uk

«Later, as he sat on his balcony eating the dog, Dr Robert Laing reflected on the unusual events that had taken place within this huge apartment building during the previous three months» (Ballard, 1975).

Ballard's brilliant opening sentence could be construed as summarising today's world events – a thoroughly unhinged and disturbed world and for which Ballard's High-Rise can, in part, act as a metaphor. Ballard's vision of 1975 was subsequently successfully translated for the screen by Ben Wheatly and Amy Jump in 2015. The film is an adaptation not of a future imagined in 2015 but of how the future would have looked forty years earlier – a form of retro backcasting. Wheatly explained: «The future Ballard was projecting was forward of '75 and we have lived into that future. We were making a futuristic film about a projected past and because we have seen what happened and Ballard saw it coming down the pipe [...]. The film is a look at the book from the perspective of the people that survived it. We are in a perpetual 70s/80s/90s. Boom followed by bust, then boom followed by bust again» (Wood, 2018).

High-Rise's enticing trailer's voice-over[1] evokes perfectly the potential of a better future, inviting us to be immersed into a carefully constructed film world: 'Ever wanted something more? Ever thought there could be a better way to live free from the shackles of the old tired world? This development is the culmination of a lifetime's work by esteemed architect Anthony Royal. The high-rise has 40 floors of luxury apartments filled with every modern convenience. Onsite we have a fully stocked supermarket, gym facilities, swimming pool, spa and school, there is almost no reason to leave [...] ...so why not join us...join us!'».

But the promise of this better future turns out to be a chaotic nightmare; a fast spreading epidemic of violence amongst residents soon reaches pandemic proportion, leading to self- isolation and barricades, while fighting over nearly empty supermarket shelves. Presiding over this fine mess is the god-like-figure of the architect Anthony Royal, who symbolically occupies the whole penthouse floor, most of the time hunched over his drawing board, dressed in full modernist attire, and seemingly unperturbed by the chaos below. Allegedly Ballard had been inspired by the example of modernist architect Ernö Goldfinger, who «had famously moved into Flat 130 of the Balfron Tower for two months in 1968 to "test" the design of the building» (Luckhurst, 2016).

In search of film sets, Wheatley was inspired by a range of buildings, especially Le Corbusier's Unité d'Habitation in Marseille inaugurated in 1952. The influence is palpable with the High-Rise supermarket halfway up the building and the gymnasium on the roof. Wheatley embraced the brutalist aesthetic of the béton brut that had been sprouting everywhere in London in the 1960s and 70s. Indeed the model of L'Unité d'Habitation in Marseille had paradoxically more resonance in London than in France. «In the United Kingdom the celebrated near-realization of such a ville radieuse would be the Alton West Housing project (1955-59), Roehampton Lane, London, on its sylvan site sloping towards Richmond Park, built under the LCC team [...]» (Kite, 2010).

Memorably, the Alton West Housing project, the English vision of la ville radieuse became the prime location for François Truffaut's translation of Ray Bradbury's dystopian vision of Fahrenheit 451 (1966), the setting of a repressive, totalitarian regime seeking out to burn all books. Stanley Kubrick, with *A Clockwork Orange* (1971), also used to good effect the emerging brutalist architecture of London South Bank and the newly constructed Thamesmead Estate in East London. The new modernist aesthetic and the purity of the form afforded by le *béton brut* had become shorthand for dehumanised spaces, the perfect setting for Alex and his 'droogs' to indulge in a 'bit of ultra-violence'.

High-Rise, Fahrenheit 451 and *A Clockwork Orange* have all in common that they associate modernism and brutalism with dystopia – and we may ask ourselves – why is that? Why is it that the new aesthetic found itself associated with violence, fascism and debauchery? The explanation resides partly in the fact that in the 1970s the brutalist aesthetic was very unpopular at the time – indeed «it is hard now to recollect quite how much high-rise housing was demonized and despised in the mid-1970s. After the 1968 collapse of the system-built Ronan Point [...], towers essentially stopped getting built, with the assumption that they were unsafe structurally and potentially hugely damaging socially, creating 'no-go areas' and dystopias [...]» (Hatherley, 2016).

In fact, if we look at the history of cinema, modernism is almost invariably associated with dystopia, as remarked by Andersen: 'The most celebrated episode in Hollywood's war against modern architecture is *L.A. Confidential*. Richard Neutra's Lovell house, the first great manifestation of the International Style in southern California, plays the home of Pierce Patchett, pornographer, pimp, prince of the shadow city where whatever you desire is for sale'[2]. The implication is that by associating modern architecture with characters of dubious reputations, such as Pierce Patchett, cinema is seen as being critical of modernism. There is a perceived reflexive relationship between the setting and the action, between the architecture and the film's narrative. In other words, the Lovell House found itself tarred with the same brush as the criminals that occupy it[3].

This mechanism of association between space and narrative is central to cinema. In order to convey the required dramatic effect, filmmakers carefully select architectural features to underline the emotion of the drama. This device can be referred to as "spatially organised drama", whereby a narrative, a story, is both spatially and dramatically organized. And the choice of location

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and architectural setting is paramount to a successful *mise-en-scène* underline the emotion of the drama. This device can be referred to as 'spatially organised drama', whereby a narrative, a story, is both spatially and dramatically organized. And the choice of location and architectural setting is paramount to a successful *mise-en-scène*.

Cinema constructs very approachable worlds that we are invited to enter and share in the same way as we would enter a home. As spectators we become fully immersed into a carefully crafted biosphere with its own ecology and climate, the architectural equivalent would be what architect Peter Zumthor calls 'atmosphere' (Zumthor, 2006). Every detail counts in order to maintain this carefully crafted ecology. Therefore the association of a modern building in a film is never an accident but a deliberate choice to serve the purpose of the narrative – and more often than not, it turns out to be a site for a dystopic narrative. In the case of the Lovell House and *L.A. Confidential*, the architecture critic of the Los Angeles Times attempted to explain this mechanism in the following terms: «The house's slick, meticulous forms seem the perfect frame for that kind of power [...]. Neutra's glass walls open up to expose the dark side of our lives - they suggest the erotic, the broken, the psychologically impure»[4]. While Neutra would have no doubt turned in his grave at this suggestion, it does raise the question of the gap between the vision of a modernist architecture and its perception and reception by the general public. And cinema, especially the so-called Hollywood cinema, as a popular medium partly reflects and capitalizes on the collective imagination of the masses. Le Corbusier's spirit of *L'Esprit Nouveau* presented in the celebrated photographs of the Villa Savoye exemplifying a new way of life, «a vision of certain eternal goods: the loaf of bread, the can of milk, the bottle of wine, light and air, access to the earth and the sky, physical health» (Anderson, 1987) remains a hard sell!

But whether it is Le Corbusier or Anthony Royal, architects always plan for the future – imagining a world not yet in existence, and in that sense they are futurists. Their work is evocative of new worlds and may help us to think of possible responses for future living. Planners and urbanists also need to have a long-term vision. By contrast nobody expects filmmakers to propose achievable future visions – although they occasionally try, for example in science fiction films, a particular genre not discussed in this essay. The vast majority of films are about the present addressing issues of the time. And if anything, when a film is released, the images projected on the screen are already of the past – however recent – same for photography – and this temporal gap can never be reduced. But this ontological challenge is no handicap for the value of film as rightly argued by Žižek: «in order to understand today's world, we need cinema, literally. It's only in cinema that we get that crucial dimension we are not ready to confront in our reality. If you are looking for what is in reality more real than reality itself, look into cinematic fiction» (Fiennes, 2006).

I regard fiction film as a barometer, an indicator of societal issues and I subscribe to Ferro's view that «In its relation to society and history, film was for a long time treated only as a work of art [...] Grasping film in its relation to history requires more than just better chronicles of the works or a description of how the various genres evolved. It must look at the historical function of film, at its relationship with the societies that produce and consume it, at the social processes involved in the making of the works, at cinema as a source of history» (Ferro, 1983, p.358). Toubiana goes further by taking a specific example, that of Jacques Tati: «Tati has filmed something essential in the course of the 20th century: he filmed the countryside, the everyday life in the countryside (Jour de fête), then he filmed 'la vie pavillonnaire' (*Mon Oncle*) [...] he especially filmed and captured in an ultra- sensitive manner, not unlike a virtuoso seismograph, the passage from the countryside to the city, this epic migration of man and objects from an ancient world towards the modern world [...] Everything was changed, the gestures, the trajectories, the atmospheres, the way people dressed. And of course the architecture. The Villa Arpel in *Mon Oncle* was replaced by the ultramodern buildings of *Playtim*e [...] words only can't convey such scale of transformation. That's why Tati's films are mute. They just exist. They are visual noises. They observe with a very precise look, they drill an entomologist's gaze onto the human world» [5] (Makeieff *et al.*, 2009) (Toubiana, 2009).

Parasite (Bong Joon-ho, 2019) provides a more recent example from which we can derive very similar observations. It is not only a hugely successful award-winning film, highly gripping and entertaining, but also a poignant exposure of Seoul's social structures and inequalities – an excellent example of film as an agent, product and source of history (after Ferro). The contrast between rich and poor is laid bare as the story reflects on the lives of the urban poor living in semi-basements, while the wealthy reside in the upper part of Seoul. Predictably the wealthy family in *Parasite* lives in a stunning modern house (a studio set), another prime example of the modernist aesthetic association with dystopia. But more to the point within the context of this essay, *Parasite* is shot in a present that will influence the future as the South Korean Government has announced that, as a direct result of the film, it will offer substantial grants to improve the semi-basement dwellings with a view «to enhance heating systems, replace floors, and install air conditioners, dehumidifiers, ventilators, windows and fire alarms»[6]. This is a particularly vivid and direct example of what Keiller had predicted: «In films, one can explore the spaces of the past in order to better anticipate the spaces of the future» (Keiller, 2013).

For the purpose of this essay, I have assigned to fiction films a number of crucial characteristics and features. Key to my argument is that the filmic image shows the visible side of a society and an epoch that image makers try to grasp in order to transmit it. And that it constitutes a valid mode of observation to reflect on future scenarios. Film has also the advantage of simplifying a complex reality, making it more digestible. It can be construed as a form of 'equipment for living', providing an accelerated education in experiencing convoluted situations.[7]

In the light of this hypothesis, I am proposing to do a rapid survey of the history of future scenarios as portrayed in cinema, concentrating on how the architecture and the city have been represented. As highlighted above, the architecture in film is never a mere background but a crucial part of the narrative from which we can derive some insights as to how historically the future was envisioned.

It would be difficult to discuss how films have depicted the future without mentioning Fritz Lang's *Metropolis* (1927), with its celebrated vision of the future city inspired by Manhattan. In the same breath we must mention *Things to Come* (William Cameron Menzies, 1936), HG Wells vision of the future city which is purposely diametrically opposed to *Metropolis* as the new city has developed underground. So, no agreement there as to what the future would look like and that's at least a consistent aspect of future depictions on the silver screen, they are all slightly at odds with each other. But interestingly both *Metropolis* and *Things to Come* are projected in a faraway future, a 100 years on. They also both hail a rather positive future where technologies are a central part of life.

Following from that, and pre-World War II, we find films that evoke what I would call the near future, looking only at 10 to 30 years ahead. Such a selection would include Murnau's Sunrise (1927), where the city is inspired by the Bauhaus or Maurice Elvey's High Treason (1929), a London in 1940 made of existing buildings and 'new ones'. *A Nous la Liberté* (René Clair, 1931) also fits this category with Lazare Meerson's acclaimed sets of the assembly line factory that evokes a prison, an idea that Chaplin would perfect in *Modern Times* (Charlie Chaplin, 1936). All such movies create a near future made of carefully constructed film sets entirely inspired by modernism. And on the dystopian scale, it is a rather mild form, especially in comparison to *High-Rise, Fahrenheit 451* and *A Clockwork Orange*.

Post-World War II, the near future grouping would include *Tati's Playtime* (1967), a near future film, based on the Seagram building. It evokes what *Le quartier de la Défense* in Paris would look like in the 1990s. The Villa Arpel scenes in *Mon Oncle* would also fall in this category. Both films are a humorous and rather gentle critic of modernism. In the same category we could also include the evocation of future cities but using the existing city such as Godard's *Alphaville* (1965) entirely made up of existing locations in Paris. Truffaut's *Fahrentheit 451*, already evoked, also uses the existing fabric of the city, ditto for *A Clockwork Orange*. Similarly, Chris Marker's *La Jetée* (1962), a dystopian authoritarian vision of a future society, is set in the aftermath of World War III in a post-apocalyptic Paris and is entirely shot in existing buildings. The trend in using existing cities evolves further with *La Mort en Direct* (Bertrand Tavernier, 1980) shot in Glasgow. Most famously *The Truman Show* (Peter Weir, 1998), shot in the existing town of Seaside Florida, is an Orwellian big brother vision of the world. Worth also mentioning is *Gattaca* (Andrew Niccol, 1997), shot in Frank Lloyd Wright's last building project, Marin County Civic Center (CA, USA), which tackles the emergence of a disturbing biological future.

Closer to us is *Children of Men* (Alfonso Cuarón, 2006), a film where London, subject to terrorist attacks, is fully recognizable. Michael Winterbottom's *Code 46* (2003) also belongs to the near future group, a useful film because of the way it brings in visions of the globalized future cities – Shanghai, Dubai, etc. – offering a culturally diverse vision of the future. But there is no longer grand cinematic vision as explored by *Metropolis* and *Things to Come*. One of the latest examples of what could be construed as an atrophied vision is *Vivarium* (Lorcan Finnegan, 2020). Gone are the grand and utopian architectural gestures to be replaced by an endless labyrinth of cloned detached houses out of which a young couple will never manage to escape. The most disturbing element in *Vivarium* is the estate itself, the endless suburban pavilions that remind us of what Graham Greene wrote about the semi-detached houses: «these houses represented something worse than the meanness of poverty, the meanness of the spirit» (Greene, 2001). It makes us yearn for the chaotic environment of *High-Rise*.

There is also a perceptible erosion of the belief that technology and science can solve problems. In fact, as we progress across the 20th century to present days, films imply that technologies and sciences have become the problem as opposed to the solution. What also emerges out of this quick overview, is that films looking at the future have a tendency to look at no more than 10 to 20 years ahead – *Children Of Men* a 2006 film is set in 2027 or they may stand outside time as with Michael Hanneke's *Time of the Wolf* (2003). The bold 100 years future visions of *Metropolis* and *Things to Come* are no more. Several films in the 1960s and 1970s were an evocation of the year 2000 e.g. Godard's *Alphaville* and Truffaut's *Fahrentheit 451* are set respectively in 2000 and 1999. But a different tendency emerges past this landmark. A particularly poignant case is *Amélie* (Jean-Pierre Jeunet, 2001), a film rooted in the present but harking back to the poetic realism of Marcel Carné, Doisneaux and Prévert of the 1930s. It indicates that the past is more reassuring than the future. In the same vein, we could add the Harry Potter franchise; its popularity indicates that there is reassurance in looking at a past of mythology and waving magic wands. The history of future scenarios as portrayed in cinema indicates that filmmakers may have lost sight of the future, their entomologist vision is getting blurred. Cinematic futures are getting closer and closer to the present – to the point of looking to the past. There is no Hollywood happy ending for future scenarios – architects remain the only true futurists. But one thing that films teach us for sure is that whatever future we may consider, it will be dystopian to a degree.

NOTES

[1] Available at: https://www.youtube.com/watch?v=XRBeZGYisLg.

[2] Voice-over in Thom Andersen's *Los Angeles Plays Itself* (US, 2003).

[3] For a more detailed explanation see Penz, 2017, p. 121.

[4] Voice-over in Thom Andersen's *Los Angeles Plays Itself* (US, 2003).

[5] My own translation from French.

[6] See: http://www.koreaherald.com/view.php?ud=20200218000706.

[7] I have developed this argument at some length elsewhere, see Penz, 2018, p. 55.

REFERENCES

Anderson, S. (1987), "The fiction of function", *Assemblage*, Vol. 2, pp. 19-31.

Ballard, J.G. (1975), *High-rise / J. G. Ballard*, London: Jonathan Cape, London, United Kingdom.

Ferro, M. (1983), "Film as an agent, product and source of history", *Journal of Contemporary History*, Vol. 18 (3), pp. 357-364.

Fiennes, S. (2006), *The pervert's guide to cinema by Slavoj Žižek.*

Greene, G. (2001), *A Gun For Sale: An Entertainment*, New Ed. edition, Vintage Classics, London, United Kingdom.

Hatherley, O. (2016), "Crimes of the retro-future: historicising J.G. Ballard and Ben Wheatley's High-Rises", *Critical Quarterly*, Vol. 58 (1), pp. 70-75.

Keiller, P. (2013) *The View from the Train: Cities and Other Landscapes*. Verso.

Kite, S. (2010), "Softs and Hards: Colin St. John Wilson and the Contested Visions of 1950s London", Crinson, M. and Zimmerman, C. (Eds.), *Neo-avant-garde and postmodern: postwar architecture in Britain and beyond*, Studies in British art, New Haven, Conn., Yale University Press.

Luckhurst, R. (2016), "High-Rise 1975/2015", *Critical Quarterly, Vol.* 58 (1), pp. 63-69.

Makeieff, M. *et al.* (2009), *Jacques Tati: deux temps, trois mouvements*. Paris: Naïve: Cinémathèque française.

Penz, F. (2017), "Absorbing cinematic modernism: from the Villa Savoye to the Villa Arpel", in Cairns G. (Ed.),*Visioning technologies: the architectures of sight*. Abingdon, Oxon; Routledge, New York, USA., pp. 121-135.

Penz, F. (2018) *Cinematic Aided Design: An Everyday Life Approach to Architecture*, Routledge, New York, USA.

Wood, J. (2018), Ben Wheatley on High-Rise: "We were making a futuristic film about a projected past", *British Film Institute*. Available at: https://www.bfi.org.uk/news-opinion/news-bfi/interviews/ben-wheatley-high-rise (accessed 28 April 2020).

Zumthor, P. (2006), *Atmospheres: Architectural Environments - Surrounding Objects*, Birkhäuser GmbH.

WHAT'S THE MATTER? MATERIALITY AND COMPUTATION IN A STUDIO AT THE AGE OF ENVIRONMENTAL ANXIETY.
An experimental approach to architectural education

George Katodrytis,
American University of Sharjah, United Arab Emirates
gkatodrytis@aus.edu

The stagnation of current architectural education is attributed mainly to two factors. On the one hand we have all embraced universality, and on the other we are all using the same tools. This is a new form of global modernity; the production of international and well-mannered architects. There is very little difference, variation and specialized focus that enable students to develop individual architectural approaches. The prevailing modernist heritage is prone to dogmatic attitudes of design and prescriptive teaching methods.
The second half of the twentieth century was a time of change marked by increased global mobility and the exchange of ideas; a context full of diverse approaches that occurred at the end of Modernism. The beginning of the twenty-first century was time to explore new perceptions and innovative technologies such as the micro scales, materials that perform, architecture that adapts and the environment as a dynamic agent; architecture is part of complex micro systems of ecology, chemistry and biology, and not only physics.
Architectural experimentation is conducted through representation and embraces estrangement, opposition and resistance that attempts to transgress boundaries. More than just a graphic device, the act of speculative drawing and representation is a form of architectural inquiry unto itself. Pedagogy becomes again a primary agent within architectural culture. Yet representation is now shifting from mere abstracted or figurative illustrations to simulations and a new form of procedural and volumetric growth. It is possible now to transgress the limits of architecture through replication, reproduction and time-based processes.
To provoke an even more challenging process of discovery, design studios of architecture can establish a starting point that is non-architectural. A project would then follow a specific design process, an incubator of ideas, which involves experimentation, intellectual rigor, precision, continuous testing and evolution of propositions. The first version of the students' concepts is prepared before considering the program or the site. We need more non-linear thinking systems that do not seek obvious and predictable outcomes. The notion of 'lateral' causes thinking 'out of the box'. Purely skill-driven design modes stand out, but this is not enough. In the ear of abstract technological influences, it is fundamental to maintain and foster a studio focused on culture as a basic pre-condition for learning and as a platform for experience and interaction.
The work of an architecture studio should investigate the impact of innovative technologies on current design practices. The process looks at advances in new digital media and materials or biotechnology within a design context that is increasingly more interdisciplinary, while simultaneously focusing on a new spatial, programmatic and linguistic dimension of architecture.
The design of habitats today is being shaped by the outcomes of two key revolutions, material technology and computation, and our exposure to the long-lasting effects of climate change. Nature plays a central role that goes beyond being a simple environmental regulator or inspiration; it is a system of ecologies and complex, subtle behaviors. It is not organic or biomimetic but a new Avant Garde of expressions, efficiencies and impulsive simulations.
A discussion on aesthetics and the unpredictable dimension of nature and growth challenges our traditional preconceptions in favor of more a contemporary understanding of tectonics and new aesthetics, which includes more three-dimensional, complex and unique patterns and typologies of occupation.
The crucial motivation of this cross-disciplinary research is a new and holistic approach in design. This method involves an ecological understanding of landscape and urbanism in which the concept of sustainability is understood as a dynamic agent rather than an outcome to satisfy green ratings. The influence of local traditions, the research of socio-economic conditions, and the role of digital design is complemented by a coherent employment of innovative technologies in the field of energy and materials. This research focuses on new experimental design solutions that are anarchic, formal, material and with a spatial three-dimensional complexity. A major area of research is the architectural, urban and environmental strategies in extreme rural (desert) and urban environments.
Paradoxically, the research-driven approach makes projects unique. Material and fabrication studies and spatial iterations (programmatic possibilities and user experience) are then transformed into systems (typological variations) that are subsequently interrogated, adapted and applied to unpredictable sites and contexts. Issues of program and site are components to define a project rather than to generate it. The discomfort and rawness of the architectural project could work in opposition to a site, a 'lateral' thinking approach that generates a discourse. It is more meaningful to make architectural spaces of quality, open and pure, (referring here to the modernist dogma) that can adapt to time and transformations rather than offer a quick solution to solve a site problem which, by default, is temporary and fake. Abstraction here supersedes figuration.
The sequence of operations in the process follows a logical structure: concept, narratives, tools and machine, physical modeling, digital modeling and scripting, simulation, systems and iterations, representation, prototyping and detail and ultimately a fabrication. It is a sequence of continuous and rigorous transformations.

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The studio progresses in a series of stages, with each stage corresponding to an increase in complexity, scope and scale. The quality of both the process and the outcome are equally important. By adopting contemporary practices such as modeling in physical and digital form, the work of the studio attempts to go beyond some of the preconceived limitations of architecture, notably that of the traditional sequence of site, program and solution. We like the incomplete, raw, crude, unpolished and endless potentialities of architecture; atmospheric than glossy. The studio is interested in questioning as to what architecture might be—not what architecture is already understood to be, or how it is already created and practiced.

Studio projects develop an architecture that is built up by many different layers of applied scientific knowledge, software-based morphologies, micro-worlds and intelligent environments such as physical and chemical forces, gravity, fluid dynamics, particles and temperature. This is a type of performative application rather than aesthetic composition. Dynamics, topology and systems then become tools that pertain in large degree to the control and manipulations of formal strategies.

The studio reconsiders architecture as an eco-system that mediates between environment and inhabitation. We look at the new challenges posed by climate change and how this thread can recondition architecture and its materiality. Climate change offers an opportunity for creative architectural interventions more than solely policies. There are opportunities to include changes in cultural and social behavior. The challenge is to engage with an architecture that renegotiates the boundaries between the natural, the artificial and the visionary.

The studio seeks intense design experimentation for ambiguous proposals situated at the intersections between technology, landscape and art. Students are encouraged to develop individual research themes, narratives and manifestos. They are asked to imagine a fictional construct and present it through a series of intricate (small and large) drawings. We combine disruptive technologies and experimental materials with hybrid drawing and modelling techniques.

Architecture is liberated and it starts as an open field. Projects describe narratives and time-based concepts. They include scientific research on found, natural or artificial material, its behavior, its application and its imaginary projection.

The studio encourages digital and analogue making, shifting quickly between the hand and the computer. We juxtapose organized and spontaneous systems and arrive at hybrid structures and programs. We begin by selecting themes that will explore the potentials of formlessness and experiments with appearance that cannot be reduced to a singular figure or shape and maintain a tendency towards change, transformation, openness and ambiguity. We reimagine architecture as the link between the real and the imaginary.

Architecture is drawing, making and simulating space. We think through seeing and doing. Doing can also be seen as a ritual act analogous to everyday habitation, the rhythms, cyclical repetitions and irregularities that determine the social life of buildings. Historically, architecture begins with a concept, an overall strategy and a pre-meaning that justifies the design of buildings. This studio proposes a re-examination of design as an autonomous act influenced by selected parameters to inform a form-generation process and outcome. These parameters can be internal and external, programmatic and behavioral.

The challenge is to engage with an architecture that renegotiates the boundaries between the natural, the artificial and the visionary. And the glossy object becomes experiential.

URBAN DATASCAPES[1]

Carlo Ratti,
Sensible Lab MIT and CRA, United States

ratti@mit.edu

In a short story written in the late 1960s, the Italian writer Italo Calvino imagined a dystopian society in which every detail and every moment is recorded for posterity. All information would be compiled into the greatest document ever conceived, blending the details of every individual life. The concept is problematized by intrigue and paradox surrounding information control and deletion, and a final twist puts an uncanny spotlight on the condition of absolute archiving. How will humanity remember itself? And how will it act when it knows that it is being recorded? These are prescient questions for a society that, today, is confronted with a similar situation of total recall.

Fifty years after the first publication of "Memory of the World", data is turning Calvino's fiction into a reality. As digital technologies become increasingly pervasive, permeating our physical spaces with the Internet of Things, every individual is generating a staggering amount of data. It is not always easy to precisely quantify how much aggregated data our digital society is producing. In 2016, it was famously estimated that, in that year alone, mankind produced as much information as had been created since the beginning of human civilization. One can also consider this sense of scale through our billions of everyday digital devices, most of which contain more computational power than NASA wielded in the time of Apollo 11. Every time we send a message, make a call, or complete a transaction, we leave digital traces. As digital information is captured and stored, our "Memory of the World" – the virtual copy of it – becomes more detailed.

At the forefront of this data-driven revolution there are cities. With their population density and sensor-laden streets, cities are the first places where we are experimenting with new ways of using data for improving our daily life. How can designers and urban analysts leverage this huge amount of information to improve the way we understand and design our cities? To foster a discussion, we are putting forward a reflection on the different types of data available today, and some examples of their possible uses, as drawn from the work of the MIT Senseable City Lab.

Any dataset collected for a specific purpose has an array of potential data by-products. Working with this deluge of urban information is what researchers often call opportunistic sensing: using data that has been generated for a specific reason and analyzing it in a different context to arrive at new conclusions. Datasets are often enriched with many dimensions, and whether or not every one of those dimensions was intended to have an explicit use when it was created, every aspect can be instrumentalized in creative ways. Credit card transaction data, for example, includes unique IDs for the vendor and the consumer. These tags allow researchers to filter the data by location and type of purchase (food, gas, clothing) to understand patterns of economic behavior in cities. Similarly, analysis of telecommunications data and social media have proven them both to be powerful tools for understanding human networks and social dynamics.

When sensors are distributed in a dynamic network, datasets can be considered individually, but far greater insights lie at their intersection and superposition. Geographic space is the common denominator that allows them to be linked. As early as 2006, our researchers at the MIT Senseable City Lab began compounding telecommunications with transportation data. The aggregate urban portrait that emerged – specifically during such extraordinary events as the final match, in Rome, of the 2006 soccer World Cup – revealed collective behavior tied directly to the event. Before the game, movement and communication were frenzied. Activity slowed almost to a stop during the match, spiked sharply at halftime, fell to almost zero during the tense final minutes, and exploded when the match was called. Communication traces during the following hours revealed mass movement into the downtown area to celebrate the national team's victory.

Subsequent projects in cities with more readily accessible data, such as Singapore, have compounded even more datasets. Data from weather, shipping, social media, public transit, cell networks, and more flow together to create a multidimensional portrait of cities and their patterns. Beyond opportunistic sensing, data can also be generated by deploying an array of sensors with specific intent. Embedding technology into the urban environment can yield robust and fine-grained data, whether to map an existing system, to reveal dynamics that have never been brought to light, or to gain a new understanding of humanity's fingerprint. On a macro scale, the Google Street View car, for example, has driven across the world photographing 360-degree panoramas. After its first five years of operation, the Street View team announced that their fleet had captured five million miles of road in thirty-nine countries, generating a staggering twenty petabytes of data – quadrillions of images.

As more and more of these digital elements are embedded in physical space, many other aspects of the urban environment can be revealed with a participatory approach to gain more information about our collective behavior and impact on the environment.The Senseable City Lab began a project, Trash Track, that brought the power of ubiquitous tracking to our waste disposal system. Researchers created geolocating tags and worked with residents of Seattle to attach them to thousands of ordinary pieces of garbage – effectively creating an "Internet of Trash" – to map the waste removal chain across the United States. Over the following months, the devices revealed a surprising network that had been completely unknown before. In the future, an accelerating diffusion of technology into urban space may offer an unprecedented understanding of systems like waste management dynamics and may create data that

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can be used to optimize the entire system, even in real-time. As digital devices become increasingly lighter, smaller and able to process greater amounts of data, we are moving towards the full realization of a phenomenon that has been termed "smart dust" by Kristofer Pister. Physical space could be ubiquitously laced with nanosensors – scattered devices that are smaller than grains of rice. Large-scale networks of wireless sensors are becoming an active topic of research, promising a rich array of data in a future of ubiquitous. In fact, a pervasive network already exists in our cities today: citizens themselves. Internet-connected humans are producing huge amounts of data. The computer scientist Gordon Bell was one of the first to explore the idea of individual data in a practical way – in 1998 he began a project called Your Life, Uploaded, making himself the subject of the first full-resolution experiment in so-called life-logging. Bell created the hardware and software to capture every moment and every action of his life through photos, computer activity, biometrics, and more. The technology was primitive, and in many ways disruptive, but the project was successful in cataloging his existence for more than a decade. "The result?" he wrote. "An amazing enhancement of human experience from health and education to productivity and just reminiscing about good times. And then, when you are gone, your memories, your life will still be accessible for your grandchildren." What Bell initially set out to do as a full-scale scientific and sociological study is now the unconscious norm – the default condition – of an Internet generation. Our spatial and social activity is tracked and logged; in many cases, it requires more effort and determination to opt out of documentation than to opt in. Tweets, Uber calls, text messaging, restaurant reviews, and check-ins have become the natural activities of daily living.

The resulting trove of data can provide a deep understanding of how people interact with physical space as digital traces are mapped and overlaid-revealing, for example, the movement and activity of tourists. Using Flickr data, Senseable City Lab researchers started the project "Los Ojos del mundo" to map a crowd-generated cartography of Spain, showing how visitors and residents see and use their environment and identifying hotspots, or "visual magnets." Researchers could effectively borrow the eyes of the population in a continuing analysis, applying computer vision image-processing and color-matching to landscape photos. The user-generated photographic data began to reveal natural ecological conditions like drought and urban green spaces.

The categories of data collection in cities mentioned above – opportunistic sensing, ad hoc sensor deployment, and crowdsensing – can be hybridized. On the backbone of telecommunications networks, a new universe of urban apps has appeared, allowing people to broadcast and exchange geolocated information and reveal the city from their personal perspective. Air quality, for example, is poorly understood because data is collected in static and sparse ground-based stations. In a possible future, citizens themselves could carry a distributed network of sensors that create a real-time atmospheric map. Using smartphone-integrated sensing devices, pedestrian commuters could generate data at the human scale, as though a tracer were running through the veins of the cities, showing the urban environment that the commuters live in and move through. This concept may inspire manufacturers of consumer electronics to include environmental sensors and to publicly release the resulting data for analysis.

NOTES

[1] This text is an adapted elaboration of: Matthew Claudel and Carlo Ratti, The City of Tomorrow: Sensors, Networks, Hackers, and the Future of Urban Life (New Haven: Yale University Press, 2016).

INTERACTING COMPONENTS

Kas Oosterhuis,
Department of Architecture and Urban Planning, Qatar University, Qatar
koosterhuis@qu.edu.qa

Introduction

Since my entrance into the architectural area at the end of the eighties of the last century and more intensively after I was appointed professor from practice at the Faculty of Architecture at the TU Delft just after the millennium shift, I have written and edited a vast number of essays and books[1], securing to have the theory as directly as possible connected to hands-on practice. Our practice ONL (Oosterhuis_Lénárd) has been since its foundation a platform for the fusion of art, architecture and technology. Hyperbody has thrived at the forefront of interactive architecture until its self-selected abolishment in 2016. The name Hyperbody is the logical extrapolation of Hypertext and Hypersurface (Perella, 1994). Hyperbodies are consistent embodied vehicles that live simultaneously in physical and digital space in real time. In a programmable Hyperbody, non-physical and physical changes can be performed by jumping from one mode of operation to another. In this essay I will look briefly back at some key components of our combined theory and praxis, and then quickly peer into what I believe is looming ahead of us.

Building relations

Key components in building up my theory and praxis are adequately understood by reading the titles of paragraphs in my introduction to the proceedings of the GSM II international Conference[2]: "Space is a computation", "The building becomes the installation", "Quantum theory", "Real time behavior", "Swarms of building components", "Personal history from synthetic architecture to swarm architecture", "Implications for the daily practice of architecture", "Swarm Architecture from research to practice", "Uncertainty and unpredictability", "Top-down styling interventions and bottom-up swarm behavior". Currently I am writing a new book entitled "The Component ", compiling what we have done and speculating on the times ahead of us based on the mutual relationships between real time interacting components. Much of our work is ubiquitous atomic in its initial condition, building universes from a dynamic point cloud of reference points. My realized buildings are without exception based on a coherent series of reference points in space, while my nanoscale, mesoscale and macroscale thinking often is referring to swarms of such communicating points. The core principles of bidirectional relationships are at the basis of the collaborative design games we have designed at Hyperbody over the years between 2000 and 2016. Every component in the design game is parametrically connected to its neighboring component, while families of components are connected to other families of a different nature. We simply adopted the natural principles of complex adaptive systems. Not just to be studied and analysed as observers, but to be performed in real time as actors. In our thinking and doing we lived the Internet of People and Things. Both People and Things are actors in a level playing field, playing with the same set of rules.

Robotics

The robotic painting project entitled "Machining Emotion"[3] successfully established a direct link between the analog intuitive gesture by the artist Ilona Lénárd and the ABB robot arm. The intense collaboration between artist, designer-programmers and robot arm meant a novel procedure to produce works of art, whereas the artist, the concept designer and the programmers collaborated to find an output that was equally exciting for all involved. Machining Emotion is by no means an automation project; intuition and logic went hand in hand, people and machines were immersed in a recursive input > processing > output process. For us it meant a look into the future of robotic architecture. Imagine a building site equipped with people and machines and ready to start to produce building components and assemble the parts to construct a building. There is a clear design strategy and a rule-based concept for how to use the means of production, i.e. a diverse swarm of robots. The spatial layout is not yet decided in greater detail, however there is a clear vision of the procedure of how to operate. The level playing field is then used to play the design to production process. Designers, programmers and robots work on the fly to develop the final configurations. This design to production process as foreseen is not an automation process per se, it deeply involves people – designers and programmers – during the whole process until the project can be declared done. Robotic machines may vary from CNC routers, 3d printing robots to deposit steel and concrete, to self-aware assembly machines. Basically all the machines on a traditional building site that are operated manually today can be easily converted into machines that self-operate. Like self-driving cars, they need to be equipped with sensors and actuators all over. Machines and their somewhat remote designers – like tele-operating surgeons – make major design decisions during the construction process on dimensions, shape and texture of the constituting components. Learning from 3D printing on Mars as proposed by, for example the IA SpaceFactory designers[4], the materials used and processed in the production of the components are to be found as closely as possible to the building site, thus reducing transports costs. More and more, also on Earth, it will be required to use local materials as much as possible, in combination with the most sophisticated design software and production methods.

Interacting components

Foreseeing what the future will bring can only be a personal view based on one's personal experience with building. My future is per definition the here and now. I am emphatic with available social devices and technologies and feed that knowledge into my design concepts. I will here in this essay share what I believe could be future steps to be taken and where they could possibly lead to, all based on the current state of things. As I prefer to design real-world constructs, that is not as some hypothetical construct in a distant future,

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much of it depends on whether I will have the pleasure to find an enlightened client who will allow me to do what I would need to do to further develop my vision on architecture in practice. Our work has never been futuristic, always firmly based on the here and now. This pragmatic attitude was for the first time crystallized on a larger scale in the notorious Saltwater Pavilion project completed in 1997. We took the world by surprise with a radically designed sculpture-building with an interactive programmable interior. Clearly the next step will be to realize a fully programmable building body, allowing the body itself to be interactively tweaked by its users. Right now we have all the necessary expertise to do this. Yet not one enlightened client came to us to commission such a hyper-building. There would be nothing futuristic about such an enterprise, because we can achieve it using existing state-of-the-art technology. Many of the necessary techniques we have already tested at Hyperbody[5] over the years, designing and executing 1:1 scale prototypes for interactive environments, involved our master students and PhD candidates. At Hyperbody we educated a crowd of people who would be able to team up with us and just do it. With my office ONL, I proposed schemes for fully programmable bodies, the interactive installation Trans-Ports 2000 at the Architecture Biennale in Venice in 2000[6] featuring an interactive arena to virtually change on the spot the shape and the content of the 360 degrees projected building body. The public was deeply immersed in the very making / tweaking of the hyperbody and the content on the hypersurfaces shaping the body. A second important step towards fully programmable bodies was our bespoke NSA Muscle installation at the Centre Pompidou in 2003, the physical embodiment of the Trans-Ports paradigm of a programmable body. The Trans-Ports project appeared on the front page of the Libération daily newspaper in France[7]. After having realized these interactive indoor installations, the focus of ONL went to the realization of large scale buildings like the A2 Cockpit in Utrecht, the Bálna Budapest and the Liwa tower in Abu Dhabi, none of them offering an opportunity for further developing my concepts for programmable buildings that change shape and content in real time. The radical concept of real-time adaptive architecture somehow lost its momentum, and only recently have I encountered renewed interest, yet mostly from the academic side and not yet from practice. At the "Alive!" conference at the ETH Zurich in 2013, not surprisingly co-organised by my PHD candidate Tomasz Jaskiewicz whom I promoted in 2009[8], I met many like-minded researchers in one way or another involved in building interactive installations. Yet the projects that were presented were disappointingly small-scale, in none of the cases catapulted to the larger scale of building. To implement the paradigm of fully programmable buildings into the structural fabric of a substantially large building one will need to rethink its use and modality. As in physics, everything single component behaves in space and time, nothing is an isolated object, all components live in relation to each other, to their immediate neighbors in the first place. The condition to consider for a truly "alive" building is that a number of key components can be programmed to change shape. That would include the entire structure, the complete skin, and the overall interior spatial development. Structural components would become actuators, possibly in the form of electronic pistons or shape-changing materials, all of that existing technology. When we design the structure to consist exclusively or perhaps only partially of actuating pistons, the spatial conditions can be programmed to dramatically change over time. I made a radical proposal in that direction commissioned by a South-Korean exhibition developer with the design for a Digital Pavilion (2008), a programmable environment for a real time educational gaming environment unfolding in an existing structure. We envisaged the structural components to be mutually connected electronic pistons, while the surfaces spanned between the triangulated structure would have been made of stretchable fabric to project upon. Unfortunately, it was not selected to be built. The road ahead is clear though. The technology is there, the concepts are there, but the societal urgency, represented by motivated clients, has not yet emerged.

Ground Zero

The most radical concept for a large programmable structure was our Ground Zero proposal, invited by Max Protetch Gallery and exhibited in early 2002. The radical eradication of the Twin Towers required in my view an equally radical response. My response was equally critical on the dramatic act itself as on the devastating response by the American president. The tragic event redrew the global political sphere into stubborn black and white positions, without the much needed in between nuances. After condemning the attacks, I also criticized the USA for striking back unproportionally. I noticed that – as in Hollywood movies – the "good" typically kills more people in revenge than the "bad". Max Protech called me and kindly requested to soften my tone in the project description for the exhibition catalogue[9]. With the inconvenient truth of the inconceivable destructive act and the disproportionate revenge in the back of my head, I proposed a fully programmable building, to be programmed by international users of all faiths and beliefs, to be modified after their own preferences. We visualized our concept in 12 radically different scenarios[10], one radically different mode of operation for each month of the year. The built structure—which we animated to take on radical different configurations using actuators for the internal structure and sensors for the flexible exterior skin—responds to events taking place in that particular time of the year. For January we proposed United Nations Mode, February was for Valentine's, March for the transformation economy, April for international Art, May for Love Parade, June for Doomsday, July for Independence featuring the structure disguised as the American Flag, August was for the Body Snatchers, September for the 911 Memorial reconfiguring the structure into two separate twin towers, October for Theatre, November for the NY Marathon, December inevitably for X-mas. It could be any other mode at any other time as well, to be decided by the public. We designed a multitude of buildings rather than offering a proposal to rebuild Ground Zero with one fixed spatial design concept as the other invited designers / architects did.

Multimodality The "where we are now" and "where we are going" using available technology and social resources would not be complete without mentioning the concept I recently developed for Multimodal Accomodations for the Nomadic International Citizen (MANIC)[11]. Building upon my fascination of iconic projects like the heroic New Babylon project of the Dutch artist Constant Nieuwenhuys, and the ironic Continuous Monument project by Superstudio architects, I developed the concept of a Ubiquitous Booking system for the new nomadic citizen. Earlier I had already developed the concept for the Pop-Up Apartment, a Hyperbody project in collaboration with and funded by the Rotterdam-based project developer Blauwhoed ("Blue Hat"). I envisaged a $50m^2$ apartment that could be programmed to be either a $50m^2$ living room, a 50 m^2 sleeping room, a 50 m^2 kitchen or even a 50 m^2 bathroom, or any combination of the above. The ultimate configuration is the 50 m^2 empty space, a Zen-space to be filled with thoughts and the absence of thoughts rather than with furniture. The Pop-Up Apartment offers the luxury of a spacious apartment in the compact envelope of a standard classroom. As always, my design projects start with a simple calculation. I underpinned the Multimodality concept with a simple equation. I contemplated that, although the interactive furniture would come with a stark increase in cost for the furniture, the reduction from a 100 m^2 into a 50 m^2 built-up area would lead to a substantially cheaper luxury apartment. The formula was: $A + 3*F < (B + F)$, where A represents the costs of a 50 m^2 apartment, B for the 100 m^2 space, and F for the furniture. We assumed that programmable furniture would be 3 times more expensive than normal refurbishment. As we assume that A = 100k EUR, B 200k EUR and F 20k EUR, then the equation would be 160 < 220k EUR, which is true and obviously competitive. We further developed the Pop-Up Apartment concept for the MANIC research. Now that we had imagined the spatial building components, the classroom cubicles and the interactive furniture components, we proposed a 24-hour building structure hosting 200 of such programmable units. They would be contained in a rather straightforward tower with the units at both sides of a large atrium. The atrium would be criss-crossed by bridges, stairs and elevators as to provide for a maximum of possible communication lines. We developed the Ubiquitous Booking system. Each unit can be booked for shorter or longer periods of time, ranging from a 2-hour time slot for private dinners or business meetings.

MERCREDI 24 DÉCEMBRE 2003 — DEUXIÈME EDITION N° 7074 — WWW.LIBERATION.FR

cinéma «Ma Vie sans moi», mélo optimiste, et toute l'actualité des films, cahier central

Libération

L'hôpital dans de sales draps

Avec la mise en examen de cinq médecins et d'un pharmacien, la justice se saisit des maladies nosocomiales, responsables de plus de 4000 décès par an en France. **Page 2**

Voile: l'exception française

TERRE
Espérance de vie: abîme Nord-Sud P.12

VOUS
Sapins de fantaisie sans aiguilles P.22

GRAND ANGLE
Jeux d'Icare PP.30-31

Archi numérique

A Beaubourg, une exposition utopique d'«Architectures non standard» programmées par ordinateur. Page 25

01 | Trans-Ports on cover page La Libération, 2002

02 | Ground Zero | design Kas Oosterhuis / ONL | invasion of the body snatchers mode, 2002

Ubiquitous booking app The furniture configurations as needed and other preferences can be pre-programmed using the Ubiquitous Booking app, for which we designed a simple mock-up.

03 | programmable Pop-Up Loft / MANIC, design Kas Oosterhuis / ONL, 2014-2019

04 | Interactive stage GSM III Conference, design Kas Oosterhuis / Hyperbody, 2016


| 03


| 04

Longer periods can stretch all the way from weekly to monthly to virtually permanent, while the methods of payment can vary from prepaid by credit card to leasing contracts. Thus a diverse community would be established facilitating the nomadic international citizen. Naturally, the lower regions would be dedicated to social gatherings for larger groups, grand café-restaurants, lounge spaces, conference rooms, as to enhance a thriving vibrant community. We are currently looking for clients to adopt the MANIC concept in the Middle East region. The MANIC project shows that the structural idea of building relations is not confined to the design to production process itself but needs to be extended to the operation of the venue. The principles of mass-customization invade every inch of our society, from design to production to assembly to operation. Building of the here and now must respond to changing circumstances from within and from without. They respond via their adaptive facade membranes to changing weather conditions. They respond via the interior envelopes of the working / living spaces including the interior face of the facade membranes to changing preferences of the individual user. The MANIC concept is definitely something we can do in the here and now, in its aspects of building and operation.

Merging multimodality with complex geometry

Having realized both buildings as a natural outcome of the parametric design to robotic production process and having developed programmable installations and concepts for a radial multimodality, there seems to be a contradiction in combining the two approaches. While interactivity does not have a specific relation with mass customization of the programmable components themselves, and while parametric design does not have a specific relation with complex geometry, both ONL and Hyperbody however have aimed at merging interactivity with complex geometry from their very inception. The ultimate example until now has been the design for ProtoSpace 4.0, developed with Hyperbody master students in 2010. I asked the students and ONL / Hyperbody tutors to design a full-bodied single-space building, whereas floor, wall and roof are one coherent system of as large as possible complex building blocks. Eventually we produced 20 of such components (out of the 200 constituting the complete building) on a 1:1 scale using robotic hot wire cutting to shape the components. The components were assigned different performative qualities, ranging from components with window openings, components containing climate control elements, and interactive programmable pop-up components performing the interaction with the users. Each component has a definite unique shape, while following the same design to production procedure and sharing the same principle for the connection detail. The components are designed to be "dry" assembled, as to be prepared for a second life, as we did before with the design of the Web of North-Holland becoming the iWEB lab for Hyperbody. The ProtoSpace 4.0 components were re-used to form the interactive stage for the 3-day GSM III conference at the Faculty of Architecture TU Delft, after which I effectively left TUD having reached the involuntary retirement age of 65 years and 5 months. One of the grey polyurea coated components interacted with the public through a light program, disseminating the pulses through the veins between the components. The other interactive component was the lecture desk. Before each speaker the lecture desk would fold up in three hinged parts and fold down again afterwards using actuators, electromotors and hinges. The re-assembly of the components formed part of Hyperbody's master course program[12].

Choosing direction

In conclusion, answering the challenge to write about the future of architecture, my point of view remains. There is only the here and now, the actual, the real time and the full scale. I have consistently been against making scale models because they communicate so much false information. Although useful to sketch out ideas in an analog 3d environment, I insisted my students at Hyperbody make 1:1 scale prototypes. Especially when developing interactive installations, there is only 1:1 interaction, can't be scaled down. Scripting and modeling is 1:1 per definition, although visually represented on a "flat" screen. Looking at 3d printed models gives the impression that the roofscape is more important than how the user experiences the space. Navigating using walk-throughs or using virtual reality is a much better way to check out the designs. The here and now per definition incorporates all accessible technologies and all available inventions in material science, geometry development and social interactions. Still one will have to choose direction. As if dropped in the middle of an ocean with no land in sight, one still has to choose a direction, informed by the highest form of intelligence, which is intuition. Intuitively we know where to go from here, but this is something you cannot really share with anyone else since intuition is highly individual. The direction I have chosen is to merge complex geometry with a radical form of interaction, and to parametrically design to robotically build as large as possible components that fit together as the pieces of a 3D puzzle. No more manual plaster works as in the virtual designs of the ZHA's and Gehry's, no more disconnection from main structure and skin, no more scaffolding, no more waste at the building site, no more moulds either. The new building components must be designed, produced, assembled and interacted with close collaboration between people and devices. The future of my own direction in the vast sea of possibilities lies in working with an interactive swarm of robotic devices, sensors and actuators, operated during every step of the process in sync with the designers and programmers. We have done it, we do it, and we will keep doing this, learning from our peers, our students, our colleagues, our technicians, reaching out to the industry and learning from the industry. I could not have realized the Web of North-Holland and the A2 Cockpit (to name a few) without the intense collaboration with hands-on leaders in the steel industry. We at Hyperbody could not have done the Interactive Wall project without the intense collaboration with Festo, leaders in the process industry. The future is intense teamwork, involving students, staff, designers, programmers, technicians, material experts, producers, inventors, sociologists from scratch. This is of course common sense and shared logic, yet to be implemented at the scale of substantially large buildings.

NOTES

[1] Among others: Sculpture City (010 Publishers, 1994), Kas Oosterhuis, architect, Ilona Lénárd, visual artist (010 Publishers, 1998), Programmable Architecture (l'Arcaedizioni, 2000), Architecture Goes Wild (010 Publishers, 2002), GSM I [TU Delft Press, 2002], Towards an E-Motive Architecture (Birkhäuser, 2003), GSM II (Episode Publishers / Jap Sam Books, 2006), iA bookzine series (Episode Publishers / Jap Sam Books 2006-2013), ONLogic (Images Publishing, 2008), Towards a New Kind of Building (NAiPublishers, 2010), Hyperbody First Decade of Interactive Architecture (Jap Sam Books, 2012), The Component (forthcoming 2020).

[2] GameSetandMatch II, On computer games, advanced geometries and digital technologies, pages 14-28, (Episode Publishers / Jap Sam Books,2006).

[3] Machining Emotion, available at: http://lenard.nl/?page_id=114, Dubai Design Week, 2015.

[4] IA SpaceFactory, Marsha, 2019, available at: https://www.aispacefactory.com/marsha.

[5] Hyperbody design studios between 2011 and 2016: vhPARK, reRDM, reNDSM, multiMOD, cICO, 2628 Climator, I.P.E, M4H, RE, ex25, GSM, RBSE check http://www.hyperbody.nl/education/msc1/introduction/index.html

[6] Trans-Ports 2000 Interactive installation, Architecture Biennale Venice 2000, available at: http://www.oosterhuis.nl/?page_id=559.

[7] Libération, Cover page, 24 December 2003.

[8] Tomasz Jaskiewicz, Towards a methodology for complex adaptive interactive architecture, dissertation TU Delft, 2013.

[9] Max Protetch Gallery, A New World Trade Center: Design Proposals, 2002.

[10] Architecture Goes Wild, pages 004-027, Kas Oosterhuis, 010 Publishers 2002.

[11] MANIC, research project, Qatar University, 2019.

[12] GSM III, available at: http://gsm.hyperbody.nl/index.php/Main_Page.

THE FOREST AS HERITAGE

Valentina Puglisi[a], Marco Introini[b],
valentina.puglisi@polimi.it
[a] Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Italy
[b] Photographer, Italy

Imagining the future has always been the task of architects, but do they still have the tools to do it?
Giancarlo De Carlo had no doubts. By definition, the role of the architect is to prefigure the future, to persuade others of their reasons, to design what still does not exist, and to coordinate the various results so they can be implemented. De Carlo was certainly aware of his position within society and felt the capacity to imagine and design the future as his own (Lima, 2020).

Climate Change

Today, radical climate change and a severe lack of resources imply a complex situation which design and planning activities should address in the near future.
Due to human-induced climate change, today we are living in the Anthropocene epoch (Crutzen, 2006).
According to data from the Global Alliance for Buildings and Construction, the building sector was responsible for 36% of global energy consumption and 39% of atmospheric CO_2 emissions in 2019 (Global Alliance for Buildings and Construction, 2019).
With the growing population and consequences of climate change, sustainable architecture is considered one of today's main challenges. Engineers and architects are contributing to reducing waste, maximizing building efficiency, and incorporating recyclable materials within structures, as well as harmonically blending new constructions into the surrounding environment.
As humans, we have always adapted our existence in the world through objects and tools, constructing spaces to give a (precise) shape to the image of the future environment in which we will live. Today, however, we are overpowered by a feeling of accelerating time, technological transformation, and a rapidly changing society, creating worry and deep expectations at the same time[1].
In fact, it is clear that with the great spread of digital technologies, the project culture is undergoing significant changes (Lucarelli, 2020).
Today the architectural project lies at the centre of discussion as a complex phenomenon capable of summarizing scientific, social, political, and cultural points of view at a time when the anthropocentric perspective has radically changed our approach to the environment, construction, technology, and materials, given their impact and effects on the scarcity of resources.
Sandra Piesik confirms the need for a new holistic, multidisciplinary approach that knows how to blend modern advantages with solutions developed by humans over the millennia. Only thus will it be possible to address challenges of this type. The keyword for the future is "adaptation": «If we do not want to be struck by the most devastating effects of climate change, we have to take a holistic approach that integrates the benefits of modernity with the solutions developed by humanity over millennia. To do this, more multidisciplinarity and interaction among different bodies of knowledge are needed» (Piesik, 2017).
Nature-based solutions (NBS) are systems that provide cities with multiple services and represent a way to address urban problems with a holistic approach. These are defined by the European Commission as «solutions inspired and supported by nature […] designed to address various societal challenges efficiently through adaptation to the resources and to simultaneously provide environmental, social and economic benefits» (Bauduceau et *al.*, 2015). Nature-based solutions represent emerging, innovative tools to address urban environmental and social challenges.
«Adaptation to climate change profoundly deconstructs the planning of urban projects and architecture, inviting us to introduce risk in the various phases of city programming, planning, design, and construction through a more holistic approach among areas of knowledge» (Manigrasso, 2012).
The international scientific community, and the Intergovernmental Panel of Climate Change (IPCC) in particular, now largely recognize that the decisive, specific contribution of human activities has become superimposed on the natural cyclic mutations that have historically occurred in previous millennia. At the centre of this scenario is the city, the place where the main human activities are conducted and where the population is concentrated; the place where the effects are most severe due to the prevalence of artificial objects over nature, and therefore where resilience must be ensured by humans themselves.
The report by the Intergovernmental Panel of Climate Change (IPCC, 2018) confirms that a rapid decarbonization of 50% by 2030 and of 100% by 2050 will be necessary to avoid a climate catastrophe. These challenges affect daily existence in the biosphere and require the alignment of short-term design actions with long-term objectives.
Many cities around the world have introduced the issue of climate change in their urban policies (Los Angeles, Chicago, New York, London, Rotterdam, etc.), creating original tools (climate plans, adaptation plans, sustainability plans, etc.) in which a complex palimpsest of adaptation strategies has been organized.
Among the programming points presented at COP25 in Madrid (UN Climate Change Conference), the following may be cited: growing awareness in the building production chain to identify the new competencies necessary for professionals to organize architectural, urban and landscape projects on the premise of sustainability; aiming to be key representatives to ensure that cities and infrastructure are designed in accordance with international objectives, in particular considering the 2030 Agenda for Sustainable Development and the European Roadmap 2050; requesting that the National Plan for Adaptation to Climate Change (Piano Nazionale di Adattamento ai Cambiamenti Climatici, PNACC) be updated; building an open-source database of materials, technologies, detailed solutions, and innovations available for the profession and feeding exchange with the business world.

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Natural capital

The development of our society has always been based on the use of the natural resources available on our planet, such as air, water, soil, geological resources, and living organisms. It is precisely this set of natural goods that constitutes what is called "natural capital and it is the good state of this capital that guarantees the social and economic well-being of our society.

The concept of economics is closely tied to the concept of ecology – also from the etymological point of view – in that social development and collective well-being depend on the balanced use of natural resources and all the services and goods deriving from them. It follows that imbalances between the two lead to weakening in the ecosystems and, therefore in the related ecosystem services.

The Millennium Ecosystem Assessment (MEA)[2] has calculated that the loss of ecosystem services contributes to food and energy insecurity, increases vulnerability to natural disasters, decreases the level of health, reduces the availability and quality of water resources, and undermines the cultural heritage. However, since the value of these services is not recorded on the market of economic and manufacturing services, they are not given adequate weight in decision-making policies even though they constitute the total economic value of the planet. From the political point of view, the fact that natural capital has not been assigned an adequate role in economic processes constitutes an urgent problem today and it certainly lacks an awareness and ecological culture for which the idea of sustainable development can be embraced on the individual and collective level. The severe lack of resources and radical climate change constitute a complex scenario that design and project activities will have to address in the near future.

The scientific community agrees on the fact that human activities – such as industry, domestic heating, vehicular traffic, and farming/herding activities – have led to an ever growing increase in greenhouse gases in the atmosphere since the alteration of atmospheric balances is mainly due to the use of fossil fuels. It should also be noted that deforestation constitutes 25% of CO_2 emissions on the planetary scale.

The concentration of CO_2 in the atmosphere has increased by 40% in the last 200 years, causing global warming and all its related problems. The reversal of this process is deemed to be impossible, and a hypothetical slowing would require a profound change in political, economic, productive, social, and energy terms.

In this vision, forests represent a fundamental resource for well-being on a global level, not only in the present, but especially for future generations.They are therefore an essential heritage on which our existence depends; it is our duty to guarantee their protection and feed their growth. In this sense, awareness and collective knowledge regarding these issues are the starting point for understanding the problem.

Biodiversity

Biodiversity is an essential component of natural capital due to its intrinsic value and related activities. Heterogeneity on a climate and lithological/morphological level allow for the presence of a notable variety of vegetation, fauna, and ecosystems. The system of protected areas is essential in this sense. They occupy 21% of the terrestrial territory and 19,1% of the national marine surface area, and are presented as a major path for conserving biodiversity. These areas are also rich in archaeological, historical, architectural, and artistic goods, thereby strongly tying the protection of natural capital to the protection of cultural capital since throughout history, the relationship between nature and related human activities has inextricably shaped the character of the territory. Many sites have been recognized by UNESCO for their cultural and aesthetic quality, which is also tied, for example, to excellence in food and agriculture. Such a strong link has guaranteed the integration and protection of both and demonstrates the existence of a historical relationship between humans and nature.

In Europe, Italy is one of the countries with the most land and marine biodiversity – the fauna includes more than 58.000 species, of which 98% are insects and other invertebrates – and most habitats that host living species are found in the national parks. Italy has 24 national parks extending over nearly 1,5 million hectares of land and 70.000 hectares of sea. The parks play a very important role in combatting the greenhouse effect and land consumption; the forest surface is capable of absorbing 50% of the carbon dioxide emitted in a year. Today the list of invasive species is growing, a phenomenon that tends to be due to anthropic activities. This represents a threat in that the spread of these species is potentially damaging to human health, the environment, and related economic activities. In addition, they tend to spread invasively and thereby threaten native species. According to the International Union for Conservation of Nature Red Lists, around 1.400 plant species and 672 vertebrate species are deemed at risk of extinction. Traditional agricultural, herding, and forestation practices strongly depend on the habitats in which they are carried out and the conservation and protection of the territory is therefore very important, not only on the purely environmental level, but also on the social, economic, productive, historical, cultural, and identity levels.

The impacts of climate change make the conservation of large natural areas even more important, since the probability of maintaining habitats suitable for threatened species there is higher. Nevertheless, it will be necessary to increase the extent of the natural habitats to compensate for losses caused by climate change or human-induced modifications. The reconstitution of habitats and the designation of possible new protected areas should therefore be incentivized and planned, considering future climate spaces 3 for at-risk species and the need to reduce the fragmentation of existing natural habitats.

The forest as heritage to preserve

Four billion hectares, that is, 31% of the Earth's land area is covered by forest, based on data from the FAO (Food and Agricolture Organnization of the United Nations). More than a third of this (1,4 billion hectares) is classified as old-growth forest, that is, forest without visible signs of human intervention. Forest area protected in the form of national parks or natural protected areas has increased by more than 94 million hectares since 1990, equal to 13% of the total forest area (FAO, 2020).
In Italy, more than a third of the national territory is occupied by 12 billion trees, 11 million hectares of forest, and nearly 2 million hectares of other forested land. Without maintenance, however, there is an increased risk of fires that are disastrous for the environment and biodiversity (Mipaaft, 2019).
In the last hundred years, forested area has increased constantly. Based on the three national forest inventories made in 1985, 2005, and 2015, an annual increase in the total forest surface was observed: 0,3% between 1985 and 2005, and 0,2% between 2005 and 2015.
The project, called CORINE Land Cover (CLC), was created on the European level specifically to survey and monitor coverage characteristics and land use, with particular attention for the needs of environmental protection (CORINE Land Cover, 2020). The goal was to create a mosaic of Europe as of 2006 based on satellite images, thereby deriving the digital land use/coverage maps for 2006 and maps of the related changes. The study showed that from 1990 to today, in Italy there has been an increase in forested and urbanized area to the detriment of agricultural lands, primarily due to the progressive abandonment of agricultural activities in favour of growing urbanization.
The expansion and recovery of spaces by the forest is not the fruit of forward-looking policies to protect and "renaturalize" the territory, but rather the result of progressive depopulation and neglect of cultivation and management of the territory and rural, mountain, and inland areas of the country. Contributing to this increase in forested area are not only numerous acts of reforestation implemented over the years, but also national (e.g. Progetto Speciale 24, formerly CASMEZ), and especially European (Council Reg. (EEC) no. 2080/92, programme for rural development 2001-2006, 2007-2013, 2014-2020) incentives to plant forests and woodlands on agricultural and non-agricultural land.
Sustainability in architecture – aimed at reducing human impacts on the environment and thereby avoiding the depletion of energy and materials – translates into a careful choice of techniques, morphologies, and components. «The role of architecture in the era of sustainability therefore shifts from the defence of people against nature to the protection of nature from human impacts» (Raman, 2007).
It is clear, therefore, that nature-based solutions can improve the liveability and prosperity of cities, providing services for ecosystems (Millennium Ecosystems Assessment, 2005).
Forests and the forestry sector represent a fundamental component of our country in terms of the landscape, environment, and economics.
The role of the forest and its rational management is recognized and demanded on an international and European level to support a new, more sustainable model of development for present and future generations. Forests and their sustainable management are becoming increasingly recognized as a fundamental tool in the prevention of hydrogeological risks, the fight against climate change, biodiversity and landscape protection, etc. At the same time, the forest represents an important renewable resource for production and energy.
As a component of the national natural capital and a good of important public interest, forests perform a strategic role. They represent the past, our identity, and the future that the world is constructing.

01 |

01 | Chicago. Photography by Marco Introini

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02 | Chicago. Photography by Marco Introini

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03 | Chicago. Photography by Marco Introini

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04 | Chicago. Photography by Marco Introini

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05 | Los Angeles. Photography by Marco Introini

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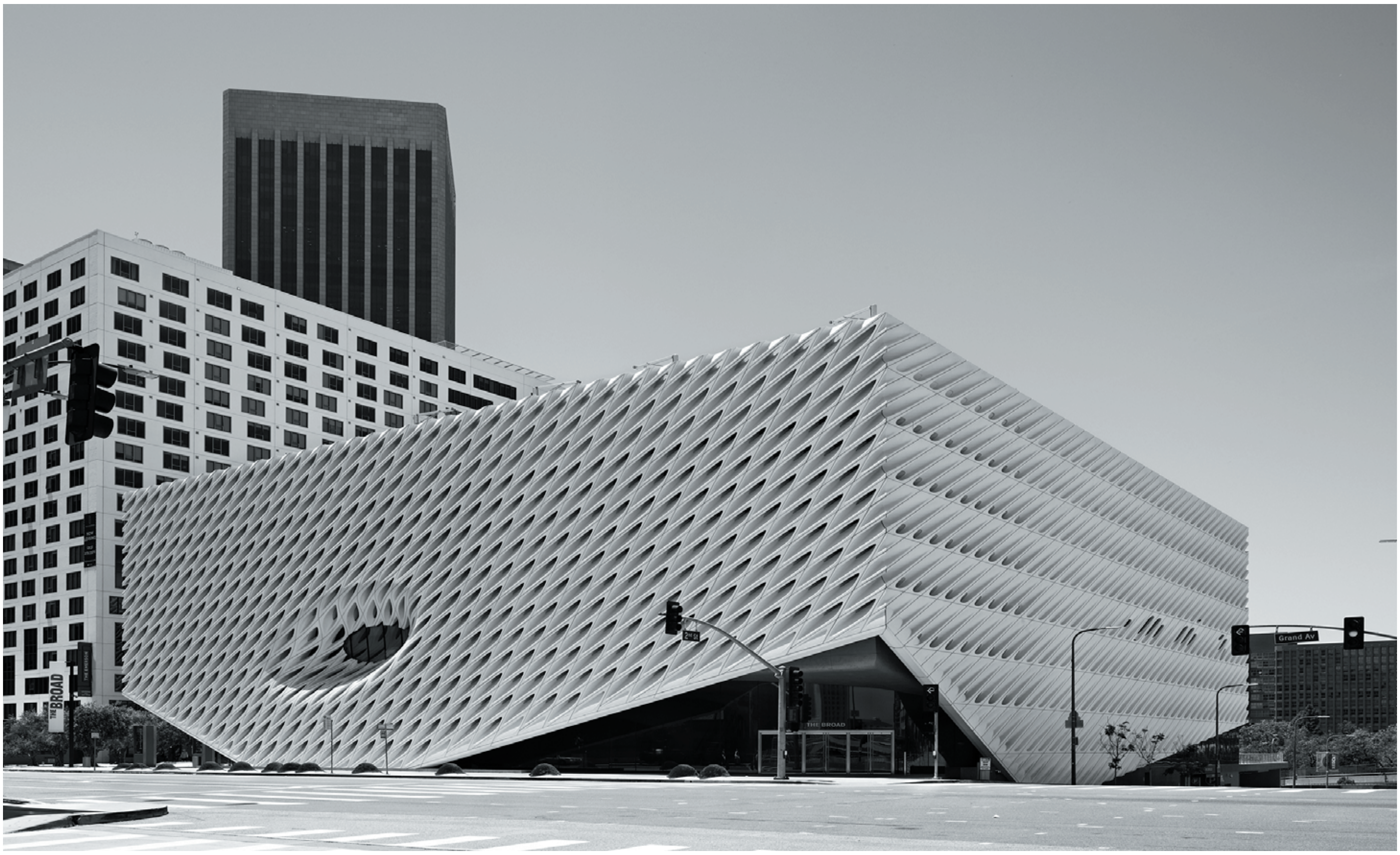
06 | Los Angeles. Photography by Marco Introini

| 07



07 | Los Angeles. Photography by Marco Introini

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08 | New York. Photography by Marco Introini

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09 | New York. Photography by Marco Introini

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11 | New York. Photography by Marco Introini

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12 | Pigra (CO). Photography by Marco Introini

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13 | Pigra (CO). Photography by Marco Introini

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14 | Deliceto (FG). Photography by Marco Introini

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15 | Deliceto (FG). Photography by Marco Introini

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16 | Ostiglia (MN). Photography by Marco Introini

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17 | Ostiglia (MN). Photography by Marco Introini

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18 | Marmirolo (MN). Photography by Marco Introini

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19 | Marmirolo (MN). Photography by Marco Introin

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20 | Val di Fiemme (TN). Photography by Marco Introini

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21 | Val di Fiemme (TN). Photography by Marco Introini

NOTES

[1] Paoletti, I., Campioli, A., and Converso, S. (2020), *Call for paper Techne Special Issue n. 2*, Firenze University Press, Florence.

[2] The Millennium Ecosystems Assessment (MEA) was a research project that started in 2001 with the support of the United Nations that aimed to identify changes in the ecosystems and develop scenarios for the future based on trends in the changes.

REFERENCES

Lima, A.I. (2020), *Ginancarlo De Carlo. Visione e valori*, Quodlibet, Macerata.

Piesik, S. (2017), *Habitat: Vernacular Architecture for a Changing Planet*, Thames & Hudson, Londra.

Manigrasso, M. (2012), "Verso la Città ad_Attiva. Rispondere ai cambiamenti climatici attraverso una nuova concezione del tempo nei processi e negli esiti progettuali", *Planum Journal of urbanism*, Vol. 2, n. 25.

Crutzen, P.J. (2006), "The Anthropocene", in Ehlers, E. and Krafft, T. (Eds.), *Earth System Science in the Anthropocene*, Springer, Berlin, Germany.

Global Alliance for Buildings and Construction (2019), "GlobalABC Roadmap for Buildings and Construction 2020-2050. Towards a zero-emission, efficient and resilient buildings and construction sector", available at: https://globalabc.org/sites/default/files/inline-files/1.%20GlobalABC_Roadmap_for_Buildings_and_Construction_2020-2050.pdf (accessed 16 July 2020).

Bauduceau, N. *et al.* (2020), "Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities: Final Report of the Horizon 2020 Expert Group on Nature-based Solutions and Re-naturing Cities", Publications Office of the European Union, Bruxelles.

Lucarelli, M.T. (2020), "Note", *Techne Special Issue 2*, Firenze University Press, Florence,.

CORINE Land Cover, (2020), "Corine Land Cover Change (CHA) 2012 – 2018", available at: https://land.copernicus.eu/pan-european/corine-land-cover/lcc-2012-2018?tab=metadata (accessed 16 July 2020).

Mipaaft (2019), *RaFITALIA 2017-2018. Rapporto sullo stato delle foreste e del settore forestale in Italia*, Compagnia delle Foreste S.r.l., Arezzo, Italy.

United Nations, IPCC (2018), "Global Warming of 1.5 ºC", available at: https://www.ipcc.ch/sr15/.

Millennium Ecosystems Assessment (2005), *Ecosystems and Human Well-being*, Island Press, Washington.

Raman, M. (2007), "Sustainable? Part 3: A Quarter Century of Environmentally Conscious Design", available at: https://www.cca.qc.ca/en/issues/19/the-planet-is-the-client/221/sustainable (accessed 23 July 2020).

FAO - Food and Agricolture Organnization of the United Nations (2020), "Global Forest Resources Assessment 2020. Key findings", available at: http://www.fao.org/3/CA8753EN/CA8753EN.pdf (accessed 23 July 2020).

Metadesigning the urban space/environmental system. Inter- and trans-disciplinary issues

Filippo Angelucci,
Department of Architecture, G. d'Annunzio University of Chieti-Pescara, Italy
filippo.angelucci@unich.it

Abstract. Deindustrialisation and urban densification are shifting the vitality of the city into private spaces. Once places of socialisation and participation, public spaces are now areas of conflict, risk and separation. The horizon for regenerating and revitalising urban public space is not only technical, but also trans-disciplinary and socio-technological-environmental.
The essay reconsiders unbuilt urban space as a space/environmental system; an interface between people, technologies, nature and society that favours a more context-sensitive and responsive project.
The text highlights new roles for the metadesign process by working with material, connective, functional and relational dimensions, new vectors of urban metamorphosis and eco-relational qualities of future public spaces.

Keywords: Urban transition; Space/environmental system; Technological-environmental metadesign; Regulatory interfaces.

Urban transitions and the dissolution of public space

Processes of economic, territorial and political deindustrialisation are signalling the end of the modern idea of the city. Nonetheless, cities continue to attract those seeking better employment opportunities, economic stability and socio-cultural occasions. The global urbanised population is expected to reach 68% by 2050 and 85% by 2100 (UN, 2019).

The end of the modern city will also signal another inversion. Growing environmental problems and the need to limit the consumption of natural resources and pollution mean that demographic concentration moves hand in hand with a re-densification process of urban areas that responds to two issues.

The first regards the compensation of ecological-environmental imbalances generated by extensive urban growth through focused and selective densification (Kiang Heng and Malone-Lee, 2010; Munoz, 2012). The second concerns the possibility of welcoming flows of migrants fleeing the climatic, economic and geopolitical instabilities plaguing the globe.

Re-densification of the city can also generate a number of criticalities. The concentration of buildings often attacks the open spaces of sprawling urbanisation, reactivating the consumption of soil and the saturation of the urban fabric. Demographic-functional *mixité* has negative effects on urban vitality, concentrated in increasingly more exclusive enclaves. Public spaces tend to lose part of their value; incorrectly designed, they are transformed from spaces of social interaction and participation into territories of risk, conflict and separation.

Deindustrialisation and urban re-densification can trigger a broader dissolution of the city's public spaces. However, a loss in the meaning and functionality of urban public space can also be identified in altered interactions between people and the city caused by a *surplus* of digital technologies (e.g. Lavasa, Masdar City, New Songdo City, Ordos, PlanIT Valley, Santander).

Farinelli posits that the modern concept of space and thus also of urban space was built on the reiteration of homogeneities, isotropies and continuities (Farinelli, 2009). The spread of new digital devices means that we are constantly hyper-connected with a multiplicity of places in a global information network that ruptures the perceptive and cognitive constants of space (Henaff, 2008). Increasingly more interactive, we inhabit smart cities designed to simplify everyday activities. Yet this hypertrophy of information-communication is also diminishing the need for public spaces and reducing the physical-cognitive capacities required to make use of them (Sennett, 2018).

The field of design is still far from identifying trajectories for reintegrating public spaces within the real processes of inhabiting the city. It continues to propose strategic forecast planning for management and procedures, reiterating univocal top-down solutions. It is limited to the technological assessment of effects induced by deterministic interventions. Design remains trapped in the resolution of individual problems and the development of specific services and products.

Urban public spaces have become the field of disharmonic design incursions, from above and below. Transformed into a «no man's land» (Giallocosta, 2006), it must, instead, be entirely re-imagined, starting from its multiple and synchronic identities. The public spaces of contemporary cities are characterised by a complex dendritic and heterogeneous structure made of absences, incisions, natural elements, residual conditions, margins and shifting boundaries (Gausa, 2003). The flow of continuous urban transitions is one of voids, intervals, in-betweens, third landscapes, heterotopias, liminal spaces, edges and fringe areas.

This situation reveals the importance of reinterpreting urban space as a "place/non-place" of co-evolution between man-nature-technology (Dierna and Orlandi, 2005), as a perennially new spatial-temporal infrastructural system (Easterling, 2014).

For the field of design this challenge assumes an inter/trans-disciplinary value that cannot develop as a "phenotypic" definition of closed and predetermined forms. Instead, there is a need to reconnect the different skills and trajectories of environmental, urban, landscape, technological and architectural design. We must work with "genotypic" codes that permit investigations, hypotheses and forecasts of the multiple potentialities of public space as a system of relations that is inhabited, perceived and imagined (Tagliagambe, 2018).

For a redefinition of public space as a space/environmental system

With the transition from the modern to the contemporary city, the urban environment increasingly resembles the *metapolis* hypothesised by Ascher or Gausa: a matrix of relations generating multiple combinations of functions, uses, practices and behaviours. The *metapolis* questions the modern notion of void space between homes. Public space is no longer an absence of the built, but takes on a meta-spatial connotation (Ascher, 2001; Gausa, 2003).

Considering public space as meta-space means reconsidering

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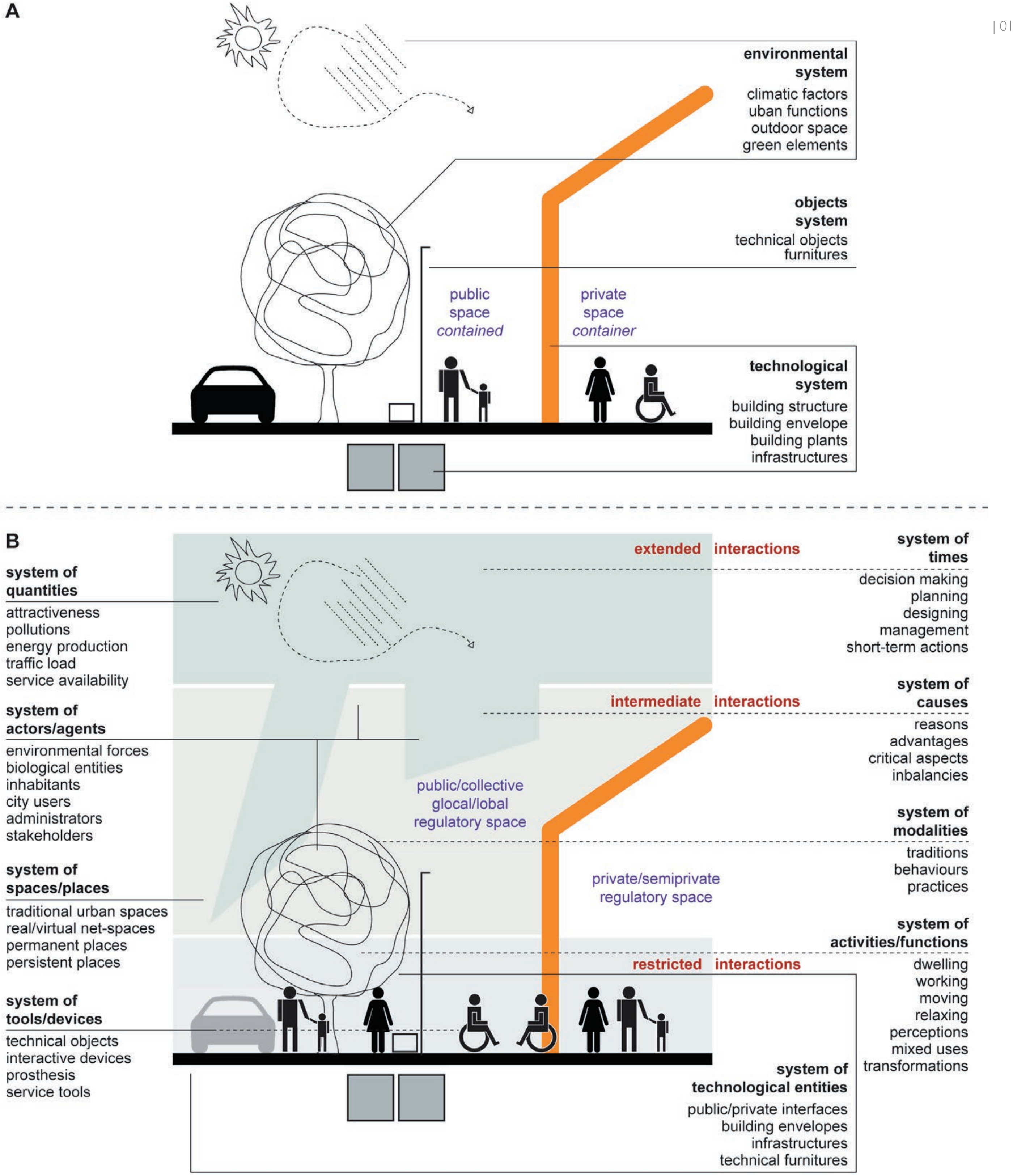
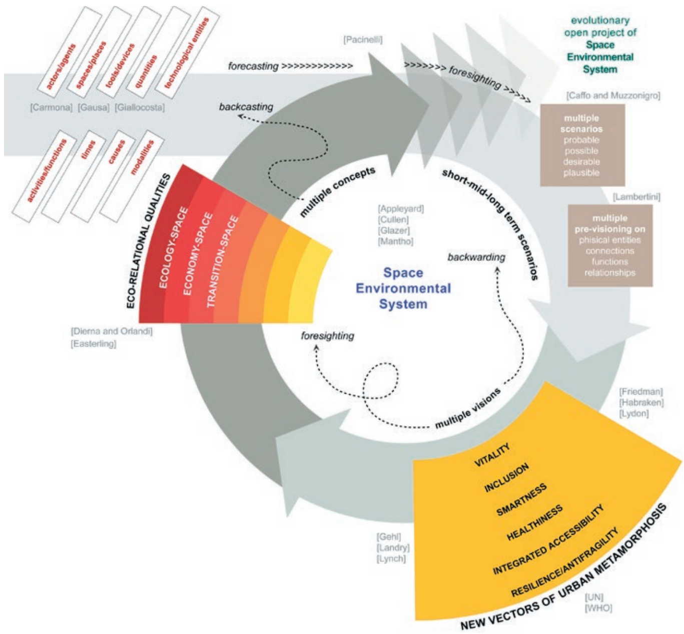
the systemic interpretation adopted to describe, analyse, design and manage it. The vision rooted in construction, based on the dualism between stable entities (technological system) and variables (environmental system), is now unsuited to the complexity of contemporary public spaces.
There is a need to reinforce a multidimensional vision of public space through cross-systemic design processes. Diverse texts highlight the multidimensionality of public space and the progressive increase in its relations with the social, individual, ecological, economic and cultural variables of context.
Some studies (Friedman, Habraken, Lydon) present public space as an interacting system that transcends the clear separation between private realm, public city, and the authorial and unidirectional vision of design (e.g. *Paris Olimpic Ville Spatiale* models, NACTO guidelines). In other fields (Appleyard, Cullen, Glazer, Mantho), public space is conceived as a system that activates ecologies, loops and supply chains that interrupt the traditional opposition between city, nature and inhabitants (e.g. Project for Public Space experiences, *Helsinki Accessibility Plan*, *Rotterdam Climate Change Plan*). Other studies (Gehl, Landry, Lynch) investigate public space as a system that generates well-being, comfort, safety and health for the city's inhabitants, exploring different codes and practices of perception, participation, identity and use (e.g. Gehl *Soft City* principles, *The City at Eye Level* projects).
What emerges from these disciplinary contributions is above all the necessity to clearly state what the public space of the city 'no longer is'.
Public space is no longer a container, delimited by buildings, of con-figuratively stable objects, infrastructures and people. More than the expression of community life, it is meta-place for the coexistence of public and individual dimensions existing in a space-temporal *continuum* with strongly blurred edges. It is difficult to distinguish between localised physical space and immaterial global space. Furtherm ore, public space cannot be manipulated by representing functional typologies from the past, as it is influenced by the continuous instabilities and unpredictability of the environment. It cannot be designed using closed forms. Its transformability must be open, dialogic and process-based. Finally, it cannot be re-imagined using dichotomic logics of deduction/induction, top-down/bottom-up, universal/specialised, public/private (Fig. 1a).
Working on the regeneration of urban public space means considering horizons for design that are not only technical-constructive but also technological-environmental. This hypothesis does not exclude the ability to measure the response to progressively more hybrid and complex problems-requirements frameworks; at the same time, however, it never loses sight of the centrality of the multiple configurations that contemporary public space can assume in the short-, medium- and long-term.
The system of urban meta-spaces should be redefined as a space/environmental system (SES): a regulatory cross-systemic entity influencing culture, behaviour, perception, ecology, socio-economics and decision-making to improve conditions of co-habitation in the city. More specifically, it is a question of rethinking the unbuilt parts of the city as an intermediate device for extending levels of interaction/adaptation between urban components and defining alternative context-sensitive and responsive scenarios of sustainability, as well as introducing inhomogeneities, anisotropies and discontinuities.
The notion of SES generates at least nine regulatory sub-systems (Fig. 1b):

1. the system of actors/agents interacting and changing within the SES including: inhabitants, city users, administrators, stakeholders, biological-vegetal entities and the whole of environmental forces;
2. the system of activities/functions characterised, other than by dwelling, working, moving and relaxing, by the coexisting processes of perception, mixed use and transformation involving multiple public and/or private levels of SES;
3. the system of spaces/places that integrates traditional urban space, as each inhabitable entity of the SES is a real/virtual space within globalised networks, as well as a locus of identity defined by permanent and persistent local elements;
4. the system of times linked to both the composite/long-term timelines of decision-making, planning, designing and managing the SES, and the ordinary/short-term timelines of using, modifying and adapting the city;
5. the system of causes, including the multiple questions, reasons and advantages deriving from the appropriate use of the SES, together with the imbalances and unpredictability, which can determine inappropriate use or abandonment;
6. the system of modalities relative to the multiple traditions, behaviours and practices employed by actors/agents to explore, remember and use the SES, in a continuous search for conditions to improve and/or optimise inhabitability in a changing context;
7. the system of tools/devices, including technical objects, machinery and prostheses as interactive entities, which can enable/disable individuals and communities and generate forms of inclusion/exclusion (WHO, 2006);
8 the system of quantities, to ensure that the interaction between nature, people, society and technologies can affect urban performance (touristic attraction, emissions of pollutants, energy productions, traffic loads, service availability);
9. the system of technological entities, which includes relational interfaces between public and private spaces as transportation infrastructures, building envelopes and technical furniture.

01 | Passage from the traditional systemic idea of urban public space (A) to the multi-systemic complexity of urban SES (B)





The metamorphosis of the space/environmental system

Considering the urban SES as a meta-spatial entity that changes according to variations in context also means repositioning the very meanings and objectives of designing public space[1].

The phase of metadesign once again assumes a central role in identifying more horizons of interaction between technologies, nature, individuals and societies. This condition prospects innovative implications for the entire design process (Fig. 2).

The designer passes from being an authorial figure to coordinator, co-director and harmoniser of processes of listening to, caring for and transfiguring needs, projects and transformations. The role of design technologies changes: the spread of digital innovations generates a constant flow of knowledge and feedback involving expert and diffuse designers. The co-participation of multiple actors, with different needs and skills, nurtures inter/trans-disciplinary dialogue. The opposition between synthesis-deduction and analysis-induction becomes ephemeral as it prospects a more experimental abductive framework, in which players are users, producers, designers and operators. There is also a change in levels of design modelling that, from simple forms of description, become narrative projections at multiple levels of relations (areas, units, sub-units).

The experience of metadesign becomes fundamental for moving beyond forecasting-based processes that determine 'what' will likely occur in public space. The metadesign of the urban SES becomes a multi-dimensional experience that extends into the exploration of diverse alternatives for the future, between foresighting and backwarding. This new cognitive condition is feasible for at least three reasons (Pacinelli, 2012; Caffo and Muzzonigro, 2018): exploring multiple scenarios of evolution (probable, possible, desirable, plausible); projecting more visions for dwelling, communicating, accessing, crossing and pausing in public space; defining more concepts to enable multiple quality of life levels.

Regarding the first aspect, future scenarios for the evolution of the SES can be explored by moving beyond a strategic-programmatic approach. It is important to focus not only on strategic scenarios, but to explore the tactical medium-term possibilities between long-term projections and short-term final design. The practice of foresighting can extend the exploration of scenarios to the multi-dimensional and implementation pre-visioning of the evolutionary configurations of the SES and its sub-systems. In this direction, it is possible to involve, in a synchronic manner: physical-material entities (actors, bodies, factors of context, objects), potential material links (processes, supply chains, cycles), new and unpredicted functional challenges (moments of sharing, cooperation, reduction), consolidated and/or innovative immaterial relations (communications, educational processes, information).

Regarding the development of a design vision, the practice of abductive metadesign makes it possible to forecast the evolution of the SES by comparing data, information and objective knowledge with perceptions, experiences and subjective know-how. This requires multiple visions (Lambertini, 2008) of process, both performative and relational, that explore areas exerting pressure on the SES and modifying the traditional idea of urban public space. Public space must be tested through its principal vectors of metamorphosis, resulting from new paradigms of urban sustainability (e.g. *Resilient Cities, Agenda 2030, Inclusive Cities, Healthy Cities*). From the phase of metadesign, the SES must, therefore, incorporate multiple degrees of performative redundancy; each of its sub-systems must have regulative-adaptive capacities of anti-fragility, healthiness, inclusion, integrated accessibility, resilience, smartness and vitality.

A third reason regards activities of metadesign conceptualisation. There is a need to explore more concepts in order to transfer the idea of quality into public space, interpolating parametric-performative elements (norms, guideline criteria), morphological-reactive entities and eventual retroactive processes that may also entail re-visions of the visions. The quality of the SES has value not only in morpho-generative terms with respect to the urban environment, but also as the eco-relational meaning of space and *οίκος*. In other words, the SES must have the capacity to: produce, maintain and regenerate the natural resources essential to the life of urban communities (economy-space relationships); innovate the uses and modifications of common goods, delineating horizons of compatibility between inhabiting cultures and urban space (ecology-space relationships); and interface physical, connective and functional urban variables to mediate evolving anthropic-natural dynamics (transition-space relationships).

Considering the urban SES as a meta-system of intermediate regulating spaces in continuous transition, the metadesign process will also assume a dynamic character and shed its traditional uni-directionality. The goals of the metadesign can no longer assume a static connotation, as it is indissolubly bound to the variability of ecological-environmental structures linked both to the adaptation of inhabitants-users and to the transformation of spaces and technologies.

This rising complexity of metadesign goals requires that we no longer employ closed and univocally defined forms or hypotheses/ solutions that only facilitate, simplify and standardise. The public space of the city must be investigated and confronted in all its intrinsic complexities, diversities and levels of adaptation.

The inter/trans-disciplinary dialogue that can be established by the urban SES opens up toward considerations and forecasts of possible future alternatives for urban public space. In these future explorations, the design process develops and evolves around the metamorphoses of equilibria between perceptive, social, visual, functional, chronological and morphological aspects (Carmona *et al.*, 2003).

These continuous transitions and shades of collective co-existence in the city appear to re-open the debate not only on the central role of the metadesign of public space, but also of its cultural, social and political role so that we can once again attribute the built urban environment with the Isocratic definition of *psychè poleos,* the "soul" of the city.

NOTES

[1] This paragraph summarises methodological reflections on the metadesign process resulting from research experiences conducted by the author in inter/ trans-disciplinary teams: Chieti_Lab 2014/15, Pescara International Summer School 2015 and 2016, LIMEN 2017/18, RE-Live 2019, RE-live 2020 .

REFERENCES

Ascher, F. (2001), *Les nouveaux principes de l'urbanisme*, Édition de l'Aube, Paris, France.

Caffo, L. and Muzzonigro, A. (2018), *Costruire futuri*, Bompiani/Giunti, Milan, Italy.

Carmona, M. *et al.* (2003), *Public Places-Urban Spaces. The Dimensions of Urban Design*, Architectural Press, New York, USA.

Dierna, S. and Orlandi, F. (2005), *Buone pratiche per il quartiere ecologico,* Alinea Editrice, Florence, Italy.

Easterling, K. (2014), *Extrastatecraft. The power of infrastructure space,* Verso, London, United Kingdom.

Farinelli, F. (2009), *La crisi della ragione cartografica,* Einaudi, , Turin, Italy.

Gausa, M. (2003), "Metapolis", in Gausa, M. *et al.* (Ed.), *The Metapolis Dictionary of Advanced Architecture,* Actar, Barcelona, Spain, pp. 430-431.

Giallocosta, G. (2006), "L'approccio sistemico nella gestione di fenomenologie interscalari", in Di Battista, V., Giallocosta, G. and Minati, G. (Eds.), *Architettura e approccio sistemico*, Polimetrica, Milan, Italy, pp. 119-126.

Henaff, M. (2008), *La ville qui vient*, Édition de l'Herne, Paris, France.

Kiang Heng, C. and Malone-Lee, M.C. (2010), "Density and urban sustainability: an exploration of critical issues", in Ng. E. (Ed.), *Designing High Density Cities*, Earthscan, London, United Kingdom., pp. 41-52.

Lambertini, A. (2008), "A conversation between Giampaolo Proni e Raffaella Trocchianesi", *Rivista*, January-June 2008, pp. 49-60.

Munoz, F. (2012), "L'urbanistica dell'intensità. Quattro strategie per trasformare l'urbanizzazione diffusa in città", in Angrilli, M. (Ed.), *L'urbanistica che cambia. Rischi e valori*, Franco Angeli, Milan, Italy, pp. 19-24.

Pacinelli, A. (2012), "I metodi della previsione", in Arnaldi, S. and Poli, R. (Eds.), *La previsione sociale*, Carocci Editore, Rome, Italy, pp. 149-163.

Sennett, R. (2018), *Building and dwelling. Ethics for the city,* Penguin, London, United Kingdom.

Tagliagambe, S. (2018), *Il paesaggio che siamo e che viviamo*, Castelvecchi, Rome, Italy.

United Nations (2019), *World Urbanization Prospects 2018 Highlights*, United Nations, New York, USA.

WHO (2006), *International Classification of Functioning Disabilty and Health*, Erickson, Geneve.

Back to Future. Morpho-typological approach and environmental performance of urban fabrics

Carlotta Fontana[a], Shuyi Xie[b],
[a] Department of architecture and urban studies, Politecnico of Milan, Italy
[b] School of Architecture, Huaqiao University, Xiamen, China
carlotta.fontana@polimi.it
shuyi.xie@polimi.it

Abstract. Human settlements grew up over time due to the action of many generations, taking shape according to the local geo-climatic characteristics and resources. This article discusses the co-evolutionary, largely unintentional and complex quality of the built environment, envisaged by studies on its morphogenesis since the mid-20th Century, in its relationship to the studies on the energetic performance of building fabrics, based on an urban morphological approach. The research-and-action proposal for the adaptive reuse of a historic residential neighbourhood in China, described here, endeavours to provide fine-tuned and 'tailor-made' improvements, making the most of the existing quality of the built environment while meeting present-day needs and expectations of the inhabitants.

Keywords: Adaptive Reuse; Morpho-typology; Historical urban fabric; Environmental performance.

Introduction

Human settlements grew up in layers over time, due to the action of many generations, taking shape according to the geo-climatic peculiarities of places and to local resources. This co-evolutionary nature of the built environment, noticed a long time ago by scholars, such as Geddes and Mumford, pairs with the notion that the built environment itself is mostly made up by ordinary buildings. One cannot understand the structure of cities without exploring the urban common fabric, the back streets, their pattern and the way they change in time (Habraken, 1998). Evolutionary overtones – often recur in the works of Saverio Muratori in Italy and M. R. G. Conzen in the UK (Muratori, 1959; Maretto, 1960; Muratori et Al., 1963; Conzen, 2004), who recognised the role of time in shaping the built environment, and identified the permanent morphological elements as long-lasting traces of complex cultural systems. Urban morphology represents the physical grounding of populations, as the process of urban growth reveals a civilization's progress. Local cultures operate over time, shaping the environment by uses, dimensions, materials and forms, which endure or change – that is: evolve – according to their capability to meet the challenges posed by the succession of historical events. Thus, permanence represents an evolutionary condition of fitness, and morphological endurance represents diachronic fitness of urban fabrics.

The morpho-typological aspects of traditional architecture as a response to environmental forces represented the core of Victor Olgyay's seminal bio-climatic studies (Olgyay, 1963). Giving full account of the huge variety of buildings in different regional traditions, Olgyay demonstrated how all main typological variations find a reason in the environmental site-specific situation, and can be seen as «building expressions of true regional character», harmonising their place and shape to the constraints posed by local climate and topography.

Further development of this line of research, which takes into account the whole urban morphology rather than single buildings (Martin and Steadman, 1971; Martin and March, 1972; Bottero *et al.*, 1984; Alvarez *et al.*, 1991; Weber and Yannas, 2014; Franco, 2015; Morganti, 2018; Scudo, 2018) brought about a deeper knowledge of the relationship between energy and the built environment. Both the solar radiation that buildings receive and their energy needs depend upon the set of geometric and dimensional characteristics of the local urban form: the road network and orientation, the plots, the blocks and the intermixed open spaces all combine to determine the energetic behaviour of buildings. Such behaviour should be analysed within the system of urban morphology to be fully understood (Morganti, 2018). Accordingly, persistent urban settlements layered over time within the mould of local geo-climatic characters provide significant clues about their 'environmental fitness' and promote meaningful strategies for adaptation and sustainable reuse. This consideration gives a further, fresh perspective to morphological studies, which have recently been proposed as a planning framework to promote guidelines and to support self-maintenance by inhabitants, towards sustainable reuse and urban regeneration of historical neighbourhoods in South-East China (Xie, 2018, 2019).

Time, the great Master Builder

The idea of the built environment as a «palimpsest, an accumulated, if partly erased and rewritten, record of human history in a place» (Conzen, 2004), implies that the reality of the urban structure grows during time, through a succession of reactions and processes that develop from previous stages. Muratori's *operante storia urbana* revealed the logic of morphogenesis as a result of culture layering material form over time, within the mould of the local physical environment. In his own words, urban morphology expresses a continuity of development, and a vital and unifying exchange with the environment.

Such an evolutionary idea of the built environment resounds in the work of Gianfranco Caniggia (Caniggia and Maffei, 1979; Caniggia, 1981). Typological analysis discloses «formation and transformation processes of anthropic structures», revealing how the built environment is spontaneously structured, slowly becoming «unitary, homogeneous and organic» due to the «self-correction mechanisms that derive from being produced by a community operating in time and space». This process produces a «spontaneous planning» and guarantees the best performance of the individual contributions, thus «structuring the environment»[1].

It has been noted (Samuels, 2005) that since the 1970s, when morphological studies all over Europe introduced the physical aspects of urban fabrics into the realm of planning and later in urban design, the main focus has not been «concern with the aesthetics of buildings», but rather with «the deeper and more enduring elements of the townscape»[2].

In the early 1960s, Christopher Alexander (Alexander, 1964; Alexander, 1966) argued that *form* represents the solution of a complex problem posed by a context, as «an irregular world tries to

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compensate for its own irregularities by fitting itself to them»[3]. Following D'Arcy Thompson, who defined form as the diagram of forces for the irregularities of the world, arguing that Nature provides its phenomena «with the just right form» (D'Arcy Thompson, 1917), Alexander claimed that enduring urban morphologies represent the "good fit" for the ensemble consisting of a given human settlement plus its physical and social context over a long time.

Thus, Time appears as the great Master builder (Fontana, 2019) to which human settlements owe their most durable, fittest configuration within a given environment.

Regionalism and global thinking: morpho-typological approach and energetic performance of the built environment

In the middle of the debate on Post-modern architecture, Kenneth Frampton wrote a celebrated essay (Frampton, 1983) advocating "critical regionalism" and claiming that architecture should focus more on the local elements that shape the built environment, such as topography, climate, light, and on the qualities appealing to senses other than sight, which determine delight and comfort. It is worth noticing that this essay, groundbreaking as it was labelled, was published twenty years after Victor Olgyay's seminal book *Design with Climate - Bioclimatic approach to architectural regionalism* (Olgyay, 1963), that focused on the assumption that the «ancients recognized that regional adaptation was an essential principle of architecture». In Olgyay's work, the term "region" relates to the solar altitude angle, and the regional characters of buildings are defined in terms of heat conservation, thermal demand, orientation, natural lighting and ventilation[4]. Olgyay famously explained how basic building forms, in traditional architecture, answer to the needs of comfort and protection against the local environmental difficulties; yet there is no prosaic determinism in this approach. His research took into account cultural and symbolic factors, and his idea of regionalism in architecture encompasses enduring knowledge and wisdom, quite far away from shallow questions of style, vernacular compliance or commonplace functionalism. However, in those days, his ideas did not make their way to the forefront of the architectural mainstream cultural debate, as was the case with the Cambridge group (Martin and Steadman, 1971; Martin and March, 1972), which investigated the flows of energy and matter according to urban morphology. The research focus here was on the interaction between clustered buildings and their neighbouring open spaces, as well as the thermal performance of the built environment as a whole. This approach provided inspiration to studies about energy and the built heritage for many years to come (Franco, 2015)[5] but, once again, the theme remained in the outskirts of the architectural debate, apparently restricted to the realm of "technical issues".

Built surfaces represent both morpho-typological features and the main interface for radiation exchanges. Building characteristics and elements, such as size, shape, geometry, material, colour, windows, balconies and roofing, define the architectural character as much as the environmental behaviour of the urban fabric. They determine heat transmission, shading, and the flow of wind and rain, making each building interact with those nearby[6].

There should be no doubt that the ability to shape the built environment in order to achieve thermostable conditions, that – in Olgyay's words - has been the main goal of generations of anonymous builders for centuries, rightfully belongs to the architectural culture[7].

A transcultural proposal for chinese endangered historical neighbourhoods

Chinese philosophical and religious traditions do not provide strong support to the physical conservation of the built heritage[8], focusing more on immaterial elements, such as the spiritual and symbolic meaning of particular buildings and places, rather than on preserving physical objects (Xie *et al.*, 2020).

This approach has greatly changed in recent times (Xie, 2018; Xie *et al.*, 2020). Intellectual and government awareness about conservation gradually developed during the 20th century. After the foundation of People's Republic of China in 1949, the legislation for the protection of monumental buildings was reinforced, and the conservation system gradually extended from antiques and single monuments to historical built complexes and sites. Urban policies, on the other hand, generally promoted renovation of the old cities, with the main goal of meeting new needs and of providing a brand new, socialist image of cities, in opposition to the old feudal one.

After the economic reforms of 1978, communication between China and the Western world increased, and the domestic tension between development and conservation intensified, causing significant contradictions in the approach to urban heritage. On the one hand, the attention to historical heritage preservation grew, and legislation and policies striving for the international principles of physical protection of the built heritage were gradually introduced[9], making urban conservation more practicable[10]. On the other hand, a thriving real estate market developed, as well as a growing flow of foreign tourism. Urban development projects were driven by the socialist market-oriented economy, while the old urban fabrics were often altered by new inhabitants[11], leading to heritage loss (Buiard and Xi, 2007) and widespread gentrification (Abramson, 2001). Ironically enough, destruction and gentrification were often induced by "conservation projects", which substituted the original urban fabrics with new, pseudo-historical buildings, thus turning large parts of old cities into 'theme parks' for tourists.

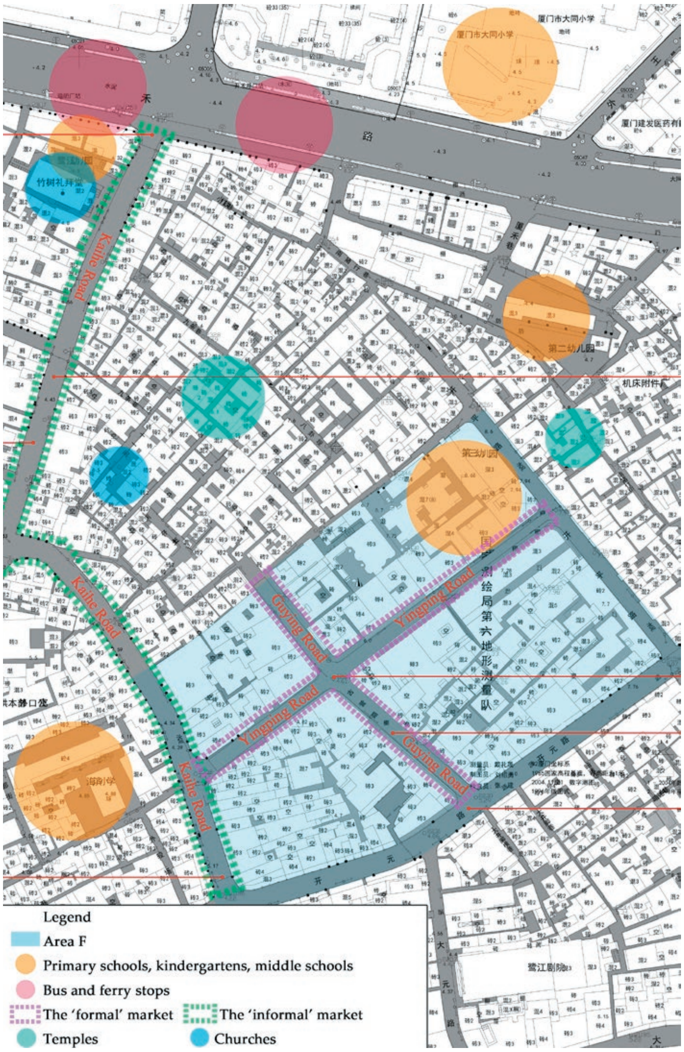
In the case of Yingping, the research question is how to preserve the historical fabric and heritage value, while improving living

01 | In Area A (North), older buildings and poorer inhabitants and activities are concentrated in a dense and intricate urban pattern. Area F (South) has a more regular pattern, dating back to the 19th century; it hosts two very popular seafood markets: the "formal" covered market, and the "informal" one, where the local shopkeepers occupy the street with makeshift extensions to display their goods, by S. Xie

02 | The "formal market", by S. Xie

03 | The "informal market", by S. Xie

01 |



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conditions and, at the same time, resisting gentrification. Many aspects of this question entail, first of all, economic and social issues, which need a specific political stance and consistent policies. On the other hand, planning and urban design aspects were addressed with an approach derived from the Italian morpho-typological studies and experience (Xie, 2018 and 2019), supporting both the local planning action and the self-maintenance capability of inhabitants towards sustainable regeneration.

The historic neighbourhood of Yingping dates back to the Ming Dynasty (1368-1644). It is located in the city centre of Xiamen Island, Fujian Province in southeast China, beside the Taiwan Strait. At 24° 28' N, it has a subtropical climate, with hot and humid summers and short, dry winters, with a mean minimum temperature of 12°C and typhoons in late Summer and early Autumn. Yinping covers about 25.42 ha, and had 22,027 inhabitants at the 2010 census, with a density of 866 persons/ha, mainly living in poor, low rise dwellings. Its main function is residential, with lively commercial activities distributed along a few main streets. Between the main streets lies a network of narrow and winding streets and alleys, and the urban fabric is dense and stratified, due to the complex topography, traditional customs, and long-term spatial practices (Xie, 2019). There is still a strong sense of community among the population, and outdoor spaces maintain their traditional significance for social life (Figs. 2-3).

In 2006, a municipal regeneration plan, aiming to replace most of the ancient fabric with a mixed commercial, financial, and tourist district, was suspended due to widespread criticism. In 2013, a group from the School of Architecture of Huaqiao University in Xiamen was invited by the local administration to complete a physical survey of the whole neighbourhood, and to provide a new proposal for regeneration (School of Architecture of Huaqiao University, 2013). Intensive survey activity and field work with the inhabitants provided deeper knowledge of the densely stratified urban fabric, and of the complex and intertwined layers of activities that give it life. Six typical areas were identified, according to geographical, physical and sociological characteristics (Fig. 1). In 2015, a pilot project provided the restoration of the Lujiang Theatre and the creation of a new high quality public space: the Old Theatre Cultural Park (Fig. 6). In the same year, general guidelines for controlling and managing private additions and renovations were proposed. As a result, the government of the Siming District provided financial contributions to local property owners for self-maintenance and self-renovation actions, such as the reconstruction of façades and interiors. Most of the interventions (involving 51 owners until March 2016) included commercial functions, such as coffee bars, galleries and small restaurants (Fig. 4). This improved the local economy of the neighbourhood, as well as its touristic appeal, since the renovation also involved its six listed monumental buildings. Nevertheless, the housing situation remained largely critical. Yingping is popular and vibrant not only because of its heritage, its busy commercial

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04 | Arcade buildings (Qilou), with shops at ground level, dwellings at the upper floors, and layered additions for ancillary space, by S. Xie

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05 | A typical courtyard house (Dacuo), by S. Xie

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06 | The Old Theatre Cultural Park after renovation, by S. Xie

centre and shops, but also because of its good accessibility and low rent housing stock, which attracts low income tenants. These inhabitants make an essential contribution to the colourful street life, which is so appealing to visitors; at the same time, they cannot afford to take care of the existing buildings, which are mostly in poor conditions. This means that they rather sub-divide spaces and add service units, makeshift storages and awnings in inner courtyards and even in public open areas (Fig. 5). Therefore, their participation in any regeneration project is paramount, and the proposal entails the development of suitable criteria and guidelines to support self-maintenance interventions by local inhabitants.

The comprehensive, morpho-typological approach proposed aims to evaluate the actual environmental quality of the existing fabric and its "aptitude" to meet the present-day expectations of the inhabitants, and to provide fine-tuned and "tailor-made" improvements, promoting adaptive reuse and conservation rather than radical modification or reconstruction. Morphology-led planning practices[12] identify, within the urban fabric, the recognisable parts that have survived countless events to the point of representing a significant urban landscape. At the same time, they investigate the daily spatial practices of dwellers and different city users, revealing the multi-layered nature of urban structures, their specific dynamics and their mutual interaction. Regarding the methods of intervention, a morpho-typological approach[13] reveals the material and technological consistence of buildings, their strong and weak points, together with their aggregation rules, thus clarifying their actual capability to afford new uses and to satisfy new needs.

Conclusions

Under the effect of the changing needs of their inhabitants, built environments adapt, expressing at the same time both change and persistence. Paying closer attention to the interplay between the built environment and the daily spatial practices of human communities that change it while allowing permanence, recalls the idea of "affordance-based transformation"[14]. This idea takes into account both the users' present and perspective needs and desires and the opportunities offered by the built environment in its evolutionary condition. This approach could also help clarify the meaning of "adaptive reuse". Furthermore, the morpho-typological analysis of urban fabrics that developed long before technical heating and cooling systems became of common use, provides valuable knowledge of the environmental wisdom and the skilful strategies perfected by generations of builders in order to achieve the best site-specific "well-tempered environment".

These assumptions can be traced to the maintenance-oriented planning framework proposed for the regeneration of Yingping. Its morpho-typological approach provides strong foundations to incremental, fine-tuned and 'tailor-made' improvements, while enhancing the qualities that urban fabrics have acquired over time.

NOTES

[1] G. Caniggia, G.L. Maffei (1979), p. 30.

[2] I. Samuels (2005), p. 138.

[3] C. Alexander (1964).

[4] The notion of Critical Regionalism had been introduced a few years earlier into the realm of proper architectural critique by Alexander Tzonis and Liane Lefaivre, in "The Grid and the Pathway", 1981. The Authors promoted a vision of architecture focused on regional topography, climate, and culture.

[5] An excellent overview, together with important advancements, is provided by G. Franco, 2015. Liguria seems to be a hotbed for this kind of studies. An early example is in B. Merello, L. Zuaro, 1982, where the analysis of the energy system in the built environment entailed the correlations between local urban morphology of a small hamlet in the hinterland of Genoa.

[6] See M. Morganti, 2018. The Author further investigates the property of density in urban fabrics, which allows "to measure and express in quantitative, objective factors both the morphological and the typological-constructive components, so that they can be related to energy behaviour".

[7] Kenneth Frampton himself, from a strictly critical point of view, noted that the environmental issue should be seen as a cultural, rather than technical issue, and complained that architectural culture did not seem prepared to fully embrace it as such. See: Cairns, 2012.

[8] A comprehensive overview of the Chinese heritage and urban conservation culture and policy is in: Xie, 2018, and Xie *et al.*, 2020.

[9] In 1982 the Cultural Relics Preservation Act was published. In 1985, China joined the UNESCO's Convention Concerning the Protection of the World Cultural and Natural Heritage and became a member of ICOMOS.

[10] The Historical and Cultural Conservation Areas was published in 1986, addressing both historic buildings and cities. This principle was incorporated into China's urban conservation system in 1996, and in 2008 the concept of Historic and Cultural Quarters was proposed. The Principles for the Conservation of Heritage Sites in China, issued in 2002 and revised in 2015, adopted contemporary Western conservation ideas - in particular, the concept of authenticity.

[11] In 1965, private urban real estate property was nationalised, and large houses and establishments were rented out by the local municipalities to low income tenants. The new inhabitants often fragmented the original, large spaces, adapting them to their own needs.

[12] Main references were the plans of Urbino (De Carlo, 1966) and Caltagirone (Leone *et al.*, 1988), and the structural plan of Antwerp (Viganò and Secchi, 2009).

[13] The main reference for this aspect was the Plan of Schio (Mancuso, 1990).

[14] The reference is to Gibson, 1979, and Maier *et al.*, 2009.

REFERENCES

Abramson, D. (2001), "Beijing's Preservation Policy and the Fate of the *Siheyuan*", *TDSR,* Vol. XIII n. 1, pp. 7-22.

Alexander, C. (1964), *Notes on the Synthesis of Form*, Harvard University Press, Cambridge, USA

Alexander, C. (1966), "A city is not a tree", *Design, Vol. 206,* pp. 46-55.

Alvarez, S. *et al.* (1991), *Architecture and Urban Space*, Proceedings of the Ninth International PLEA Conference, Seville, Spain, pag. 24-27.

Bottero, M., Silvestrini, G., Scudo, G. and Rossi, G. (1984), *Architettura solare – Tecnologie passive in edilizia e analisi costi/benefici*, CLUP Edizioni, Milan, Italy.

Buiard, M. and Ju Xi (2007), "The Heritage of the Temples, a Heritage in Stones", *China Perspectives*, n. 4.

Caniggia, G. and Maffei, G.L. (1979), *Composizione architettonica e tipologia edilizia. 1. Lettura dell'edilizia di base,* Marsilio, Venezia.

Caniggia, G. (1981), *Strutture dello spazio antropico*, Alinea, Florence, Italy.

Conzen, M.R.G. and Conzen, M.P. (2004), *Thinking about Urban Form. Papers on Urban Morphology 1932 - 1998 ,* Peter Lang AG, New York, USA.

Cairns, G. (2012), "A Critical Architecture: Comments on Politics and Society - Interview to Kenneth Frampton", *Architecture Media Politics Society* Vol. 1, n. 4.

D'Arcy W. Thompson (1917), *On Growth and Form*.

De Carlo, G. (1966), *Urbino: la storia di una città e il piano della sua evoluzione urbanistica*, Marsilio, Padova.

Fontana, C. (2019), "Architecture and Systemics: Performance Revisited", Minati, G., Abram, M.R., and Pessa, E. (Eds.), *Systemics of Incompleteness and Quasi-Systems*, Springer Nature Switzerland.

Frampton, K. (1983), "Towards a Critical Regionalism: Six Points for an Architecture of Resistance", in Foster, H. (Ed.), *The Anti-Aesthetic. Essays on Postmodern Culture*, Bay Press, Seattle.

Franco, G. (2015), *Paesaggi ed energia: un equilibrio delicato*, Edicom Edizioni, Monfalcone.

Habraken, N.J. (1998), *The Structure of the Ordinary*, The MIT Press.

Gibson, J.J. (1979), *The Ecological Approach to Visual Perception,* L. Erlbaum Associated Publishers, New Jersey.

Leone, N.G., Iacona G., Merlo, V. and Quartarone, C. (1988), *Il disegno e la regola: recupero e Piano quadro del centro storico di Caltagirone*, Flaccovio, Palermo.

Maier, J.R.A., Fadel, G.M., and Battisto, D.G. (2009), "An affordance-based approach to architectural theory, design, and practice", *Design Studies*, Vol 30 (4), pp. 393-414.

Mancuso, F. (1990), *Un manuale per "Nuova Schio",* Arsenale, Venezia.

Martin, L. and March, L. (1972), *Urban Space and Structures*, Cambridge University Press, Cambridge, United Kingdom.

Martin, L. and Steadman, P. (1971), *The Geometry of Environment,* RIBA Publications, London, United Kingdom.

Merello, B., Zuaro, L. (1982), "Recupero e riqualificazione energetica di un nucleo storico", *Recuperare* n. 1, first series.

Morganti, M. (2018), *Ambiente costruito mediterraneo. Forma, densità, energia*, Edicom Edizioni, Monfalcone.

Muratori, S. (1959), *Studi per una operante storia urbana di Venezia*, Rome, Italy.

Maretto, P. (1960), *L'edilizia gotica veneziana*, Rome, Italy.

Muratori, S. *et al.*, (1963), *Studi per una operante storia urbana di Roma*, Rome, Italy.

Samuels, I. (2005), "Conzen's Last Bolt: Reflections on Thinking about urban form", *Urban Morphology*, Vol. 9 (2), pp. 136-44.

School of Architecture of Huaqiao University (2013), *Design of Yingping Area of Xiamen*, Unpublished Report, Xiamen.

Scudo, G. (2018), *Architetture e paesaggi*, Mimesis.

Viganò, P. and Secchi, B. (2009), *Antwerp, Territory of a New Modernity*, Sun Publishers, Amsterdam.

Weber, W. and Yannas, S. (2014), *Lessons from Vernacular Architecture*, Routledge, London, United Kingdom.

Xie, S. (2018)*, The vital preservation of Chinese historic quarters for contemporary living: reconsidering the Italian planning tradition in the physical maintenance of the historic city*, Doctoral dissertation, Supervisor Prof. B. Bonfantini, Doctoral Programme in Urban Planning, Design and Policy, DAStU, Politecnico di Milano.

Xie, S. (2019), "Learning from Italian Typology- and Morphology-Led Planning Techniques: A Planning Framework for Yingping, Xiamen*", Sustainability*, Vol. 11.

Xie, S., *et al.* (2020), "Urban conservation in China in an international context: Retrospect and prospects", *Habitat International*, Vol. 95.

Architecture and the "imaginary planet". Projects and technologies for an intermediate landscape in the city

ESSAYS AND VIEWPOINT

Paola Marrone, Federico Orsini,
Department of Architecture, Roma Tre University, Italy
paola.marrone@uniroma3.it
federico.orsini@uniroma3.it

Abstract. The traditional ecological and environmentalist thinking that theorised the 'return to nature' by contrasting cities and nature seems to be unable to remedy the destructive relationship between city and biosphere. For this reason, it is necessary to rethink the relationship between anthropised and biotic systems, in order to respect the objectives of the Paris Agreement. This rethinking process involves imagining a 'third space' with a positive environmental value, much like an intermediate landscape in which buildings and urban realities can be designed - in a backcasting process - as tools capable of incorporating different types of 'biospheric' capabilities. The essay investigates urban forestation technologies by evaluating their potential and long-term limitations in extreme climatic scenarios.

Keywords: Urban Forestation; NBS; Climatic Scenarios; Urban Regeneration; Intermediate Landscape.

Climate change scenarios and images of intermediate landscapes

Despite the evidence of the risks associated with an extreme rise in temperatures, reported by scientific reports (IPCC, 2018) and by the Press (New York Time, 2020), the fight against Climate Change (CC) seems to affect only part of the international community, as the recent failure of COP25 shows (UNFCCC, 2019). The absence of a global agreement for the reduction of greenhouse gas emissions (GHG) and their removal from the atmosphere, in fact, makes it almost impossible to respect the limit of +1.5°C, as established by the Paris Agreement (European Commission, 2015). In this context of uncertainty many studies, including Climate Action Tracker (CAT), prefigure different CC scenarios (Fig. 1), calculated on the real capacity of national policies to reduce climate-altering gas emissions in the atmosphere in 2020-25-30. CAT, for example, defines a CC range from a minimum of + 1.5°C (ideal scenario), to + <2°C (compatible with the Paris Agreement), to <3°C (insufficient), to <4°C (highly insufficient), up to >4°C (Critically insufficient) (Ritchie and Roser, 2019).

As global warming increases, the risks for urban areas, which are the most vulnerable to CC due to the high concentration of people (in 2050 two thirds of the world's population will live in cities), infrastructure and economic activities, will grow accordingly. For this reason, as Habitat III hopes in the New Urban Agenda roadmap, it seems to be necessary to rethink urban systems and their physical form by interpreting the urban settlement as a source of solutions and not as the cause of the problems that the planet is facing. The increase in the urban heat island, water management, loss of biodiversity and increase in air pollution, according to the CDP Disclosure Insight Action, are some of the risks to pay attention to (CDP Global, 2019). In fact, these risks could be potential causes of the non-habitability of many territories, including coastal and the Mediterranean areas, which are among the most populated regions today.

To cope with these environmental scenarios, numerous public administrations and private companies have decided to invest in the transformation of cities, proposing to transform the 'grey' spaces into green areas, vegetable gardens or urban farms. This presents numerous benefits (Fig 2, top): cost savings, flood risk mitigation, habitat creation for urban fauna, reduction of air and heat pollution, and food production.

Once the assumptions of the industrial revolution are exhausted and the progressive reduction of ecosystem services provided by the natural environment is evident, the image of the Garden City Tomorrow by Ebenezer Howard is replaced by new dystopian and utopian visions. Dystopian visions are like the ones already described in numerous apocalyptic films. Utopian visions are like the ones defined by the artist and activist Bert Theis or Vanessa Keith of Studio TEKA who, in The City After Climate Change, prefigures a city of 2100 (Fig. 2, in the centre). These images, as stated by the thesis of the sociologist Saskia Sassen, together with those elaborated by other well-known designers (Fig. 2, below), demonstrate the need for a 'third way' in which the contrast between artificial and natural - typical of contemporary settlement systems – has to be rethought, identifying a new model capable of overcoming this dichotomy and defining a third intermediate space, a bridge between the biosphere and the urban environment (Sassen, 2016). This would be a hybrid interstice where different positive articulations can be experienced, using innovative knowledge and technologies. The rethinking process is about imagining and building a 'thirdspace' with a positive environmental value, which can function as a reserve of capacity to draw on in order to improve the living conditions of the residents. An intermediate landscape (Desvigne, 2008), in which buildings and urban realities are imagined and designed - in a backcasting process - as tools capable of incorporating different 'biospheric' capabilities. Today, the ecological and environmentalist thinking, which prevailed decades ago and which theorised the 'return to nature' by contrasting cities and nature, is, in fact, proving no longer sufficient to remedy the city's destructive relationship with the biosphere. For this reason, it is necessary to use the urban built environment as a tool for incorporating and developing the biosphere's capabilities.

Methodological assumptions for the study of technologies for the intermediate landscape

If we consider the city as 'a type of socio-ecological system with a broad expanding spectrum of connections with nature's ecologies', these connections can be used to improve its sustainability by exploiting its systemic complexity and multi-scalar capacity (Sassen, 2012). Since, as is well known, cities incorporate a variety of nested scales in which a given ecological condition works, interventions at the micro-level can represent, in an upscaling process, effective interventions also on a global scale. In this sense, technological solutions to mitigate CC at the city scale also become a key element for implementing environmental policies.

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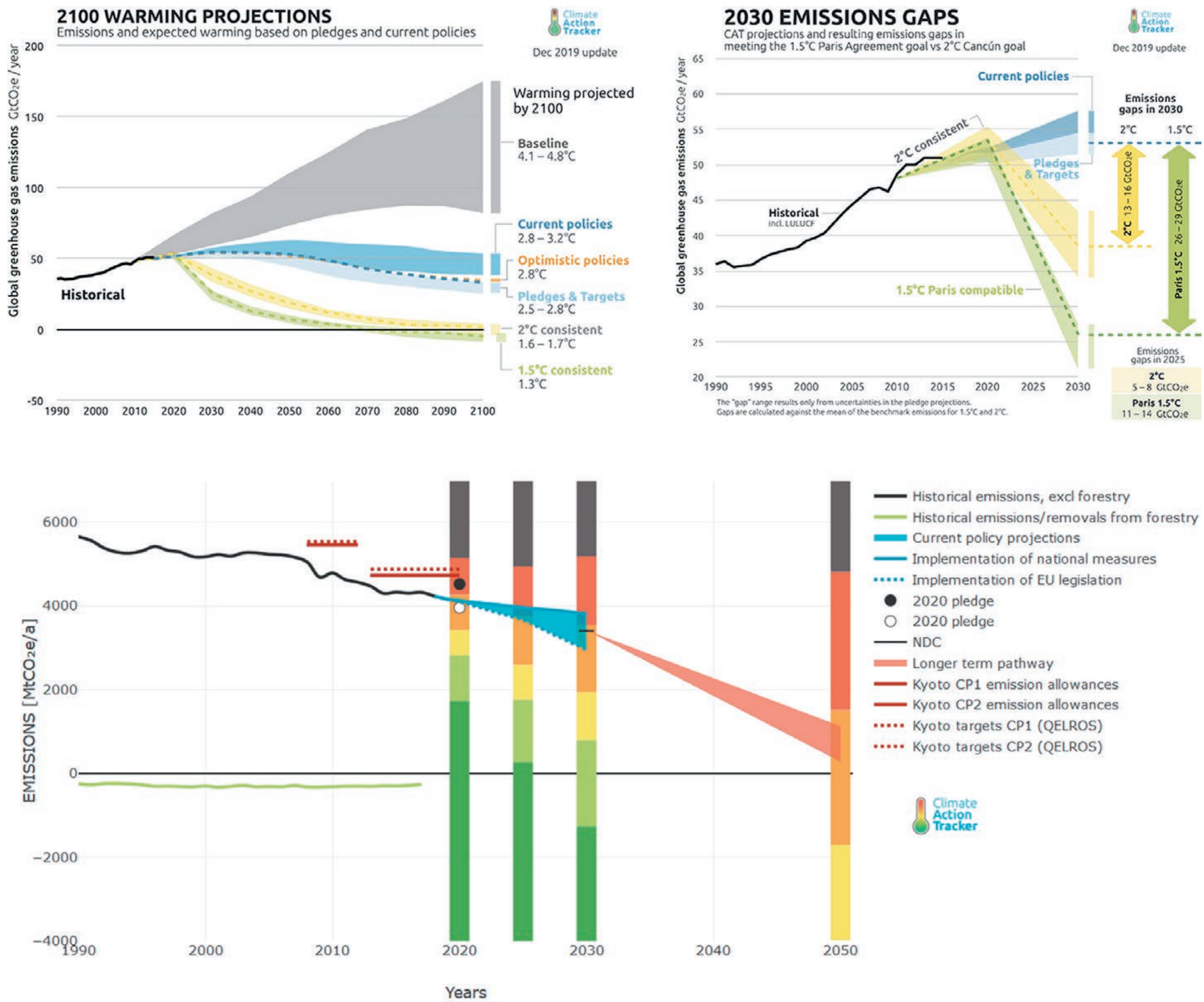


01 |The images show (top) the changes in the climate scenarios compared to the possible worldwide policies adopted in order to reduce CO_2 emissions and (bottom) the climate scenario linked to the current policies adopted by the European Community (<3°C) (source: https://ourworldindata.org)

The paper fits into this cultural framework and analyses the contribution that some urban forestation technologies (UFT) can have in order to redefine future scenarios for architecture. The study limits the research field to the implications that CC may have in the short and long term on the performance of these technological systems.
In section 1, CC scenarios and main urban risk have been identified and described.
In section 2, methodology has been described.
In section 3, some case studies exemplify UFT and limit the research just to some of these.
In section 4, the performance variations of UFT with respect to the different climate scenarios are analysed, as well as the risks identified in section 1. To achieve this goal, an interdisciplinary literature review is developed based not only on research pertaining to the technology architectural design, but also on research related to other disciplines (i.e., urban ecology). The considered studies, mainly chosen among those reporting direct verifications of the performance of the technological systems, allowed to depict how the performance of UFT could vary in relation to the variant of the Climate Scenario and the identified risk.
Based on these data, the paper reconsiders the performance framework with respect to various environmental risks (heat island, rainwater cycle management, water consumption, biodiversity reduction, energy consumption, CO_2 reduction) in the five climate scenarios defined by the Climate Action Tracker. The performance study, which is carried out on a case study, is developed through a qualitative system analysis based on quantitative data derived from scientific research.
In section 5, UFT potential and limitations are discussed and, thanks to some innovative best practices, new research fields are identified in order to improve the performance of urban forestation technologies.

02 | The image shows scenarios of imaginary cities: at the top, Bert Theis' Utopia Island (source: Isola Art Center-ostra Aggloville, Turin 2015); centre, 2100: A Dystopian Utopia - The City After Climate Change (source: Studio Teka); below, Grand Site Tour Eiffel by Gustafson Porter + Bowman (source: Gustafson Porter + Bowman)

03 | The figure shows some examples of "external technologies" at the top (MOF Park and Oerliker Park, Zurich), "edge technologies" in the centre (NY roofs and detail of the green façade of the Musée du Quai Branly, Paris) and "internal technologies" below (vertical farming in the greenhouses of Ilimelgo)

Technologies for an intermediate landscape

Moving away from more consolidated approaches, some contemporary architecture experiments performed at different scales show innovative technological solutions for CC mitigation and adaptation. These solutions work on an intermediate landscape in which the artificial and the biotic systems relate, hybridise and complement each other (Raymond *et al.*, 2017).

These approaches to urban forestry find multiple applications, coded in this study, such as:

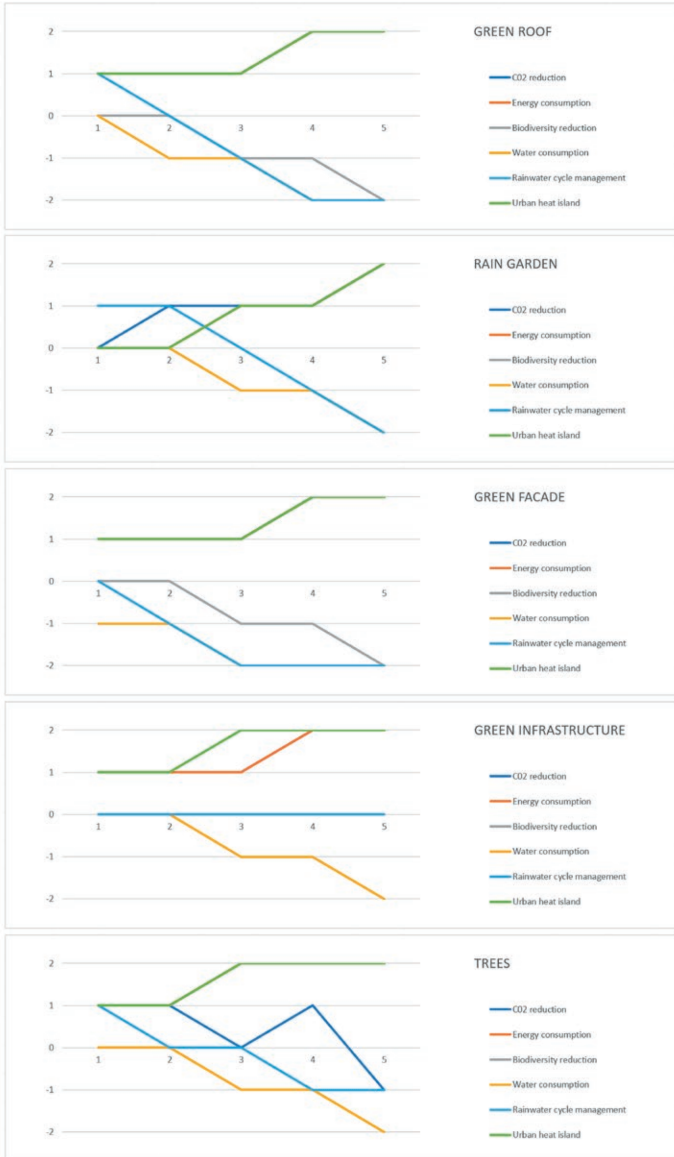
1. "external technologies", technologies that interact with the open space;
2. "edge technologies", technologies that interact with the building envelope;
3. "internal technologies", technologies inserted within volumes and buildings.

Examples of "external technologies" are the recent urban forest planning in Paris and Prato, the integration of greenery in Zurich, such as the MOF Park, characterised by a green infrastructure, and the Oerliker Park, defined by a real urban vivarium (Fig. 3, top), and the design of the Passeig Sant Joan by Lola Domenech.

Examples of "marginal technologies" are the pioneering experiences of Patrick Blanc and his thin vegetable facades, testified by the famous projects of the Caixa Forum in Madrid, the Musée du Quai Branly in Paris, and the thick green façade that grows on a special metal structure, tested by ENEA at Casaccia (RM). Green roofs are also examples of this typology, which is useful for new buildings, as shown by Renzo Piano's project for the California Academy of Science in San Francisco, or for implementation in modern cities, as supported by the legislation for green roofs introduced in 2018 by the New York City Council (Fig. 3, in the centre).

Examples of "internal technologies" are greenhouses integrated into buildings, like the garden designed by RPW in the NY Times building, or hydroponic systems, which find application, also from a production point of view, in London's underground urban framing experiments or in the hybrid buildings that integrate food production (SOA), intended to build urban vertical farming (Ilimelgo), or self-sufficient and sustainable neighbourhoods (Effect) (Fig. 3, below).

Despite being insufficient to describe an exhaustive picture, these examples, however, show how it is increasingly plausible to imagine extending greenery - where possible - in cities and to configure buildings and open spaces in order to recreate a new nature, a hybrid city. This scenario requires a non-traditional approach due to the requirement not only of specific skills (in the field of biology, materials science, agronomy, geography, physics and engineering) but, above all, of different figures assigned to the development of urban policies of public interest with the involvement of citizens. Numerous studies are evaluating the actual effectiveness of urban



05 | The image represents an example of the performance of the forestation technologies analysed with respect to six risks and to the five CC scenario (1-5). Effectiveness was assessed on a -2/0/2 scale, with the values indicating respectively a loss, constancy or an increase in performance, thus describing their potential effectiveness

to quantify, for example, the ecosystem effects (Wang *et al.*, 2014), to demonstrate a close correlation between their concentration and the reduction of pollutants (Irga *et al.*, 2015) , or to evaluate their benefits in terms of heat island reduction (Orsini and Marrone, 2018) and, again, to control the negative effects of gentrification processes (Haase *et al.*, 2017).

Even if the early results of these studies seem to support their effectiveness, little is known about the evolution of the performance of UFT in case of extreme or, at least, variable scenarios.

Performance of forestation technologies and climatic scenarios

Imagining backcasting scenarios or formulating dystopian scenarios would allow us to face the evaluation of a design and technological solution by imagining, backwards, both potential and limitations in the long term or in an extreme scenario. Five hypothetical climatic macro-scenarios, proposed by CAT were discussed to support a discussion on UFT. The analyses were conducted using the city of Bologna as a case study, for two main reasons: Bologna can represent, at a national level, the type of urban settlement of the Po Valley, and it is the most densely populated Italian natural region. Furthermore, due to its geomorphological conditions, Bologna represents an urban context extremely that is vulnerable to CC. In fact, in the most severe scenario, it would reach average temperatures similar to those of Port Said, in Egypt (Fig. 4). Hence the decision to analyse only some technological solutions of forestation, among the most widespread ones, easily implemented in urban contexts and representative of external, edge and internal technologies, particularly:

1. green roof;
2. rain garden;
3. green façade;
4. green structure;
5. trees.

The performance of the UFT, extracted from the data of the scientific literature, is analysed and elaborated in graphs that report their variation with respect to the climatic conditions analysed and to the risk considered. The effectiveness was assessed on a -2/0/2 scale, with the values indicating a loss, constancy or an increase in performance, respectively, thus describing their potential effectiveness (Fig. 5).

From the analysis, some considerations emerge on the potential, limitations and possible corrective actions of the forestation systems considered, which are shown in table 1.

In general, it can be observed how the UFT, with increasing temperatures, either maintain or increase their effectiveness allowing a reduction of: the energy consumption of buildings; the effects of the urban heat island; the air temperature, thanks to the effects of green cover, evapotranspiration, surface temperatures and, therefore, average radiant temperatures. At the same time, however, as temperatures rise, there is a loss of efficacy against risks, such as CO_2 absorption or water stress. Furthermore, scenarios with a strong increase in average temperatures could also correspond to alterations in the rain cycle (increase in intensity associated with a reduction in distribution over time) with consequent drought periods, harmful to some forestry technologies, such as the garden roof and the green façades.

04 | The image has been reworked by the authors on Climate Central data (CLIMATE CENTRAL, 2020)

06 | The figure outlines possible adaptation processes of forestry technologies to varying climatic conditions, highlighting that, as temperatures increase, it is necessary to increase the thickness of natural substrates, to introduce rainwater management and accumulation systems, and to adopt suitable plant types to extreme climatic scenarios

07 | The figure shows some examples of innovative technologies. Top, the Air Factory of PNAT; centre, the BIUP House of ARUP; below that, the tent with algae from EcoLogicStudio; bottom, the American Pavilion of Expo 2015

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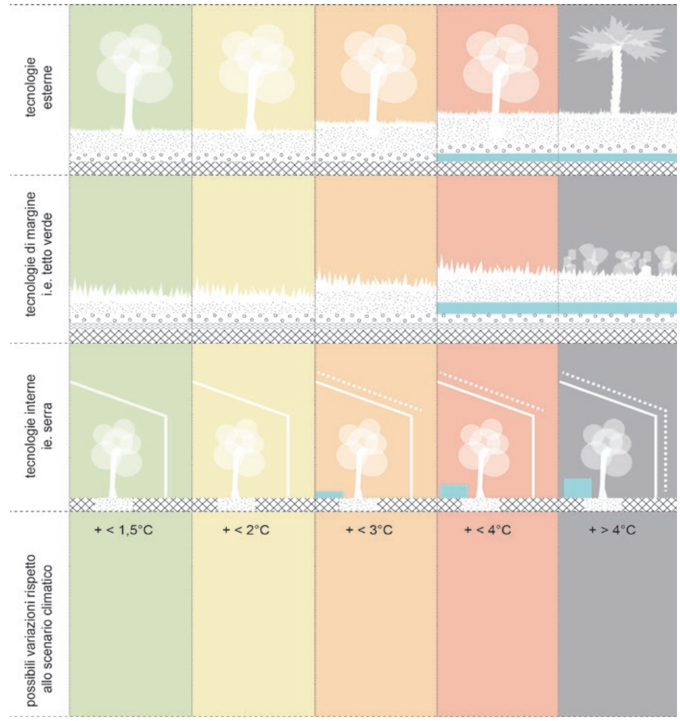

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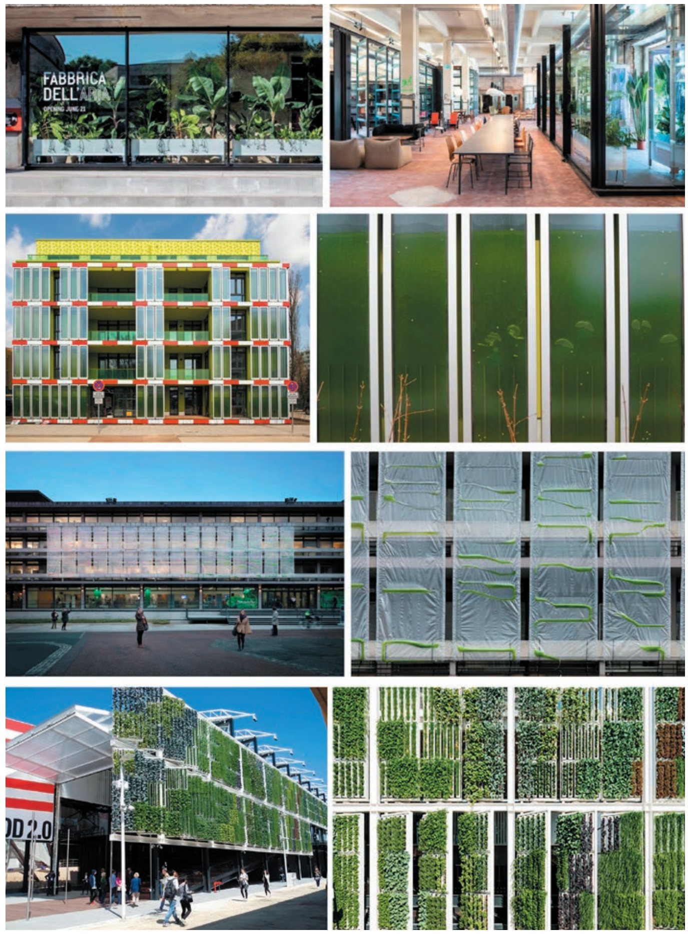

Beyond urban forestation technologies: innovation scenarios

UFT offers interesting solutions to increase the performance of eco-systemic services in urban settlements and, thus, contribute to the reduction of environmental risks due to CC. The increasing spread of these strategies, highlighted by numerous recent urban forestation plans, is tracing a third way for urban development, characterised by an intermediate landscape in which the biotic and anthropic systems coexist, overcoming the artificial/natural dichotomy that has characterised human history. In this context UFT can improve the mitigation of the negative effects imposed by CC, on the one side, but can be strongly affected by it, on the other.

This essay investigates the performance variation of UFT in five climatic scenarios characterised by an increment in average temperatures. From this study, in general, it emerges that a sharp increment in temperatures, with a consequent environmental alteration, may compromise the performance of some forestry technologies with respect to certain risks, such as the absorption of climate-changing gases or the management of the water cycle, reducing their absorption capacity during heavy rains and requiring greater quantities of water during periods of prolonged drought (Fig. 6).

Today, the possible loss of effectiveness of some UFT, compared to particular extreme climatic scenarios, becomes an interesting area for new research fields with the aim of developing new systems or components that, as plug-ins, are able to make the various technological systems adaptable to changing climatic conditions, either maintaining or increasing efficiency. In support of this thought, some forestry experiments (Fig. 7) are moving in this direction, hybridising technology with nature in order to produce energy, purify the air and improve urban food production.

A first example is the 'Air Factory', developed by the Start Up PNAT of the University of Florence. This system is based on a glass box containing several plants with huge leaves. The system works by purifying indoor air by using the soil and the huge leaves of the plants. It can filter 5,000 cubic metres of air per hour, reducing atmospheric pollutants by 98%. This technological device develops a controlled environment for the plants in order to protect them from the possible extreme effect of CC and guarantees their performance, integrating them into building spaces.

The use of algae application on the façade, tested for example by ARUP in the "BIQ House" or by EcoLogicStudio during the Climate Innovation Summit (Dublin, 2018), is another example. ARUP's idea is based on a new stable façade with glass panels incorporating algae. The solution allows the implementation of these green technologies even when the climatic conditions vary. Furthermore, growing the algae into the panels allows different uses, like biomass production and hot water for heat exchange (solar collector), achieving around 30 kWh/m^2 energy for each system (ARUP 2020). The prototype of EcoLogicStudio is based on the same principles as ARUP's prototype but with simpler and lighter technologies that can be used for rapid and inexpensive retrofit strategies. Each panel, with a surface

Tab. 01 | The table shows the scientific references of the study and a synoptic picture of the potential, limitations and possible corrective actions that can be introduced

| Tab. 01

Risk		Effects of climate change on forestation technologies	Reference
Heat island	+	The increment of temperatures increases the differential between outside and inside, and therefore the effectiveness of green technologies, compared to traditional technologies.	(Berardi, GhaffarianHoseini and GhaffarianHoseini, 2014) (Zhang *et al.*, 2019)
	-	Thermal stress of plants, especially in systems with little plant substrate, could be a problem that can be solved with an increase in irrigation or with the selection of species with reduced water requirements.	
Rainwater cycle management	+	Water absorption capacity with strong reduction of the sewer load. Water purification.	(Klein and Coffman, 2015) (Moghadas *et al.*, 2011) (Debele *et al.*, 2019) (Vanuytrecht *et al.*, 2014) (Liu, Li and Yu, 2019)
	-	With extreme phenomena, the positive impact is reduced. To remedy this problem, systems for the accumulation of water (storage tanks) or systems that allow greater infiltration of water into the subsoil (canals) could be integrated.	
Water consumption	+		(Szota et al., 2017) (Menzel et al., 1995)
	-	An increase in temperatures corresponds to an increase in arid periods, with consequent water stress. The problem can be solved by using plants suitable for scarce rains or by increasing the thickness of the substrates in order to retain greater soil moisture.	
Biodiversity reduction	+		(Madre et al., 2013) (Radić, Dodig and Auer, 2019) (Zhang *et al.*, 2019)
	-	Risk of biodiversity reduction with increasing climate, also due to possible non-native predatory species.	
Energy consumption	+	The effect of green roofs allows to reduce energy consumption for cooling, as temperatures increase, their effectiveness increases.	(Chan and Chow, 2013) (Talaei, Mahdavinejad and Azari, 2020) (Campiotti, Giagnacovo and Nencini, 2020)
	-	Thermal stress of plants, especially in systems with little plant substrate, could be a problem that can be solved with an increase in irrigation or with the selection of species with reduced water requirements.	
C02 reduction	+	Green technologies generally prove to be useful systems for reducing the CO_2 present in the urban atmosphere.	(Bastin et al., 2019) (Foster, Lowe and Winkelman, 2011) (Wang *et al.*, 2014)
	-	Drought reduces plants' ability to absorb CO_2. The problem can be solved by increasing the areas planted and using plants resistant to hot climates.	

area of 2 m² and 50 kg of weight, is able to absorb 22 kg CO_2/year, the same quantity as a 5,000 kg mature tree (Photosynthetica, 2020). The production of vegetables, in addition to the aforementioned urban greenhouses, has also recently been released in the "American Food 2.0" pavilion for expo 2015 by architect James Biber. Developed by the startup Bright Agrotech, the structure is a particular façade that integrates hydroponic systems for growing vegetables and producing food every two weeks in an urban centre.
These innovative experiences show possible interesting scenarios to develop new technologies capable of dealing with CC that will affect our cities, and to define new models in which the anthropic system and the biosphere merge into an "imagined" rather than an "imaginary" planet.

REFERENCES

ARUP (2020), available at: https://www.arup.com/ (accessed 06 May 2020).

Bastin, J.F. *et al.* (2019), "Understanding climate change from a global analysis of city analogues", *PLoS ONE*, Vol. 14 (7), pp. 1-13.

Berardi, U., GhaffarianHoseini, A.H. and GhaffarianHoseini, A. (2014), "State-of-the-art analysis of the environmental benefits of green roofs", *Applied Energy*, Vol. 115, pp. 411-428.

Campiotti, C.A., Giagnacovo, G., Nencini, L. and Scoccianti M. (2018), "Le coltri vegetali nel settore residenziale", *Energia, ambiente e innovazione*, Vol. 2, pp. 76-81.

CDP Global (2019), "Cities at risk: dealing with the pressures of climate change", available at: https://www.cdp.net/en/research/global-reports/cities-at-risk (accessed 16 January 2020).

Chan, A.L.S. and Chow, T.T. (2013), "Energy and economic performance of green roof system under future climatic conditions in Hong Kong", *Energy and Buildings*, Vol. 64, pp. 182-198.

Climate Central (2020), "This Is How Climate Change Will Shift the World's Cities", available at: https://www.climatecentral.org/

Debele, S.E. *et al.* (2019), "Nature-based solutions for hydro-meteorological hazards: Revised concepts, classification schemes and databases", *Environmental Research*, Vol. 179, pp. 198.799.

Desvigne, M. (2008), *Intermediate Natures*. Birkhauser, Basilea.

European Commission (2015), "Accordo di Parigi", available at: https://ec.europa.eu/clima/policies/international/negotiations/paris_it (accessed 14 November 2018).

Foster, J., Lowe, A. and Winkelman, S. (2011), "The Value of Green Infrastructure for Urban Climate Adaptation", available at: http://dev.cakex.org/sites/default/files/Green_Infrastructure_FINAL.pdf.

Haase, D. *et al.* (2017), "Greening cities - To be socially inclusive? About the alleged paradox of society and ecology in cities", *Habitat International*, Vol. 64, pp. 41-48.

IPCC (2018), *IPCC REPORT 2018.*

Irga, P.J., Burchett, M.D. and Torpy, F.R. (2015), "Does urban forestry have a quantitative effect on ambient air quality in an urban environment?", *Atmospheric Environ*ment, Vol. 120, pp. 173-181.

Klein, P.M. and Coffman, R. (2015), "Establishment and performance of an experimental green roof under extreme climatic conditions", *Science of the Total Environment*, Vol. 512, pp. 82-93.

Liu, Y., Li, T. and Yu, L. (2019), "Urban heat island mitigation and hydrology performance of innovative permeable pavement: A pilot-scale study", *Journal of Cleaner Production*, Vol. 244, pp. 118.938.

Madre, F. *et al.* (2013), "A comparison of 3 types of green roof as habitats for arthropods", *Ecological Engineering*, Vol. 57, pp. 109-117.

Menzel, C.M. *et al.* (1995), "Water deficits at anthesis reduce CO_2 assimilation and yield of lychee (Litchi chinensis Sonn.) trees", *Tree Physiology*, Vol. 15(9), pp. 611-617.

Moghadas, S. *et al.* (2011), "Regional and seasonal variations in future climate is green roof one solution?", paper presented at the 12th International Conference on Urban Drainage, Porto Alegre, Brazil.

New York Time (2020), "How Much Hotter Is Your Hometown Than When You Were Born?" available at: https://www.nytimes.com/interactive/2018/08/30/climate/how-much-hotter-is-your-hometown.html?smid=pl-share (access 10 May 2020).

Orsini, F. and Marrone, P. (2018), "Resilienza e ambienti urbani aperti. Misure di adattamento e di mitigazione a confronto", Techne, Journal of Technlogy for Architecture and Environment, Vol. 15, Firenze University Press, Firenze, pp. 348-357.

Photosynthetica (2020), https://www.photosynthetica.co.uk/system, (access 06 May 2020).

Radić, M., Dodig, M.B. and Auer, T. (2019), "Green facades and living walls- A review establishing the classification of construction types and mapping the benefits", *Sustainability*, Vol. 11(17), pp. 1-23.

Raymond, C.M. *et al.* (2017), *An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects*, Seacourt Limited. Oxford, United Kingdom.

Ritchie, A. and Roser, M. (2019), "CO_2 and Greenhouse Gas Emissions", available at: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions.

Sassen, S. (2012), "Cities and the Biosphere", *The Berkshire Encyclopedia of Sustainability*, pp. 36-43.

Sassen, S. (2016), "A Third Space: Neither Fully Urban nor Fully of the Biosphere", *Climates Architecture and the Planetary Imaginary*, pp. 172-179.

Szota, C. *et al.* (2017), "Drought-avoiding plants with low water use can achieve high rainfall retention without jeopardising survival on green roofs", *Science of the Total Environment*, Vol. 603, pp. 340-351.

Talaei, M., Mahdavinejad, M. and Azari, R. (2020), "Thermal and energy performance of algae bioreactive façades: A review", *Journal of Building Engineering*, 28, p. 101.011.

UNFCCC (2019), "COP25", available at: https://unclimatesummit.org/?gclid=EAIaIQobChMI5p21kMuq5gIVBOJ3Ch0KHQ3QEAAYASAAEgK1LfD_BwE (accessed 16 January 2020).

Vanuytrecht, E. *et al.* (2014) "Runoff and vegetation stress of green roofs under different climate change scenarios", *Landscape and Urban Planning*, Vol. 122, pp. 68-77.

Wang, Y. *et al.* (2014), "Effect of ecosystem services provided by urban green infrastructure on indoor environment: A literature review", *Building and Environment*, Vol. 77, pp. 88-100.

Zhang, L. *et al.* (2019), "Thermal behavior of a vertical green facade and its impact on the indoor and outdoor thermal environment", *Energy and Buildings*, Vol. 204, pp. 109.592.

Technological transition in building design at the intersection of living and manufactured

ESSAYS AND VIEWPOINT

Berrak Kirbas Akyurek[a, b], **Masi Mohammadi**[a], **Aysen Ciravoglu**[b], **Husnu Yegenoglu**[a],
b.kirbas.akyurek@tue.nl
[a]Department of the Built Environment, Eindhoven University of Technology, Eindhoven, The Netherlands
[b]Department of Architecture, Yildiz Technical University, Istanbul, Turkey

Abstract. This paper aims to elucidate reflections of technological transition today through the 'unity' of living and manufactured components of building design. Technological advances enable living organisms from algae to humans, and many more, to become useful tools to create interior and structural elements for buildings. Thus, designing with living organisms has become a growing phenomenon in architecture by transforming building components into 'biobuilding' components. In this paper, this phenomenon is critiqued through the bonds between the concepts of nature, technology, and building design, from contemporary studies to the highlights back in history. Overall, the paper gives architects insights on the envisioned future that presents a harmony between natural and building environment.

Keywords: Technological Transition; Building Design; Biobuilding Components; Living Organisms; Smart Technologies.

Introduction

The innovations, entitled as "biobuilding components" in the framework of the paper, could be followed as the indicators of the technological transition that might place building design at the intersection of living and manufactured worlds today and in the near future. The recent advancements in technology have enabled the incorporation of living organisms with man-made productions, instead of fabricating products inspired by the elements of nature. Thus, living organisms at any scale, i.e., plants, animals, fungi, bacteria and cells, could become useful tools to design building components, such as building materials, construction technologies, interior elements, furniture, mechanical systems, and much more (Ripley and Bhushan, 2016). Some examples include air-cleaning pots with plants, self-healing concrete with bacteria, self-growing furniture made from mushrooms, and many more innovative projects could be considered as biobuilding components (Fig. 1).

Due to its heterogeneity and complexity, any technology can blend into buildings at varying scales. At this juncture, the incorporation of living organisms promisees to transform building parts into autonomously living, growing, dynamic entities. Meanwhile, designing together with living organisms in architecture presents a variety of smart and sustainable solutions for buildings, ranging from energy efficiency to degradable materials (Imhof and Gruber, 2015). Thus, the possible influences of biobuilding components might seem critical to be discussed in the discipline of architecture, particularly in building design.

Designing together with living organisms has become a topic of interest over the past years along with their potential benefits within the current degradation of the environment (Myers, 2018). Moreover, many biobuilding components have infiltrated into everyday lives by reshaping our activities, habits, lifestyles, and surroundings (Van Mensvoort and Grievink, 2015). However, much uncertainty still exists about the relationship between biobuilding components and building design. Hence, this paper aims to give a better understanding of the meaning(s) of biobuilding components by discussing relationships between the concepts of nature, technology and building design, thereby, allowing us to look through different perspectives.

This paper first presents contemporary studies manifesting the shifting notions of nature and technology. Then, the impact of the concept of nature on building design is reviewed through the approaches and examples of present and past. Finally, the influence of the development of (smart) technologies on building design is followed through the infiltration of small-scale industrial products into buildings.

Technological transition towards blending living and manufactured components

The merge of living and manufactured components may sound futuristic and even hard to achieve at first, but each innovative product could be seen as one further step to get familiar with this transition in society (Van Mensvoort and Grievink, 2015). Nowadays, technological developments have manifested a variety of innovations in which technological and natural elements have been intertwined with increasing momentum (Karafyllis, 2006)[1]. Indeed, living organisms could become 'living components' as natural (design) elements, and be united with 'manufactured components' that are man-made, technological (design) elements. Thus, many studies resonate within multiple disciplines and architecture to explore the bridges between living and manufactured worlds through the social, philosophical, cultural, and practical implications.

Through the concept of "Next Nature", Koert van Mensvoort introduces a novel approach by aiming to increase people's awareness of the fading boundaries between nature and technology (Van Mensvoort and Grievink, 2015). The Next Nature platform manifests a variety of technological products from different industries such as; health, food, textile, and more, and demonstrates the evolving relationship between people, nature and technology.[2] Moreover, a holistic approach is embraced for society to get accustomed to any man-made products and thus consider them normal.[3] For example, electric cars, lab-grown meat, and commercial space travel could become "natural" by being omnipresent soon. In this sense, designing together with living organisms is becoming a part of the industry, and shall be accepted by a larger part of society every day. Moreover, many more studies and approaches also lead researchers to be critical about the distinction between nature and technology through different aspects. The recent studies of the anthropologist Phillipe Descola concluded that even the Amazon Forest is not "untouched" by humans; therefore there is no such thing as "pure" nature (Descola, Lloyd and Sahlins, 2014)[4]. Likewise, studies on; "subnature" (Gissen, 2012) and "dark nature" (Michael, 2011) underlined the subjectivity of our understanding of the concept of nature by questioning its relationship with technology from different perspectives.

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01 | Examples of Biobuilding components exemplifying the incorporation of living organisms (from left to right, Clairy at Keukenhof Exhibition, NL, 2018, Mycelium based products at Officina Corpuscoli, Amsterdam, NL, 2019, Sample of Self-healing concrete, Deflt, NL, 2019); Source: Author's archive

01 |

All these approaches lead us to question our understanding of nature and its relationship with technology. In building design, Myers presented examples of 'biodesign' as living organisms becoming design elements in architectural design (Myer, 2018). Myers' collection includes case studies aimed to replace the industrial and mechanical processes with the incorporation of living organisms projected to be used as architectural and interior elements (Myers, 2018). Likewise, the bioarchitectural approach underlines the possibility of a wide range of innovative solutions based on living organisms for buildings (Ripley and Bhuskan, 2016). Many researches in the discipline of architecture might share similar visions with biodesign and bioarchitectural approaches. To cite a few examples, the Silk Pavilion, a 3D space created together with silkworms and designed by the Mediated Matter group, demonstrates the incorporation of living organisms in a different way (Oxman, 2015). The Silk Pavilion explores the relationship between digital and biological fabrication on product and architectural scales by inspiring the ability of silkworms to create 3D space. By sharing the same motivation yet developing novel strategies, the project "GrAB - Growing as Building", managed by Petra Gruber and Barbara Imhof, takes dynamics and growth patterns from nature and applies them to architecture by focusing on the potential of creating architectural spaces through "slime molds" (Imhof and Gruber, 2015)[5]. Moreover, in Fab Tree Hab project Michelle Joachim explores ways to grow buildings only from native trees. As a first prototype, he creates a living wall grown by "pleaching" plants (Arbona, *et al.*, 2003). All in all, from façades with living plants to mushroom chairs, to architectural spaces created by silkworms, 'biobuilding components' in multiple scales, domains, techniques, and functions, have yet to infiltrate into the buildings.

It is remarkable that the philosophical approaches are on one side, with practical implications on the other. All these researches hint ata drastic change that could happen soon. These projects are mainly at the experimental level. However, a rich history lies behind buildings to create bonds with the elements of nature, and the critical role(s) of small-scale products in building design. Thus, to give a better understanding of the technological transition from building components to biobuilding components, the paper continues with an overview of *Changing Dynamics in Building Design through the Concept of Nature.*

Changing dynamics in building design through the concept of nature

The existing academic and popular literature is overwhelmed with a wide range of approaches and practices explaining the different ways to connect, inspire, utilise and merge with nature in building design. In recent studies, nature-related examples have mostly been evaluated under bio-derived concepts such as "biomimicry", "bioinspiration", "biophilia", and many more (Pawlyn, 2011; Caperna, 2017; Gruber and Imhof, 2017; Speck *et al.*, 2017). 'Biomimicry' could be seen as the most well-known technique extensively practiced by innovators in building design (Ratti and Claudel, 2016). In architecture, biomimicry implies learning from the forms, processes, and strategies of nature for sustainable solutions (Pawlyn, 2011). Biomorphology, on the one hand, favours the imitation of the forms and structures for buildings (Speck *et al.*, 2017). Bioinspiration often refers to the transfer of aesthetic and morphological aspects of nature to building design (Gruber and Imhof, 2017). Biophilia aims to bond humans with the natural environment, and is often related to design studies supporting environmental sustainability (Caperna, 2017). All these concepts and many more could help to understand how nature works and how to use living organisms, thus they could lead the way for architects to provide smart and sustainable solutions for buildings.

With the help of bio-derived concepts and computational technology, contemporary buildings can be designed as a living, dynamic, and fluent in terms of form and structures inspired by natural elements. Thus, design principles could be emulated from biological forms, processes, and systems, and implemented into the buildings. For example, in the case of the Waterloo International Terminal designed by Nicholas Grimshaw and Partners, the flexible scale arrangement of the Pangolin is mimicked in the glass panel fittings, so they can move in response to the imposed air pressure forces (Aldersey-Williams, 2003). Moreover, living organisms could already be utilised to resolve the environmental challenges of today with increasing demand for energy, resources, and raw materials from the developing world. The case of Bio Intelligent Quotient (B.I.Q) could be given as a contemporary example in which a bioreactor façade powered by algae supplies the necessary energy for the building (Delle Stelline, 2013).

On the other hand, to bond with nature is not a new phenomenon in advance of technology nor architectural discourse. Billions of years of evaluation through its structures, algorithms, mechanisms and materials, and the achieved solutions have led humans to be inspired by nature in the discipline of architecture. At this juncture, despite the popularity of nature-related concepts in contemporary architecture, the influence of the different understandings towards nature along with the technological abilities could be traced back to the history.

In the modern discourse, metabolism in architecture indicated the potential of living and the dynamics of space. The Metabolist movement connotated the city with the metaphor of the human body as its elements can be born, grow, and die (Pernice, 2004). The Nakagin Capsule Tower designed by Kisho Kurokawa in 1972 seems to be a clear demonstration of metabolism in architecture. Before that, in early 1908, Frank Lloyd Wright introduced the word 'organic' into his philosophy of architecture by underlining a balance between buildings and architectural spaces and the natural environment. The examples of organic architecture could be seen in very well known buildings in architecture, such as Casa Milla by Antoni Gaudi, Falling Water house by Frank Lloyd Wright.

Indeed, since pre-modern architecture, symbolic, analogic, and metaphoric meanings of living and non-living elements of nature have taken place in architectural discourse. The depiction of the relationship between the human and natural environment in 'Primitive Hut' in the 18th century by Marc Antoine Laugier underlines that the notion(s) of nature and its scientific and philosophical debates have always been associated with the critical aspects of architecture since the "origin" of architecture. Primitive hut was "natural" in the sense of abstracting principles of a fundamental shelter by favouring intrinsic and natural forms in architecture just like the abstraction of proportional relationships from nature by Leon Battista Alberti (Hagan, 2001).

All in all, bonding with nature has often motivated architects from pre-modern times to present day. Meanwhile, recent technological abilities have presented new ways to bond the built and natural environment. At this juncture, this paper manifests that the rise of biobuilding components could also create drastic changes in building design by presenting a radical way of bonding living and manufactured components, thus nature and technology. However, to give a better understanding of the possible role(s) of biobuilding components, first it seems necessary to discuss *Changing Dynamics in Building Design Through Development of (Smart) Technologies.*

Changing dynamics in building design through the development of (smart) technologies

The concept of nature has maintained its significance as a matter of discussion in the scope of building design. In parallel, its evolving relationship with emerging technologies has remained the focus of contemporary concepts. Nowadays, the Internet of things, big data, pervasive and mobile computing, sensor networking, and artificial intelligence have often found a place within contemporary discussions in building design. Meantime, the term 'smart' is already a 'buzzword' of user-friendly industrial products empowering the interaction between people and their surroundings. Thus, empowering the physical world with digital systems through these so-called smart technologies has motivated architects to design smart environments.

The advances in computational technology have accelerated the developments of technologies, thereby resulting in smart technologies becoming tools for supporting the quality of daily lives in the built environment. The term, smart home, was first used in 1984 as a home that is wired with computing and information technology responding to the needs (comfort, security, and entertainment) of the occupants (Harper, 2003). Afterward, the term 'smart' was genuinely accepted in the descriptions of recent technologies. Back in history, wired homes resembled 'science function'; only the 'hobbyists' were envisioned (Harper, 2003). Nowadays smart buildings and the Internet of things have become well known in architectural discourse. Smart technologies, like having security and surveillance systems in any buildings, HVAC systems at the office and public buildings, and controlling them by smartphones, have become frequent and omnipresent in daily life. Moreover, smart environments today have presented solutions for the ageing society by assisting healthcare (Mohammadi, 2014).

Indeed, technological growth has aimed to make human life more comfortable with machines facilitating household chores throughout history. We are still experiencing the impact of smart homes and wireless technology on both our buildings and our lifestyles. Thus, the impact of popular small-scale technologies, like smartphones' significant potential to control and connect with the surroundings, seems easy to notice. However, for decades, the developments in technology have shown their impact on building design alongside the changing dynamics in society by affecting each other reciprocally.

In the 1980s, computers were moved from workplace to house by blurring the distinction between home and work environment. By this change, smartphones, the Internet, and wireless systems led people to reach any information and contact any person in any space, thus radically affecting habits and lifestyles. A few decades earlier than computers, technologies such as television and radio integrated into the homes and resulted in people spending more time in the home environment. These technologies were intended to increase the comfort of the user.

Before that, domestic technologies were aimed to ease daily life tasks with time-saving solutions. In the 1960s, washing machines, electric razors, kettles and cookers became omnipresent, while the implementation of central heating and thermostats was also widespread at homes (Aldrich, 2003). However, the first rise of domestic appliances, like refrigerator, dishwasher and vacuum cleaner, started in the 1920s. Indeed, house designs have begun to take shape around the advantages of the growing number of domestic appliances and the need for more electricity and energy ever since the arrival of electricity into the home environment (Harper, 2003).

All in all, the impact of technologies through history shows that technological developments have often influenced building design alongside societal and cultural aspects. At this juncture, a variety of biobuilding components incorporated with living organisms, such as humans, plants, and even bacteria, have yet to infiltrate into the buildings. Thus, this paper manifests that biobuilding components could also create radical changes in building design as well as affect everyday lives. While the parallel overviews elucidating the relationships between nature, technology, and building design helped us to underpin this argument, the paper concludes with the following remarks for the future.

Conclusions and remarks for future

This paper contributes to the existing literature by exploring the meanings of biobuilding components for building design. The overviews presented in the paper demonstrate the changing dynamics in building design through the concept of nature and the development of technology. Thus, the paper confirms that connecting with nature and adapting to technological development have always remained at the core of building design throughout history. This leads us to underpin the critical roles of biobuilding components in building design from broader perspectives with different angles.

Throughout history, the concept of nature has always been a significant matter in the discipline of building design with altering approaches and enhancing technological abilities. In parallel, a variety of technologies has often been added to the built environment, aiming to empower the relationships between users and their surroundings. At this point, biobuilding components present innovative ways for buildings to connect with nature by embracing technologies. Biobuilding components are not just additional or somehow upgraded technologies bringing smart and sustainable solutions to current environmental degradation. Indeed, they could accelerate the current technological transition by transforming the building design itself into living, growing and also technological entities.

The number of biobuilding components is increasing on a daily basis, infiltrating into the built environment and daily lives. This requires further studies on new design strategies and approaches in the framework of building design. Indeed, these studies shall concentrate on the technical, cultural, and social matters of biobuilding components, and their translation into the buildings. More importantly, this technological transition shall also be discussed through the relationships between nature, technology, and building design.

NOTES

[1] Karafyllis coined the term 'biofact' for these natural-technical hybrid objects (Karafyllis, 2006).

[2] In addition to Next Nature book, dynamic and updated Next Nature platform (NNN) could be followed by URL01: www.nextnature.net and also URL02: http://www.nanosupermarket.org/

[3] The Pyramid of Technology is an approach, which shows the possibility of any technological product to be 'naturalised' by means of being an essential part of daily life through seven steps; 'envisioned', 'operational', 'applied', 'accepted', 'vital', 'invisible' and, finally, 'natural'. See: van Mensvoort, K. M. (2013). Pyramid of technology: how technology becomes nature in seven steps. (Eindhoven University lectures; Vol. 3). Eindhoven: Technische Universiteit Eindhoven.

[4] In his ethnographic work among an Amazonian community, the Achuar Tribe, Descola found out that the flora and the distribution of the species have been radically transformed by people through the years (Descola, Lloyd and Sahlins, 2014).

[5] In GrAB project physarum polycephalum, an acellular slime mold, is experimented in the Biolab. Physarum polycephalum is examined as the new tool for architecture to design future since it embodies electric potential on its surface and develops sensing electronics and computing devices (Imhof and Gruber, 2015).

REFERENCES

Aldersey-Williams, H. (2003), *Zoomorphic: new animal architecture*. L. King. London, United Kingdom.

Arbona, J., Greden, L. and Joachim, M. (2003), "Nature's Technology: The Fab Tree Hab House *Thresholds*, Vol. 26, pp. 48-53.

Caperna, A. (2017), "Biophilic Design", *Journal of Biourbanism*.

Delle Stelline, P. (2013), *BIQ House + SolarLeaf - the use of microalgae*, Pocacito, Hamburg.

Descola, P., Lloyd, J. and Sahlins, M. (2014), *Beyond Nature and Culture*. 1st edn. Chicago, The University of Chicago Press.

Gissen, D. (2012), *Subnature: Architecture's Other Environments*, New York: Princeton Architectural Press.

Gruber, P. and Imhof, B. (2017) "Patterns of Growth-Biomimetics and Architectural Design", *Buildings*, 7(4), p. 32.

Harper, R. (2003) *Inside the Smart Home, Springer-Verlag London*.

Imhof, B. and Gruber, P. (2015), *Built to Grow: Blending architecture and biology.* Edition An, Birkhauser. Edition An Basel.

Karafyllis, N.C. (2006) "Biofakte - Grundlagen, Probleme, Perspektive", *Erwägen Wissen Ethik*, Vol. 17/4, pp. 547–558.

Van Mensvoort, K. van and Grievink, H.-J. (2015) *Next Nature Nature Changes Along with us*. edn., Next Nature Network, Amsterdam.

Michael, D. (2011) "Toward a dark nature recording", *Organised Sound*, Vol. 16(3), pp. 206-210.

Mohammadi, M. (2014), *DomoticaKompas. Inzichten uit een decennium slimme zorgprojecten in Nederland*, Van Litsenburg, Eindhoven.

Myers, W. (2018) *Biodesign : Nature + Science + Creativity.* London: Thames & Hudson

Pawlyn, M. (2011), *Biomimicry in Architecture*, RIBA Publishing, London, United Kingdom.

Pernice, R. (2004), "Metabolism Reconsidered Its Role in the Architectural Context of the World", *Journal of Asian Architecture and Building Engineering*, Vol. 3(2), pp. 357-363.

Ratti, C. and Claudel, M. (2016) *The City of Tomorrow: Sensors, Networks, Hackers, and the Future of Urban Life (The Future Series)*, New Haven and London: Yale University Press.

Ripley, R.L. and Bhushan, B. (2016) *Bioarchitecture: Bioinspired art and architecture-a perspective, Philosophical Transactions of the Royal Society A: Mathematical*, Physical and Engineering Sciences.

Speck, O. et al. (2017) "Biomimetic bio-inspired biomorph sustainable? An attempt to classify and clarify biology-derived technical developments", *Bioinspiration and Biomimetics*, IOP Publishing, Vol. 12(1), pp. 1-16.

Cities in transformation. Computational urban planning through big data analytics

Carlo Caldera[a], **Carlo Ostorero**[b], **Valentino Manni**[c], **Andrea Galli**[d], **Luca Saverio Valzano**[e],
[a] Department of Structural Engineering and Geotechnical Engineering (DISEG), Responsible Risk Resilience Centre (R3C), Politecnico di Torino, Italy
[b] Department of Structural Engineering and Geotechnical (DISEG), Politecnico di Torino, Italy
[c] Department of Architecture and Design (DAD), Politecnico di Torino, Italy
[d] Accurat S.r.l., Milan, Italy
[e] Department of Architecture and Design (DAD), Politecnico di Torino, Italy

carlo.caldera@polito.it
carlo.ostorero@polito.it
valentino.manni@polito.it
andr.galli@gmail.com
luca.valzano@polito.it

Abstract. Future scenarios foresee a city as a fragmented and uneven system in relation to rapidly evolving environmental, economic and social phenomena. The traditional urban planning tools, based on a theoretical-predictive approach, adapt poorly. We need to rethink how to govern the transformations of a city, which can be described by models of urban metabolism. City Sensing has changed the way a city is explored and used. With the transition from digitisation to datafication, through a computational approach, one can process georeferenced datasets within algorithms in order to achieve a higher quality of the project. This process exploits data provided by public administrations, companies and citizens taking part in inclusive and adaptive urban planning.

Keywords: City Sensing; Datafication; Big Data Analytics; Computational Urban Planning; Adaptive and Inclusive Urban Planning.

The Contemporary World's Fast Urbanisation

Nowadays about 55% of the world's population lives in urban areas. This percentage is likely to reach 68% by 2050. Globally, by 2030 the number of megacities is expected to reach 43 (United Nations, 2018). In relation to what can be deduced from the data shown, cities represent one of the major problems of the contemporary era to face both, on the one hand, environmental issues (energy consumption, pollution) and, on the other hand, economic and social ones (Fig.1).

Davis (1965) already wrote that urbanised societies, in which most people lived, crowded together in cities, represented a new and fundamental step in man's social evolution. It was clear that modern urbanisation could be best understood in terms of its connection with economic growth and availability of resources. Moreover, in those days, there was hardly any widespread perception of the problems that urbanisation could imply and only a few non-profit international associations, such as the Club of Rome, founded in 1968, started to study solutions.

Lynch (1990) is not optimistic about the increasing urbanisation of contemporary society. The satisfaction of the voracious urban metabolism transforms incoming resources into waste that is not compatible with the environment. Whereas, according to Wilmoth, Director of the UN's Population Division, progressive urbanisation, if regulated, could prove to be a positive factor both for economy and quality of life. Furthermore, the concentration of the population in large inhabited centres can help to minimise our environmental impact on the planet, optimising the location of resources, providing that administrations develop policies and practices to prepare for a huge influx of people (Meredith, 2018).

The meaningful contribution to the debate given by Rogers (2017) is remarkable. If we observe the latest transformations that have taken place in our cities, we will realise that probably, at some point in history, we have lost the ability to control the evolutionary processes of urban systems and the environment.

Theoretical evolutionary models of the urban metabolism as premises to parametric city design

The city can be defined as a constantly evolving metabolic organism, which self-regenerates by optimising its configuration over time according to the needs and availability of resources.

In 1826 Von Thünen deepened the first studies relating to the optimisation of the distribution of economic resources in a territory around a city. His work on the location of areas of agricultural land use (von Thünen, 1842) not only laid the foundations for a deeper analysis of the improvement of agriculture, but also stimulated interest in the location analysis of city resources.

Weber's model, by introducing variables relating to time and costs, and defining the minimum point of the cost of transport, attracting workforce and the agglomeration force of production factors, attempted to determine, in an isotropic space, the point where a production source must be located. The aim was to minimise costs and optimise the distribution of the product produced. Weber's analysis was very abstract. The formulation of an order in the spatial distribution of markets and cities, called "places", became the problem.

Christaller's model (Christaller, 1933) attempted to provide an answer, starting from the assumption that urban centres (central places) exist for the exchange or provision of goods and services to the population, spatially spread on a homogeneous and isotropic territory. Christaller presents the concepts of threshold and range that express in geographical terms the usual economic forces, which organise activities in space, the costs of transport and agglomeration economies, specifically the economies of scale.

Starting in the 1930s, Lösch (1954) began to update Christaller's model, treating the range, threshold, and hexagonal hinterland of each function separately. The resulting pattern is much more complex than Christaller's and yields a continuous, rather than a stepped distribution of population sizes (Fig. 2).

Parr's Comparative Statics Model (Parr, 1978) highlights how one of the fundamental forces of structural change in a territory is to be found in the technical progress and innovative processes that cause the blend of functions in urban centres. The size of its market area changes, until the disappearance of a well-defined hierarchical level.

In relation to the research on minimal path optimisation in an urban system, Rogers's studies on a small scale are remarkable, as well as his studies about circular urban metabolism (Rogers and Gumuchdjian, 1998) (Fig. 3).

Frei Otto (2011) elaborated some relevant thoughts on urban settlements and spheres of influence, referring to the eco-culture of a city and city analysis, including occupation of space and interconnections. Otto found analogies between aggregation processes that oc-

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cur in the natural world and forms of human settlements. Those archetypes are optimal models, as nature expresses itself and develops its phenomena with the minimum expenditure of energy (Fig. 4).
The contemporary latest paradigm can be defined as follows: city networks are sets of horizontal and non-hierarchical relationships between similar or complementary centres. This creates synergies and the formation of economies or externalities of specialisation.
Studies stimulated by contemporary urbanisation demonstrate how urban metabolism can be understood as a complex system of mutual relationships that a traditional urban planning approach cannot effectively drive. We should understand all the interconnected parts. Hence, the need for new planning tools. Parametric methodology, applied to urban planning, provides new tools to achieve this goal.

Parametric urban planning for the management of complexity

As illustrated, evolutionary processes of a city can be described by mathematical models that express organisational forms aimed at optimising complex processes of interaction between individual, community and environment. A further improvement in modelling urban metabolism followed the development of mathematical-statistical applications and computer science, which in those years began to be used in the analysis of economic phenomena. At the beginning, calculations were relatively simple; however, since the 1980s, the complexity of the models followed the development of micro-computing.
The development of computational tools in design had its cultural roots in studies conducted by Moretti (1954). He inaugurated studies on algorithmic urbanism, trusting in the potential offered by automatic computing. According to Moretti, a new architecture and a new urban planning process can issue only from the application of mathematical methods. This implies the analysis and study of mutual relationships of parameters to which reality can be reduced, intended as numerically expressible measures. In the late 1950s, Moretti argued about the possibility, which was innovative at the time, of applying Operational Research to urban planning. Operational Research, a methodology that aims to identify the most effective measures to achieve a pre-set goal through procedures based on mathematical and statistical concepts, consists of phases:

1. formulation of the problem;
2. collection and analysis of data;
3. construction of the mathematical model;
4. solving process of the mathematical model;
5. analysis and validation of the solutions obtained;
6. implementation of the solutions obtained.

The adoption of parametric tools in urban planning allows the definition of a new methodology that consists of a theoretical development of systemic models, whose formulation is based on the com-

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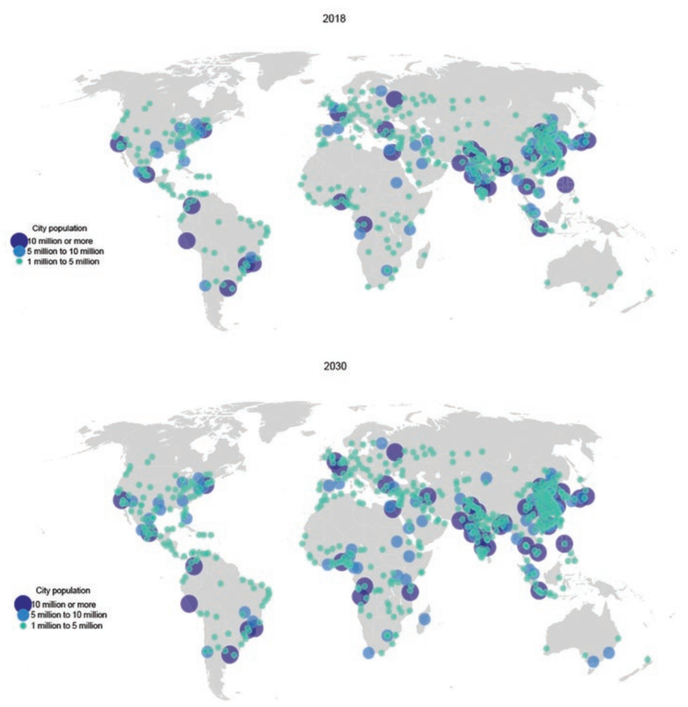

01 | Cities with one million inhabitants or more, 2018 and 2030 related scenarios (United Nations, 2018)

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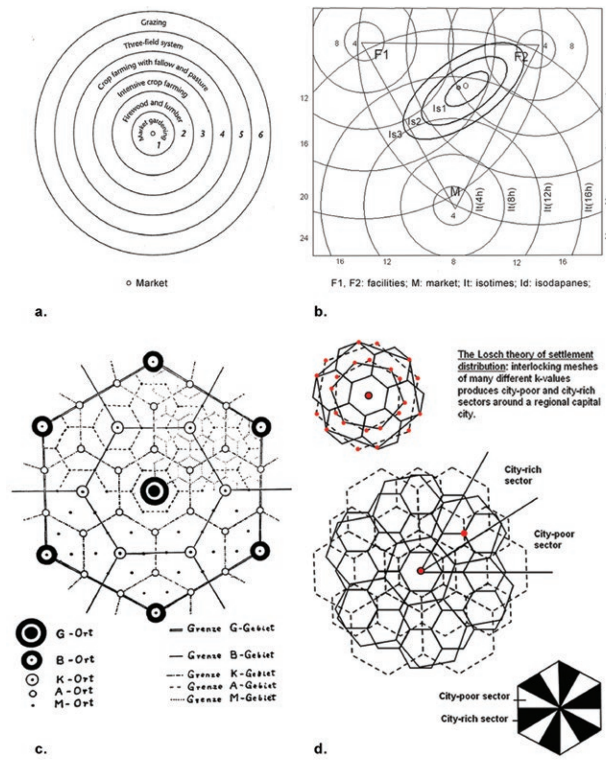

02 | a. Von Thunen's Concentric Model (Torricelli 2003); b. Weber's model (Torricelli, 2003); c. Christaller's model (Christaller, 1933); d. Lösch's model (Lösch, 1954)

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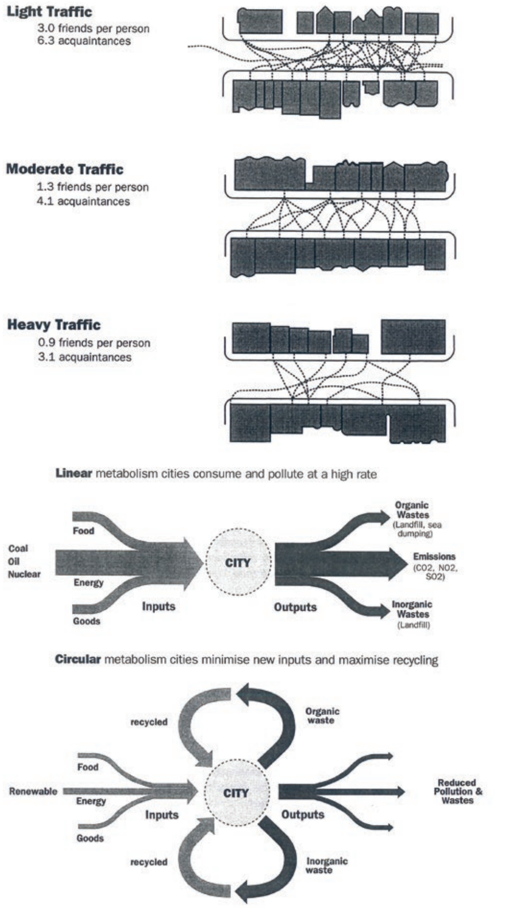

03 | Roger's studies on pedestrian minimal paths and urban metabolism (Rogers and Gumuchdjian, 1998)

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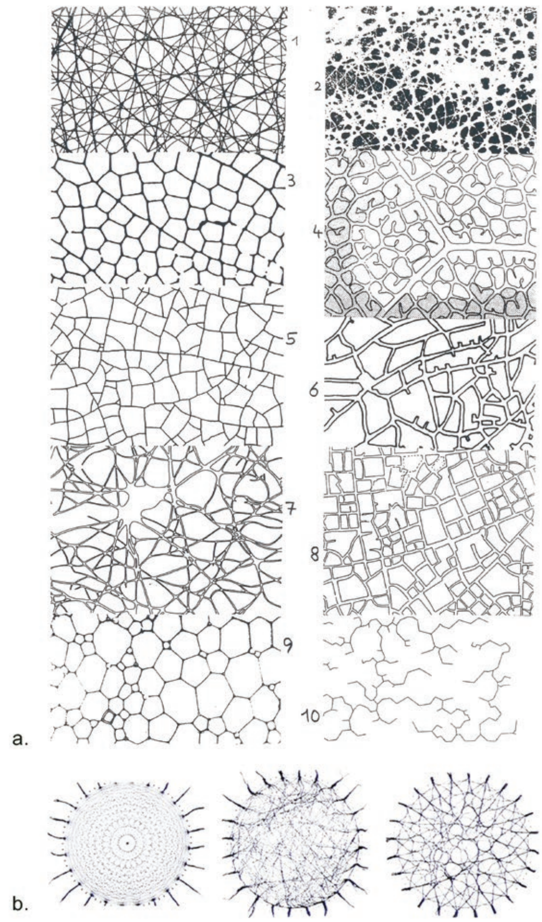

04 | a. Otto's comparative study on connection patterns in anthropic and natural environment (Otto, 2011); b. Otto et al., empirical studies of wool-thread on optimized path system (Otto and Bodo, 1996)

parison between urbanism and evolutionary processes. Through the propagation of its effects, the transformation of a single element, as parameters vary, can involve the modification of the whole organism.
Computational urban planning was successfully applied by Zaha Hadid in Kartal-Pendik masterplanning (Zaha Hadid Architects, 2006). Inspired by Otto's studies on path optimisation, this plan aimed at the redevelopment of an abandoned industrial site. An algorithmic script generates different typologies of buildings that respond to the mixed demands of each district. Through gradual transformations, the algorithmic script creates a smooth transition from the surrounding context to a new, higher density area. A masterplan is, therefore, a dynamic system able to generate an adaptive framework for urban form. It balances the need for a recognisable image and a new environment with a smart integration of a new area with the existing surroundings (Fig. 5).
In 2010 Carlo Ratti Associati and the MIT Senseable City Lab (Carlo Ratti Associati, 2010) developed the King Abdullah City for Atomic and Renewable Energy (Ka-Care) masterplan in Saudi Arabia. Focusing on algorithmic urban design, a code was developed. This could drive the evolutionary growth of the city, according to site-specific environmental parameters and design rules devised by planners (Fig. 6).
Overlapped City research by Remixstudio (2012) improves, through parametricism, urban energy efficiency, exploring the morphology of resilient post-fossil cities across three scales. These are the redefinition of urban boundaries and clusters, energy infrastructure framework and a new set of urban codes. The testing site is in West Houston, the fastest growing urban area in the US, with a rich potential for renewable energy production.

Digitisation, datafication and Big Data

Data corresponds to the Latin datum, whose meaning is 'something given'. Nowadays the word is regaining its original meaning.
Since the late 1950s, digitisation converted data from the analogue field of continuous values to the digital one of discrete values, translating them into a language decipherable by digital devices. It could be seen as the shift from atoms to bits (Negroponte, 1995). Digitisation has been crucial for data processing, storage and transmission.
Datafication is a phenomenon brought out by the continuous development of ICT. It turns many aspects of our life into data and valuable information, going significantly beyond digitisation. Datafication, postulated for the first time in 2013 (Mayer-Schöenberger and Cukier, 2013), greatly exploits digitisation.
The meeting between datafication and digitisation generated Big Data, collections of data that were so extensive in terms of volume, speed and variability to require specific analytical technologies and

05 | Kartal-Pendik Masterplan: a. minimal paths infrastructural grid; b. urban tissue densification; c. parametric masterplanning outcome (Zaha Hadid Architects, 2006)

06 | King Abdullah City for Atomic and Renewable Energy (Carlo Ratti Associati, 2010)

07 | Proposed flowchart of Computation Urban Planning through Big Data Analytics

methods for the extraction of knowledge. Big Data refers to a leap in the interpretative paradigm of economic and social reality through analysis techniques (Data Mining and Data Driven) performed on huge volumes and 'varieties' of data, stored and processed at a fast speed, often in real time. The acquisition of Big Data has been made possible through the progress of digital devices and data transmission networks.

The spread of connected digital devices has changed the individual's attitude that voluntarily or involuntarily generates information. ICTs of the Fourth Industrial Revolution strengthened the relationship between physical reality and the digital world, attributing their own digital tracks to real phenomena and to human behaviours.

Big Data Analytics, evolution of traditional analytical methods, extrapolates, collects, analyses and correlates huge amounts of heterogeneous, structured and unstructured data provided by digital devices in order to extract latent information. It allows to perform predictive analyses based on Big Data. In fact, when huge amounts of historical data are available, one can foresee scenarios on statistical bases. Big Data Analytics consists of 6 Cs: Connection (sensors and networks), Cloud (computing and data on demand), Cyber (model & memory), Content/Context (meaning and correlation), Community (sharing & collaboration), Customisation (personalisation and value) (Lee, Bagheri and Kao, 2014).

Big companies of digital revolution commonly use the potential of Big Data Analytics to interpret and exploit the exceptional information contents of Big Data. The potential of this new analytical tool can be successfully used to drive adaptive and inclusive territorial policies.

Computational urban planning through big data analytics

The pervasiveness of sensors has outlined a new sector of use of technologies for the territory, namely City Sensing, which is joining the more consolidated one of Remote Sensing. City Sensing exploits small, miniaturised, portable or low-cost personal technological detection devices and their dissemination throughout the territory. An atomised and widespread technology appeared,

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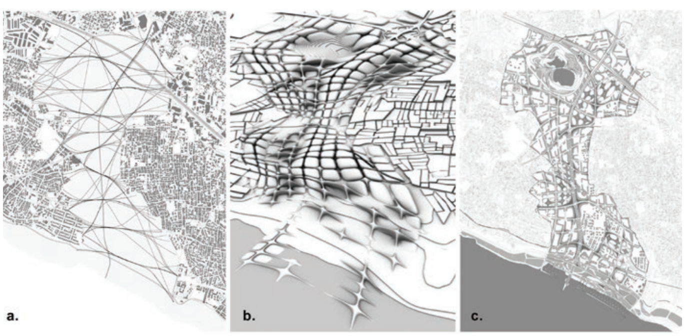

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changing the way a city is explored and used, i.e., inhabiting. The ability to virtually 'inhabit' multiple spaces simultaneously and in real-time thanks to the development of digital and connectivity systems allows to qualify and connote places in relation to one's habitus and needs, and to share experiences. The physical space is configured as a real substrate of a virtual and digital space of relationships, which is located on the Web and is characterised by its own rules and dynamics. This virtual space is the medium, which real individuals use to interact.

Hence, interconnected urban space is crossed by continuous data flows coming from a myriad of personal technological devices. Users, sharing georeferenced information, collected in first person, be-

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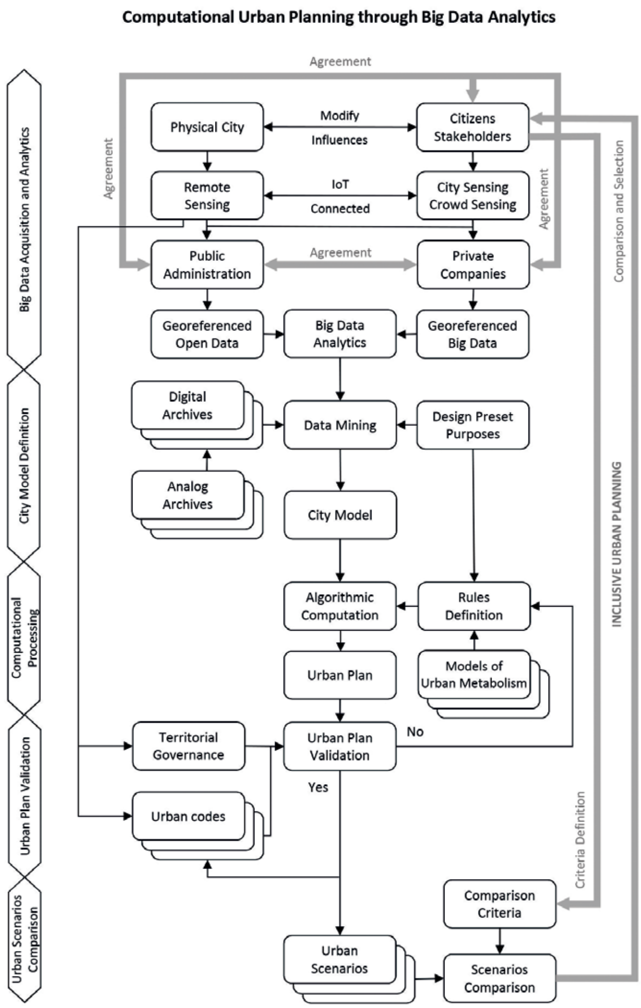

come themselves "sensors" of phenomena in progress. It becomes, therefore, possible to monitor complex phenomena that, otherwise, could not be observed (Resch, 2013). The need to effectively visualise data flows and those phenomena has pushed research into georeferenced data visualisation, which allows us to reach a deeper level of representation of urban phenomena. The City Model, new information model of a city, is digital, three-dimensional, multi-resolution and in real-time. City Sensing and City Model mutually confer meaning and effectiveness, supporting multi-actor interaction and territorial governance processes.

As Borga claims (2013), the level reached by technology in the field of acquisition and processing of territorial data is significant. In public administrations, however, technical and cultural evolution has not taken place to the extent of fully exploiting that progress. The Open Government doctrine aims to provide open information to citizens for participating in decision-making processes. This can be achieved through sharing Open Data: information collected by the public administration and freely accessible to citizens. Open Data is a subset of Big Data but its purposes and uses are different. In fact, Big Data is mainly collected by private companies for business-related purposes. If Big Data were shared as a result of agreements among private companies and public administrations, it could considerably contribute to territorial governance.

The huge amount of Big Data, however, is unmanageable when applied to traditional urban planning methods still used by public administrations. Hence, Big Data Analytics can provide a crucial aid for information management and allow the development and the application of innovative multi-layer planning methods. Therefore, the convergence among the increased availability of data, Big Data Analytics, urban metabolism evolutionary models and computational tools can create a new urban design that goes beyond the limits of a traditional approach.

This new approach is Computational Urban Planning through Big Data Analytics, in which the inclusive and adaptive design based on algorithmic calculation exploits georeferenced data through a system of interconnected logical and mathematical operators. This methodology attributes control and validation to a human supervisor, giving the possibility to optimise results of the parametric calculation and to compare the different scenarios generated. A possible articulation of this methodological process could be the following:

1. acquisition and analysis of data;
2. definition of a City Model;
3. computational elaboration of the City Model (distribution of functions, density and massing);
4. validation and recursive optimisation of the results;
5. multi-scenario comparative analysis.

A flowchart (Fig. 7) exemplifies the methodology of Computational Urban Planning through Big Data Analytics using and updating a recent study (Galli and Massimiano, 2019). It also outlines a new methodological tool emphasising the central role of Data Analysis to create an interactive process that can reach urban design optimisation. The flowchart evolves the successful techniques adopted in the urban projects previously mentioned.

Conclusions

The last two centuries have witnessed the evolution and proliferation of various interpretative models concerning the development dynamics of a city and its territory. At the dawn of these studies, proposals focused on achieving the implementation of an ideal composition of political, social and, therefore, urban planning theories. Whereas in the latter half of the 20th century, given the stratification and increasing complexity of urban and territorial phenomena, knowledge of data from indicators, such as demographic, economic, and socio-cultural development, acquired increasing importance.

New technologies offer an extraordinary opportunity to improve the system of knowledge of the dynamics of behaviour, interaction and evolution of the natural and man-made environment. The disruptive diffusion of IT culture and, in particular, the proliferation of Web 2.0, have given voice (both in terms of expression of needs and information contributions) to local user groups initially excluded from top-down organisational models.

The possibility offered by these interactive technologies is able to adapt to the continuous evolution of the various levels of knowledge, which the professional investigation addresses, aimed at drafting local government models. For the first time in the history of Mankind, we act simultaneously both on the cognitive level and on the consequential response provided by the datafication this model produces. In analogy with building physics, it is as if this revolutionary innovation evolved the predictive capacity of the building envelope performance, analysed under static conditions, to the one, much more adherent to reality, analysed under dynamic conditions.

The application of a computational tool as a processor of apparently uneven Big Data Analytics opens up new scenarios. These will be both in terms of predictability of possible strategies that can be adopted and of on-demand responsiveness, generating an adaptive process, which can drive the transformations of a city.

The optimisation obtained through this process achieves the objective of controlling complex logic, such as the one proposed by circular economy models applied to urban metabolism issues. Likewise, it manages to involve, with a bottom-up process, even wider social strata aware of the processes of dissemination of the above-mentioned models and knowledge.

In these innovative processes and technologies lie possible contradictions between the role and the value held by datafication and data management, and the role of individual freedom and, therefore, of the individual citizen's ability to self-determine. The mutual acceptance of the boundary and its positioning, which can balance mutual interests and inalienable rights, encourages reflection on these issues towards a holistic approach and a multidisciplinary involvement of skills. These involve not only technical-scientific aspects but, equally, ethical-philosophical ones[1]. Nowadays, recent experiences in city regeneration, such as the Google Sidewalk Lab for the Toronto waterfront, confirm the effectiveness and the adaptability of this tool.

Therefore, without emphasising an optimistic and consoling horizon, trust is placed in the widespread diffusion and application of technologies for the implementation of a virtuous city and wise local government policies that make use of knowledge as an antidote to unethical exploitation.

NOTES

[1] Machine learning and computational design can help planners to generate not just a few but billions of comprehensive planning scenarios. Moreover, it can help to evaluate all kinds of impact these different scenarios could have on key measures for the quality of life, producing multiple options that best reflect a community's priorities. The generative design tool neither automates the urban planning process nor eliminates the need for human-driven design. Instead, it provides a set of features that can empower planning teams to do their job even better.

REFERENCES

Borga, G. (2013), C*ity Sensing. Approcci, metodi e tecnologie innovative per la Città Intelligente*, Franco Angeli, Milan, Italy.

Carlo Ratti Associati (2010), *Ka-Care*, available at: https://carloratti.com/project/ka-care/ (accessed 12 January 2020).

Christaller, W. (1933), *Die Zentralen Orte in Süddeutschland*, Gustav Fischer Verlag, Jena, Germany.

Davis, K. (1965), "The Urbanization of the Human Population", *Scientific American*, Vol. 213, No. 3, Nature Publishing Group, Los Angeles, CA, USA, pp. 41-53.

Galli, A. and Massimiano, L. (2019), "Processi innovativi per l'adattamento delle città ai cambiamenti climatici: computational masterplanning", Proceedings of *Urban Promo 2019 - Città contemporanea, gigante dai piedi di argilla*, Turin, Italy.

Lee, J., Bagheri, B. and Kao, H.A. (2014), "Recent Advances and Trends of Cyber-Physical Systems and Big Data Analytics in Industrial Informatics", Proceedings of *International Conference on Industrial Informatics (INDIN)*, Porto Alegre, Brazil.

Lösch, A. (1954), *The Economics of Location*, Yale University Press, New Haven, CT, USA.

Lynch, K. (1990), *Wasting Away,* Sierra Club Books, San Francisco, CA, USA.

Mayer-Schöenberger, V. and Cukier, K. (2013), *Big Data: A Revolution That Will Transform How We Live, Work and Think*, John Murray, London, United Kingdom..

Meredith, S. (2018), *Two-thirds of World Population Will Live in Cities by 2050 - UN Says,* available at: https://www.theguardian.com/world/2018/may/17/two-thirds-of-world-population-will-live-in-cities-by-2050-says-un (accessed 8 January 2020).

Moretti, L. (1954), "Structure comme forme", in Coudeyre, M. and Mathieu, G.A. (Eds.), *United States Lines Paris Review*.

Negroponte, N. (1995), *Being Digital*, Alfred A. Knopf Inc., New York, USA.

Otto, F. (2011), *Occupying and Connecting - Thoughs on Territories and Spheres of Influences with Particular Reference to Human Settlement,* Bukhardt, B. (Ed.), Edition Axel Menges GmbH, Stuttgart, Germany.

Otto, F. and Bodo, R. (1996), *Gestalt finden. Auf dem Weg zu einer Baukunst des Minimalen*, Edition Axel Menges GmbH, Stuttgart, Germany.

Parr, J.B. (1978), "Models of the Central Place System: A More General Approach", *Urban Studies*, Vol. 15, SAGE Publishing, New York, USA, pp. 33-50.

Remix Studio (2012), *Overlapped City*, available at: http://www.remixstudio.org/research/design/overlapped-city (accessed 12 January 2012).

Resch, B. (2013), "People as sensors and collective sensing-contextual observations complementing geo-sensor network measurements", *Lecture Notes in Geoinformation and Cartography*, Springer-Verlag, Berlin Heidelberg, Germany.

Rogers, R. and Gumuchdjian, P. (1998), *Cities for a Small Planet*, Westview Press, Boulder, CO, USA.

Rogers, R. (2017), *A Place for All People: Life, Architecture and Fair Society*, Canongate Books Ltd, London, United Kingdom.

von Thünen, J.H. (1842), *Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie,* 2018 edn, Forgotten Books, London, United Kingdom.

Torricelli, G.P. (2003), *Introduzione alla geografia economica*, available at: http://www.gpt.adhoc.ch/Geoeconomica/Modulo2/Lezione2.pdf (accessed 12 January 2020)

United Nations (2018), *The World's Cities in 2018*, available at: https://www.un.org/en/events/citiesday/assets/pdf/the_worlds_cities_in_2018_data_booklet.pdf, (accessed 12 January 2020).

Zaha Hadid Architects (2006), *Kartal Masterplan*, available at: https://www.zaha-hadid.com/masterplans/kartal-pendik-masterplan/ (accessed 12 January 2020).

Applied innovation: Technological experiments on biomimetic façade systems and solar panels

Livio Petriccione, Fabio Fulchir, Francesco Chinellato,
Department of Engineering and Architecture, University of Udine, Italy

livio.petriccione@uniud.it
fabiofulchir@libero.it
francesco.chinellato@uniud.it

Abstract. The most advanced technological concepts aim to obtain an "organic" behaviour of the building envelope, which consequently becomes "dynamic" and variable because it is sensitive and self-adapting with respect to external environmental conditions. In this highly innovative context, solar shielding devices become important and, in some cases, they can be integrated with special types of glasses or with "active" components, such as solar panels. Instead, the orientation systems of solar devices, described below, use only the thermal expansion to self-regulate, combining the reduction of energy consumption with minimum environmental impact, without the aid of motors, computerised devices or external energy sources, overcoming some critical issues of the self-adaptive envelopes used to date.

Keywords: Façade systems; biomimetics; solar panels; thermal expansion; sunblind.

Introduction

The recent rapid evolution of the building envelope made it the undisputed protagonist of contemporary architecture. In this case, the idea was born from the observation of how nature, in the case of sunflowers, "solved" the problem with a progressive orientation towards the sun of the "corolla", exploiting the differential thermal expansion of another part of the plant, the fibres of the stem. In a similar way, the proposed self-adapting systems are able to modify the inclination of elements forming the external "skin" of the building envelope during the year without the aid of engines or solutions that require the use of external energy sources, exploiting only the force generated by natural thermal expansion. These systems are composed of two main parts: the expanding elements and the mechanisms of multiplication and transformation of movement. These are connected to the elements to be handled, according to the different possible applications. At the basis of the development of the technological systems, mathematical models have been developed to describe the temperature and, therefore, the expansion of the "expanding elements", according to the hourly climatic data. These models consider all the components that determine the heat exchange with the environment: conduction, convection and radiation. The mechanisms designed and tested can move both active and passive façade devices and solar panels on independent supports. The systems can be calibrated in order to optimise solar tracking (photovoltaic panels), or to allow the penetration of solar radiation in the colder periods of the year, and to reflect it in the summer period (in the case of sunblinds or system shielding integrated with air solar panels). The systems have been tested through a series of experiments related to the expanding elements and with the realisation of some prototypes. Four application proposals are illustrated. Three leverage a mono-axial actuator system (Warm Motion system, or WM), while another application consists of a passive biaxial solar tracker (Biomimic Solar Tracker - BST), which allows you to move individual solar panels located at the top of an independent structure. The research has already had significant recognition in regional and national Star Cups. The experimentations were completed on vertical elements by the research team of the DPIA of the University of Udine, as part of the international research project "Biomimic Solar Tracker. Eureka Eurostars, project 65103".

The WM mono-axial system, thermodynamic model, experimentations and prototypes

The attention of the research was focused on the development of a mono-axial solar tracker system composed of the following elements: a frame, the expanding elements, a movement multiplication system and the elements to be handled according to the different possible applications, i.e., photovoltaic panels, sunblind or shielding elements integrated into passive solar systems. The expanding elements act as the engine of the façade system. They are made up of elongated aluminium bars, easily available at a low cost, painted in black, a few metres long and with a flat section. The thermal variations become thermal deformations (a few mm), which are amplified by a movement multiplication mechanism, which transforms them into the rotation of elements to be moved (Fig. 1).

The expanding elements are exposed outdoors: the convective component is always present and tends to make the temperature of the elements the same as that of air, while the radiative component, due to solar radiation, varies with solar height, changing seasons and with the passing of the hours. The technological systems were developed based on a thermodynamic model capable of describing the temperature and, therefore, the expansion of the "dilating elements", according to the hourly climatic data. The equilibrium temperature of the dilating elements was calculated with a global balance of radiative and convective heat exchanges, referring to the surface unit.

A first series of experiments concerned the horizontal arrangement of the dilating elements. To analyse their behaviour in relation to the atmospheric agents, a test bench was built on which three bars of the same size and with the same surface treatment were installed (Fig. 2). We used Aluminium bars Al_Mg_Si 6060 T6 "Anticorodal" section 50x2 mm. Each of these was thermally insulated from the frame by means of PVC rods and constrained at one end, remaining free to expand and withdraw, due to thermal action, on the other side. Throughout the course of a calendar year, the temperature variations of the bars and the deformation differences between the bench and bars were recorded by means of potentiometric transducers.

Application of the WM system in the "solar panel" mode

If the mono-axial system is designed according to the "solar panel" mode, the aim is to guarantee the orthogonality of the panel with respect to the direction of the sun rays. In the winter season, for

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example, starting from an initial vertical position (night position), a progressive increase in heat exchange with the environment causes the expansion of the dilating element, allowing the solar panel to rotate according to the height of the sun. It is possible to calibrate the mechanism so that it corresponds to the maximum temperature of the dilating elements in an almost horizontal position (zenith sun position-summer). In the event the sky remains cloudy, the radiative component will be lower, with a prevalence of diffuse radiation, and the temperature of the bar will be closer to the air temperature, still guaranteeing an effective rotation of the photovoltaic panel. In the experiments carried out with horizontal dilating elements (Fig. 2), the measured values were: the air temperature, the temperature of the bars and the differential deformation between the bars and the frame on which they were mounted. The theoretical model was confirmed by the results of the experiment. There were slight deviations in the maximum values of temperatures (higher values in reality than in the mathematical model), due to the fact that the measured values are instantaneous, while the model is based on average hourly values. The system is able to operate autonomously by orienting a surface towards the sun (Fig. 3). This shows the various positions taken by a small solar panel moved by the WM system during a typical day of the autumn season. In addition to the movement check, a comparison was also made in order to verify the production of electric current between three small photovoltaic panels. One of these was mounted on the WM system, while the others were set in a fixed position, with an inclination of 0° and 90° in relation to the horizontal plane. The production of electric current of a PV panel mounted on the WM system was greater than a fixed panel arranged vertically by 25% while, compared to a horizontal one, the increase was equal to 40%.

Application of the WM system in "solar shading" mode

According to the "solar shading" mode, the requirements to be satisfied are more complex, regarding both the lighting aspects and the thermal values. Two possible applications have been studied: an integrated system with air-powered solar panels or with ventilated façades, and a sunscreen system. In the first case, it is possible to design the mechanism in order to maximise winter energy supplies and to nearly cancel summer ones, making sure that the panel can be reached by solar energy in winter, while being shielded during the hottest periods. The "Daily" variability is not considered important, but rather a behaviour linked to the external air temperature. By shielding the vertical dilating elements from direct radiation, it can be considered, as a first approximation, that their temperature is equal to that of the air. This hypothesis allows, among other things, to consider the dilating elements, which are completely "integrated" into the façade, placed inside the support frames of façade systems. The essential geometric elements of the system (Fig. 4), are the angle of inclination of the slats (β) and the profile angle of the sun's rays (ω). The mechanism generates a rotation of the sunscreen blades through the exploitation of the difference in thermal expansion (ΔL) between the steel frame and the dilating elements, made up of aluminium sheets, with a length equal to the frame and tied in the lower part by a hinge. Their upper part is connected to a first level lever, with the fulcrum hinged to the frame and the opposite end linked to a connecting rod that controls the rotation of the slats. A façade system is created by a connection between the self-adapting device of mobile slats and air solar panels. This can transform the building envelope from a static element to a dynamic skin capable of self-adaptation and of varying its characteristics in order to guarantee internal comfort and reduce energy consumption. The system is applicable in new or existing buildings, in energy recovery-requalification processes. This allows the entry and exploitation of all solar radiation available in the winter months, and the almost complete reflection of the same during the summer months. It also allows to remove heat, during the summer months, by natural convection. The system consists of a set of pre-assembled modules essentially composed of the following layers: an external self-adaptive "skin" made up of adjustable venetian blinds and protected by a transparent glass surface; an air solar thermal collector (CSTA) integrated with a thermal storage system; an insulation panel placed in the rear; a ventilation device and interface with the environments to be conditioned. The function of the thermal storage integrated in the solar collectors is to stabilise the temperature peaks reached in the central hours of the day, at certain times of the year, to accumulate heat when it is available and to make it available to heating systems, when needed. The combination of the heat pump with the CSTA, therefore, reduces many of the disadvantages of each of the two technologies. In winter, in fact, the heat pump uses air at a higher temperature than it would take from the outside, increasing its COP. During the summer, the slats are arranged in such a way as to reflect the solar radiation almost completely, totally shielding the solar thermal panels with air. During the night the outside air, starting to cool off, is let in through the lower vent of the façade system. Concerning the application to the sunblinds, by selecting the cut-off angle as an operating parameter, and with a mechanism similar to the one previously described for air solar panels, the lighting requirements can be satisfied, but with excessive summer overheating. To allow external vision, while intercepting direct radiation, a considerable amount of radiation reflected inward is introduced. Paying more attention to the thermal aspects and leaving the user the possibility of installing other internal systems (e.g. curtain) to avoid any winter glare, the maximum and minimum temperatures were, instead, considered to carry out normal daily activities both in winter and in summer. It has been observed that for external temperatures below 18°C it is better to direct the sunblinds at the angle of solar incidence, in order to maximise direct transmittance

01 | On the left and centre: hypothesis of operation of the WM system applied to a generic façade. On the right: an example of axperimental apparatus.

02 | Experiments with horizontal arrangement of the dilating elements. Above: diagram of the test bench. Below: prototype of the WM system and experimental apparatus.

for heating purposes. For temperatures above 18°C, in summer, it is advisable to tilt the shielding elements according to the orthogonal angle of incidence of the sun rays to stop them, while possibly also avoiding any inward reflections. For intermediate situations with respect to those just described, an intermediate regulation can be assumed, counting on the inward reflection in the colder periods and on partial shielding in the warmer ones.

The biomimic bi-axial system: features, experiments and prototypes

The system allows to amplify small deformations caused by the difference in thermal expansion of 3 vertical dilating elements, oriented differently in space (with an angle between them of 120°), which are subject to different thermal expansions generated by the motion of the sun. The BST system consists of four main elements (Fig. 5): the stem, the HRE (Heat Responsive Elements) dilating elements, the MTU (Motion Transmission Unit) and the support platform for the PV panels. The stem, made of a steel tube, supports the system and all elements are fixed onto it. The HRE dilating elements act as both sensors and actuators of the system. They consist of flat black aluminium bars arranged on three sides of the stem, hinged on it in the lower part and connected above the MTU. This consists of three articulated elements arranged at 120° between them and connected to the support platform by means of spherical joints. It transmits the weight of the PV panels in such a way that the stress is constantly tensile. When an HRE is irradiated by sun rays, it heats up. The amount of heating depends on the angle of incidence of the sun. The consequent thermal expansion modifies the tensional state of the system, causing it to reach a new equilibrium position, placing the solar panel orthogonally with respect to the sun's rays. Simplifying the description, the PV panel tilts towards the "hottest" bar (Fig. 5).
The inclination increases in relation to the temperature difference between the hottest and coldest bars. In addition, the system places the PV panels in a horizontal position when the three bars present the same temperature. This occurs in the following three cases: at night, in the case of overcast skies (where energy production is maximised because the diffused light mainly comes from the zenith), and in case of strong wind, when the panel is placed in a safe position to avoid the sailing effect. The system is totally passive, so it has zero energy consumption and does not require electricity from either external energy sources or from motors or sensors.
It has lower production costs than its competitors, and its maintenance costs are significantly reduced due to potentially usable elements.
Tests were carried out relating to the evaluation of the effects of surface treatments on the HRE and mechanical tests in the proximity of the south wall of the Official Laboratory Materials and Structural Testing (DPIA-UNIUD). Sixteen aluminium samples, with different surface treatments, were tested for the HRE. The samples were exposed externally on special supports and the sensors measured their surface temperatures, comparing them with the climatic data collected by a weather station installed nearby. The samples were arranged with different orientations. The experiment allowed to select the materials with the best characteristics as well as to verify the correspondence of the mathematical model with the experimental data. It has been verified that the model slightly underestimates the temperature values, compared to the real data (the differences are in the range of 6°-8°). These differences have been caused by the albedo coefficient of the surrounding areas, which may change depending on the effects of solar reflection either on adjacent walls or on other surfaces (for example parked cars). The temperature difference between the 3 bars arranged on east, south and west has been proven to be able to guarantee an optimal system operation. The experimental equipment related to the mechanical verification of the system (with reference to Fig. 6) consisted of a steel frame (C)

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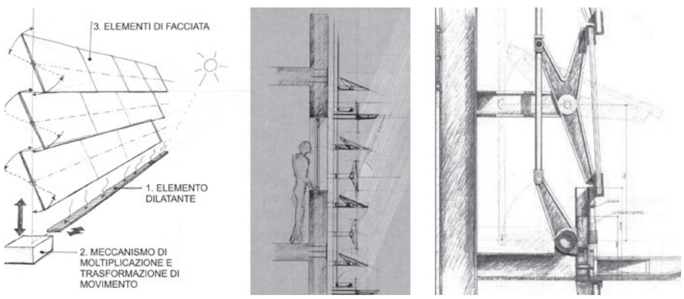

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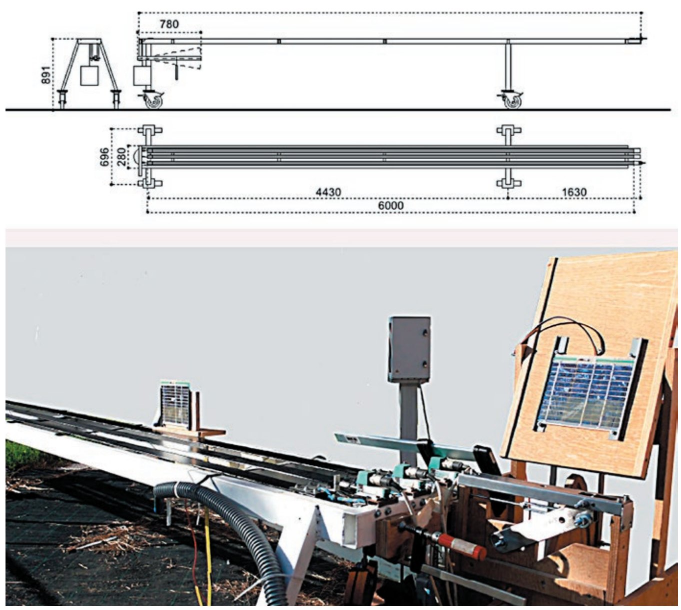

03 | Left: photographic sequence of the various positions taken by the test photovoltaic solar panel during a day in October. Right, from above: theoretical trend of the temperature of the dilating elements in relation to the air temperature of a typical year; the measured trend of the temperature of the dilating element (bar in Fig. 2) in relation to the air temperature detected during the year of experimentation: the excellent quality correspondence is noted; comparison between the electricity production of a fixed photovoltaic panel, in horizontal and vertical position, and of the self-adapting panel

04 | On the left: geometrical diagram of the position of the adjustable slats and their inclination (β) in relation to the incoming and reflected radiation, and the angle of incidence profile of the solar radiation (ω). Right: geometrical diagram of the operation of the passive slat angle control mechanism

05 | Operating principles of the Biomimic system. In the upper part of the image on the left: the system; in the centre: relationship between the expansion of the dilating elements (HRE), the position of the sun and the position of the upper platform supporting the solar panel. Top right: detail of the transmission mechanism of the HRE movement to the platform. On the right, in the centre: temperature differences between the dilating elements (HRE) exposed to the east (blue) to the south (red) and to the west (green) with respect to the air temperature (purple). In the lower part of the image: example of the movement induced in the solar panel by dilation of the dilating elements (HRE)

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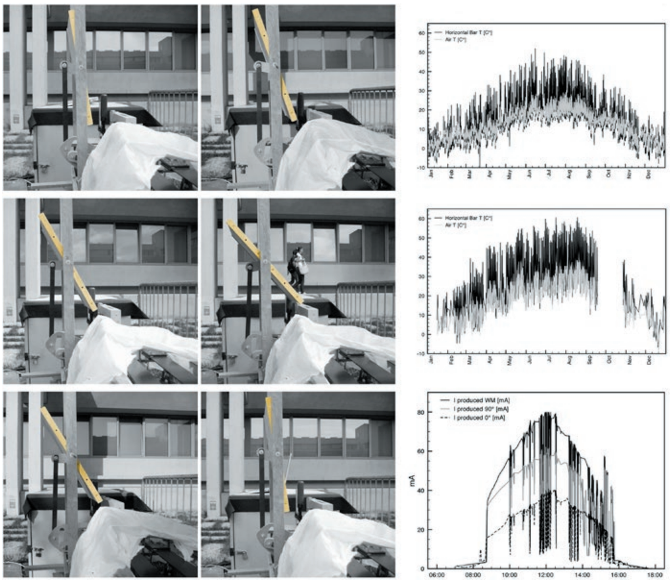

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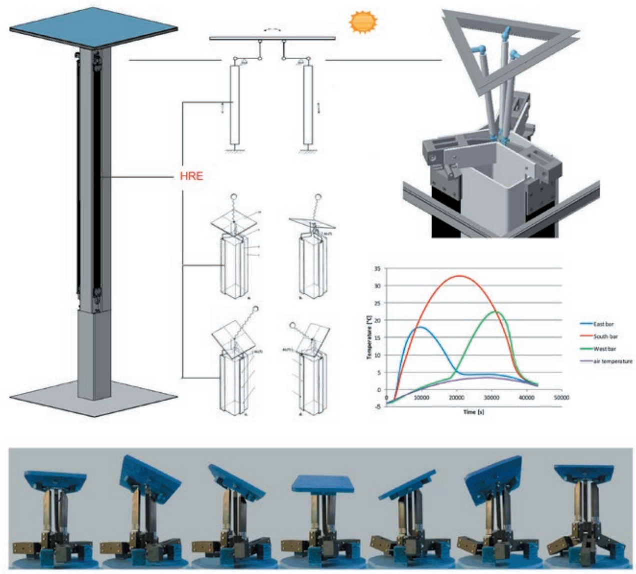

on which four HRE (D) (length equal to the real system) were fixed, subjected to different load conditions (E). For each HRE, the temperature and expansion were measured by potentiometric transducers. The weather station (A) compares the actual temperature of the bars with that theoretically calculated from external climatic data. In all cases, the angular movements of the mechanisms presented an almost perfect correspondence with the theoretical data, showing differences within an error margin of 2.5° (Fig. 7).

The effects of friction were addressed both theoretically and in the field of tests where the dissipative phenomena were mitigated by two different types of elements: the roller bearings with internal ring (mechanism C in Fig. 6) and the bushings self-lubricating and flanged composite material (mechanism D in Fig. 6). The "precision" of the system was assessed in the experiments: to what extent it always responds in the same way to similar conditions; the presence of relaxation phenomena due to the failure of the connections or the effects of friction. However, these settlements are relatively limited, as they are less than 0.6° of rotation over a month. There are no appreciable differences in behaviour between the two mechanisms mentioned above. It has occurred that the relaxation phenomena gradually decrease with time, after an initial period of settling. As far as the precision of the system is concerned, a higher dispersion in position measurements can be observed for temperature values equal to 30°C, compared to those relating to the position of the levers at 20°C.

Conclusions and possible developments

Since the results of the research have given positive feedback, after the experiments it was considered possible to create prototypes in order to monitor their operation and to verify and refine the mathematical model. In summary, possible future developments may be: optimi-

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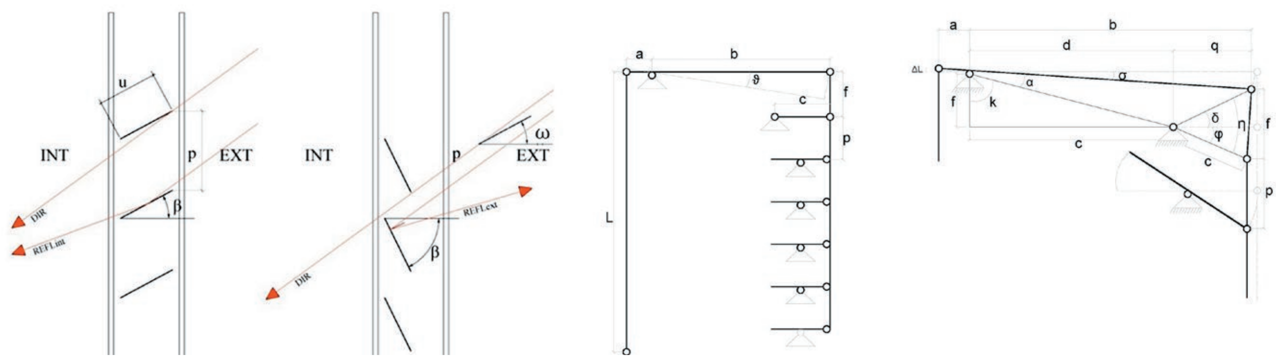

06 | Experimental apparatus built at the DPIA laboratory of the University of Udine. With reference to the photo in the centre, the following are highlighted: (A) weather station, (B) rack for supporting samples of dilating elements characterised by different surface treatments, (C) supporting frame, (D) dilating elements (aluminium bars), (E) levers and counterweights to put the HREs in traction by simulating the operating conditions. Left: the apparatus that allowed to test different movement transmission mechanisms with loads comparable to the operating ones obtained through suitable levers (B - direct load of 25.3 kg; A - maximum expected work load equal to 231.5 kg; C - equivalent load of 231.5 kg obtained from a second degree lever with hinges equipped with roller bearings; D - equivalent load of 231.5 kg obtained from a second degree lever with sliding type bearings). Right: details of the linkages

07 | Comparison between the daily diagrams of the angular movements of the two levers (solutions C and D in Fig. 6) detected in the experiments on a sample day (9 August) with the theoretical movement, calculated from the differential temperature values measured at the HRE and the chassis. It is possible to verify that there is an almost perfect correspondence between the theoretical and real values. Looking at the diagrams in detail, it can be seen that the lever D (the one with sliding friction bearings) has slightly lower angular excursions than the mechanism C (needle roller bearing). These differences, however, are less than 1° of rotation. Furthermore, by enlarging the diagrams, it is possible to observe a greater reactivity of the mechanism C, compared to the mechanism D. The first mechanism, in fact, reacts to temperature variations in the range of 1 °C, while the mechanism D reacts to temperature variations of 4°C

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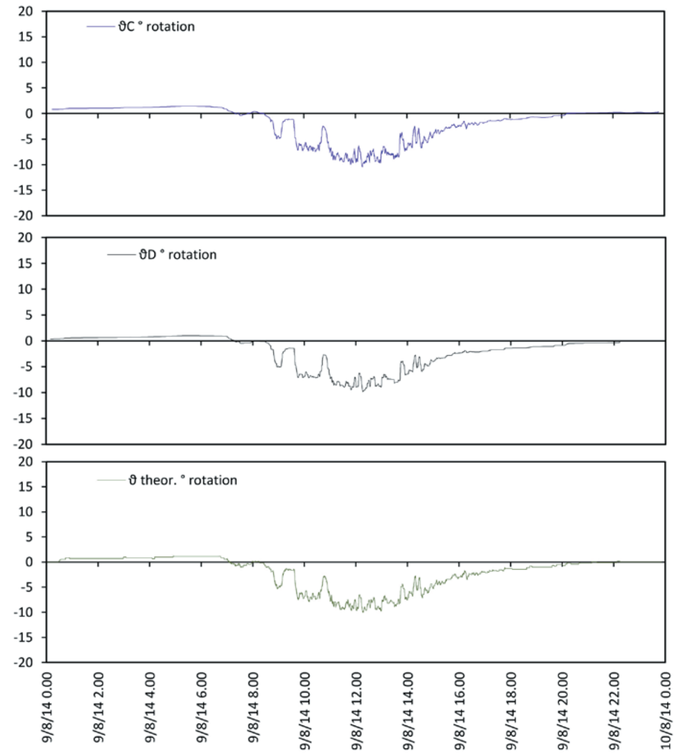

sation of the geometry of the dilating elements to maximise radiative solar input; the design, construction and installation of prototypes in order to refine the behaviour with respect to the mathematical model; the adoption of more advanced mathematical models, using finite element programmes for the calculation of the coefficients, with the variation of the physical-mechanical parameters of the systems; the optimisation of the systems in order to increase their overall efficiency by also evaluating the effects of the wind; the use of innovative materials having high coefficients of thermal expansion and surface treatments with high solar absorption and low emission; the use of other motion multiplication systems and kinematics.

REFERENCES

Bakker, L.G., Hoes-van Oeffelen, E.C., Loonen, R.C. and Hensen, J.L. (2014), "User satisfaction and interaction with automated dynamic facades: A pilot study", *Building and Environment,* Vol. 78, pp. 44-52.

Karagiorgas, M. (2010), "Solar assisted heat pump on air collectors", *Solar Energy,* Vol. 84, pp. 66-78.

Fulchir, F. (2009), "Progetto di un sistema di facciata autoadattante per dilatazione termica", *Tesi di dottorato di ricerca*, University of Udine.

Karagiorgas, M. (2010), "Solar assisted heat pump on air collectors", *Solar Energy*, Vol. 84, pp. 66-78.

Klein, K., Hutchtemann, K. and Muller, D. (2014), "Numerical study on hybrid heat pump system in existing buildings", *Energy and Buildings*, Vol. 69, pp. 193-201.

Kramer, K.S. (2013), *White paper on Solar Air Heating Collectors*, IEA.

Moon, J.W., Yoon, S. and Kim, S. (2013), "Development of an artificial neural network model based thermal control logic for double skin envelopes in winter", *Building and Environment*, Vol. 61, pp. 149-159.

Moret Rodrigues, A., Marques da Silva, F., Gloria Gomes, M. (2015), "Measuring and estimating airflow in naturally ventilated double skin facades", *Building and Environment*, Vol. 87, pp. 292-301.

Wang, R. and Gerber, S. (2014), "Megnetically geared wind generator technologies: opportunities and challenges", *Applied Energy*, Vol. 136, pp. 817-826.

Yang, M., Wang, P., Yang, X. and Shan, M. (2012), "Experimental analysis on thermal performance of solar air collector with a single pass", *Building and Environment*, Vol. 56, pp. 361-369.

Design of urban services as a soft adaptation strategy to cope with climate change

ESSAYS AND VIEWPOINT

Cinzia Talamo[a], Giancarlo Paganin[b], Nazly Atta[a], Chiara Bernardini[a],
[a] Department of Architecture, Built Environment and Construction Engineering, Politecnico di Milano, Italy
[b] Department of Architecture and Urban Studies, Politecnico di Milano, Italy
cinzia.talamo@polimi.it
giancarlo.paganin@polimi.it
nazly.atta@polimi.it
chiara.bernardini@polimi.it

Abstract. Climate change is increasingly threatening anthropic systems, which are calibrated on climate parameters that have been mostly stable during the last millennium. Reducing its impact on urban centres is one of the most pressing global challenges of our time. This study develops the concept of soft-resilience, the ability of systems to absorb and recover from the impact of disruptive events without fundamental changes in their function or structural characteristics. Starting from this assumption, this paper explores the potential of the urban services field in a perspective of city adaptation to climate change, suggesting that measures based on ICTs applications and information exploitation represent one of the pillars of soft strategies.

Keywords: Climate change; Adaptation strategies; Local adaptation plans; Soft-resilience; Urban services design.

Possible approaches to the challenge of climate change

The phenomenon of global warming and the extreme weather events connected to it are increasingly threatening anthropic systems, which are calibrated on climate parameters that have been mostly stable during the last millennium.

The five direct and indirect effects of climate change on urban areas, identified in the Fifth Report published by the Intergovernmental Panel on Climate Change (IPCC, 2014) are: heat waves, drought, coastal flooding, internal flooding and human health problems. The same document also outlines the six most exposed urban sectors: water supply, energy supply, telecommunications, built environment, green infrastructure and ecosystem services, urban and social services.

Reducing the impacts of climate change on urban centres is one of the most pressing global challenges of our time.

Options for addressing risks related to climate change, and their consequent impact, are mitigation and adaptation (Fig. 1).

In common perception, mitigation strategies are increasingly recognised as a key issue, and scientific studies in this field are constantly increasing. Research on adaptation solutions is, on the contrary, still at an early stage and has neither consolidated experience nor shared practices (Araos, 2016); (Reckien, 2018).

It is important to underline that the effects of any mitigation action undertaken are normally only appreciable in the long term (after decades) (Füssel, 2007): even if CO_2 emissions were reduced to zero today, global warming and its consequences would continue to affect future generations with unprecedented magnitudes (WMO, 2016). Therefore, while waiting for the desirable benefits of mitigation measures, the scientific community and politicians should focus on adaptation too, as a transition strategy. Since the climate is changing, anthropic systems must be prepared from now to cope with the multiple effects of global warming in the short and medium term.

At present, there are multiple obstacles to the implementation of adaptation actions by stakeholders and these can be essentially referred to: the high degree of uncertainty that characterises climate projections and impact scenarios, the resulting erroneous perception of the unlikelihood of consequences of global warming, the intrinsic complexity of anthropic systems and the absence of legislative provisions (Fig. 1).

The World Energy Council (WEC, 2018) has expressed the idea that overcoming these barriers would require a soft-approach to the climate issue: the integration of soft measures in the proposal of adaptation solutions for the built environment would offer several advantages in this context, considering their flexibility, reversibility and effectiveness in terms of costs (Tab. 1). Besides, it poses new questions for planning, design and management of urban spaces and artefacts.

Hard adaptation strategies regard tangible infrastructures. They generally require large investments of resources and may lack both flexibility and adaptability to sudden potential changes in climate projections.

Adaptation to climate change based on the adoption of non-structural or soft solutions, on the contrary, mainly deals with the operational, management and organisational aspects of systems and intangible infrastructures (Sovacool, 2011), in particular:

- it is closely linked to information and process management, supported by ICTs (Information and Communication Technologies), and to the implementation of political, legal, social and financial measures;
- it makes changes that are reversible in the short and medium term, which do not limit other future choices;
- it requires relatively low and short-to-medium-term investments
- it allows coexistence and synergy with other measures;
- it contributes to increase the well-being of residents and the attractiveness of public spaces in cities.

The study presented in this paper develops the concept of soft-resilience, which is the ability of systems to absorb and recover from the impact of disruptive events without fundamental changes in their function or structural characteristics (Proag, 2014).

Based on this assumption, this paper explores the potential of the urban services sector in the process of adapting cities to climate change, advancing the hypothesis that the implementation of measures based on the application of ICTs and the exploitation of information are one of the pillars of soft strategies and represent interesting options thanks also to the cost-benefit ratio.

This was done by applying the following methodology:

1. analysis of barriers to climate change adaptation actions through a systematic bibliography search, an in-depth literature review and collaborations with regional and local governments;
2. conceptualisation of soft-resilience and soft-approach solutions through a systematic bibliography search and an in-depth literature review;

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Tab. 01 | Example of characteristics of soft and hard adaptation measures

3. search and analysis of the available Italian, European and international regulations and standards on urban adaptation, urban facility management and urban services;
4. review and analysis of recent international publications (2015-2019) (Fig. 2), selected among the most representative of the advancements in comparative studies in the field of climate policy;
5. definition of criteria to select a sample of European cities provided with a Local Adaptation Plan: a) capital cities of European states that are the forerunners in adaptation to climate change planning at the national scale, that is to say among the first countries to adopt a National Adaptation Strategy (then transposed into a National Adaptation Plan); b) capital cities of European states that have made it mandatory to adopt local climate plans (Denmark, France, United Kingdom, Slovakia); c) Covenant of Mayors signatories and members of the C40 cities network;
6. in-depth qualitative comparative analysis of the selected Local Adaptation Plans and adaptation initiatives on a local scale;
7. proposal and application of a novel method for the classification of adaptation measures;
8. selection of examples of inefficient and ineffective investments in structural, hard adaptation solutions (defensive structures, such as sea walls, dams, desalination plants, drainage systems, etc); selection of examples of successful soft measures; analysis of case studies;
9. identification of the main enabling technologies for soft-approach solutions, distinguished in: technologies to improve situational awareness (basically regarding sensors), technologies to support decision making (related to data gathering) and sector-specific applications; detection of recurring aspects of interest and trends in the use of ICTs.

Climate adaptation planning: trends and innovation in policy tools and in the design of adaptation measures

The adoption of the European Strategy on Adaptation to Climate Change - COM (2013) 216 - by the European Commission in 2013 is a lever for the adaptation of cities. It sets out the framework and mechanisms for improving EU actions in relation to current and future climate impacts.

Climate policy tools can be distinguished in strategies and plans at all the different scales:

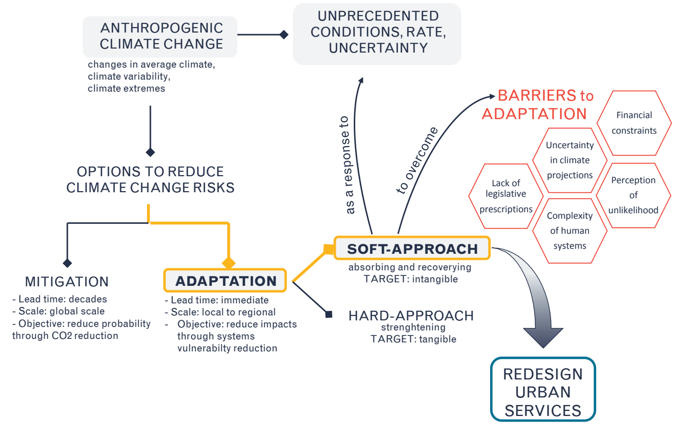
- strategies address general issues and identify objectives and guidelines, outline the need to implement planning at different scales, are useful to raise awareness of the issue of climate adaptation and the involvement of stakeholders, provide risk and vulnerability assessments;
- plans aim at implementing climate strategies and at identifying measures to achieve their objectives, report a more detailed assessment of the risks and the vulnerabilities, facilitate coordina-

Tab. 01 |

Attribute	Soft – approach adaptation strategies	Hard – approach adaptation strategies
Flexibility	Flexible, adaptable to sudden changes in climate conditions or projections	Inflexible in the short-term, not adaptable to sudden changes in climate conditions or projections
Reversibility	Reversible in the short term without adverse effects; does not narrow future choices	Reversible in the long time with impact; narrows future choices
Simplicity	Rely on simple, low nimpact technologies and intangible infrastructures	Rely on complex technologies and human-built infrastructures
Implementability	Short-medium term investments	Long-term investments
Scalability	Small scale measures	Large scale measures; large scale disturbances
Compatibility	Allow coexistence and synergies with other measures	Trade-offs with other measures; narrow future choices
Cost-effectiveness	Resource-saving; cost-effective	Resource-consuming; usually capital intensive
Intangibility	Deal mainly with organisational, operational and institutional capacity	Mainly provide for physical interventions
Adjustability	Adjustable to stakeholders needs	Hard to define proportions on the basis of uncertain data
Environmental sustainability	No environmental drawbacks	Medium to high environmental drawbacks

01 | Strategies to reduce climate change risks

02 | Selection of recent, representative comparative studies in the field of climate adaptation planning



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tion between stakeholders, establish priorities between interventions, identify adaptation options and implementable actions, conduct assessments of the identified options and actions, and outline procedures for monitoring adaptation actions.

Adaptation strategies and plans at European, national and regional levels are difficult to translate into measures that can actually be implemented on a local level due to territorial specificities such as different degrees of exposure to the impact of climate change, different tangible and intangible assets, different physical, structural and organisational dimensions of each city, etc.

Indeed, National Adaptation Strategies and Plans (NAS[1] and NAP[2]) guide local administrations by outlining climate policy objectives. Furthermore, they provide climate scenarios, approaches and methodologies for risk and vulnerability assessments, as well as procedures for monitoring adaptation initiatives. However, the local level seems to be the most suitable scale for translating policy tools into practical actions by avoiding the undifferentiated transfer of solutions and best practices, which Cortekar (2016), like many other sources (Cortekar, 2016) (Aguiar, 2018) (Preston, 2016), identifies as the cause of the ineffectiveness that has characterised adaptation processes so far. An analysis of recent international publications (2015-2019) (Fig. 02), selected among the most representative of the advancements in comparative studies in the field of climate policy, highlights that the available literature:

- does not propose a classification of the strategies presented in the analysed climate plans similar to the distinction of adaptation measures in hard and soft measures; to date, neither a shared categorisation of adaptation measures nor a settled and unambiguous definition of hard and soft measures are available;
- does not consider the integration of ICTs in climate change adaptation processes as a key issue to take into consideration in the analysis of plans.

The following considerations can be made, based on this review of comparative studies and on a further analysis of three climate plans (Tab. 2), chosen among the most representative of advanced ap-

YEAR	AUTHORS	TITLE	KEYWORDS
2018	Aguiar, F. et al.	Adaptation to climate change at local level in Europe: An overview	Adaptation; Climate change; Europe; Land planning; Municipalities; Strategies
2015	Araos, M. et al.	Climate change adaptation planning in large cities: A systematic global assessment	Adaptation; Cities; Climate change; Monitoring and evaluation; Systematic assessment
2017	Campos, I. et al.	Understanding climate change policy and action in Portuguese municipalities : A survey	Adaptation; Cities; Climate change; Monitoring and evaluation; Systematic assessment
2019	Grafakos, S. et al.	Integration of mitigation and adaptation in urban climate change action plans in Europe : A systematic assessment	Co-benefits; European cities; Evaluation; Interrelationships; Planning; Scoring; Synergies
2015	Huges, S. et al.	A meta-analysis of urban climate change adaptation planning in the U. S.	Institutional capacity; Governance; Adaptation; Meta-analysis; Networks
2020	Lioubimtseva, E. et al.	Local climate change adaptation plans in the US and France: Comparison and lessons learned in 2007-2017	Climate adaptation plan; Community; Small city; Mid-sized city; United States; France
2019	Pietrapertosa, F. et al.	Urban climate change mitigation and adaptation planning : Are Italian cities ready?	Climate change; Urban adaptation; Urban mitigation; Italy
2018	Reckien, D. et al.	How are cities planning to respond to climate change ? Assessment of local climate plans from 885 cities in the EU-28	Climate change; Paris agreement; Local climate plans; Cities; Urban areas; Urban audit cities; Europe; Adaptation; Mitigation; SEAP/SECAP
2019	Reckien, D. et al.	Dedicated versus mainstreaming approaches in local climate plans in Europe	Local climate policy/ planning; Mitigation; Adaptation; Urban areas/ cities; Urban audit; Mainstreaming; Mitigation/ adaptation tracking
2019	Woodruf, S. et al.	Quality of national adaptation plans and opportunities for improvement	Climate change; Adaptation; Adaptation plan; UNFCCC; Plan evaluation

| 02

Tab. 02 | Synthesis of the climate plans analysis of Copenhagen, London, Paris[4]

proaches (based on the criteria specified in note[3]):

1. the absence of European regulations and standards capable of harmonising the structure of climate policy tools entails difficulties in systematic comparative analysis of strategies and plans in different countries and cities (Reckien, 2018) (Woodruff, 2019) (Pietrapertosa, 2019);
2. most of Europe's local climate plans have not been updated since their first publication (see Copenhagen and London); due to the rapid evolution of climate parameters and scientific studies, the planning documents are generally not aligned with the most recent advances in this field;
3. no distinction between hard and soft measures can be found in the plans. A shared categorisation of adaptation measures in the literature is not available yet;
4. looking at adaptation plans, the approach to climate adaptation is predominantly of the hard type. The only measures definable as soft solutions in the climate plans analysed are the provision of warning systems, the reallocation of vulnerable functions and the proposal of training initiatives to increase the degree of awareness of urban communities.

However, plans published in more recent years (as in the case of Paris) suggest, alongside hard options, the implementation of some measures based on the integration of ICTs in adaptation processes and on efficient information management.

Tab. 02 |

Number of inhabitants	603,000	8,500,000	2,270,000
Area	86 km²	1,595 km²	105 km²
National climate policy tools	Denmark: NAS (2008), NAP (2012)	United Kingdom: NAS (2007), NAP (2013)	France: NAS (2006), NAP (2011)
Provisions for the adoption of climate plans	Mandatory adoption of a Local Adaptation Plan	Mandatory adoption of a local climate plan	Mandatory adoption of a local climate plan
Membership in networks	Covenant of Mayors; C40	Covenant of Mayors; C40	Covenant of Mayors; C40
Awards	C40 awards finalist in 2015; C40 Innovator city	C40 awards finalist in 2015; C40 Megacity	C40 awards finalist in 2015; C40 Megacity
Analysed documents	River flooding, heat waves, flooding, drought, coastal flooding	River flooding, heat waves, flooding, drought, coastal flooding	River flooding, heat waves, flooding, drought, coastal flooding
Documents update	2011	2011	2018
Type of risks (order of decreasing seriousness)	Heavy rainfall, flooding, heat waves, coastal flooding	River flooding, heat waves, flooding, drought, coastal flooding	Heat waves, river flooding, cold waves, strong winds, flooding, land slides
Focus of the plan	Adaptation	Adaptation/mitigation	Adaptation/mitigation
Adaptation strategies	Co-benefit strategies	Differentiated strategies by sector	Co-benefit strategies Integration of soft and hard strategies
***Hard* adaptation measures**	Green-infrastructures	Green-infrastructures; building retrofitting; adoption of new building standards	Green-infrastructures; building retrofitting
***Soft* adaptation measures**	Reallocation of vulnerable functions in areas with a low-level of flooding risk	Installation of early warning systems	Use of 3D GIS and BIM for the creation of digital models of buildings and neighbourhoods; monitoring of adaptation initiatives through web platforms; differentiation and decentralisation of climate information (*climate services*); awareness campaigns; training programmes

Local climate plans often turn out to be no more than guidance tools and do not go into more detail than strategies. They fail to specify adaptation measures that can be implemented in practice (Cortekar, 2016; Aguiar, 2018; Preston, 2016; Pietrapertosa, 2019).
In order to track soft solutions, aimed at raising the degree of resilience of the built environment, it is necessary to investigate specific initiatives and experiences at local or sub-local scale. Although these are not included in the official planning documents, they may represent an important response to the potential impact of climate change (EC, 2013). An example is the exploration of the urban services offered by local governments: the potential of this sector in the perspective of adaptation, lies in its correspondence to the characteristics of low-regret measures, defined by the IPCC as «measures that would generate net social and/or economic benefits under both current climate and a number of future climate change scenarios» (IPCC, 2014).

Urban services and possible applications of ICTs for the adaptation of urban systems to climate change

The Fifth Report of the IPCC (AR5) suggests that, at a local scale, infrastructures associated with the provision of basic services - such as water supply, sanitation, waste disposal, energy, rainwater and road management and public transport - are an essential element to increase adaptation capacity, and that "the provision of services includes a diverse range of specific activities" (IPCC, 2014). Taking this statement into account, the vision introduced in the AR5 can be broadened, investigating the potential of smart urban services (supported by the application of ICTs) for the enhancement of the resilience level of the built environment (Cortekar, 2016).
Recent ICT innovations introduce new optimisation and innovation scenarios for urban service management processes, related to the climate adaptation capacity of urban centres. While intervening on organisational and managerial aspects of systems (in line with the definition of soft-approach), ICTs facilitate:

1. the sharing of information and knowledge; the accessibility and distribution of information is an important element for supporting decision-making processes at different levels (strategic, operational) for municipalities and residents;
2. the integration of data from heterogeneous sources; the interpolation of data from different sources and fields can generate diversified information, which is useful for the development of innovative services
3. the improvement of the quality of future projections, the optimisation of weather and climate forecasts and the detection of extreme events; the application of ICTs allows to acquire, process, analyse and manage large amounts of data (Big Data) in order to predict future events and interpret the behaviour of cities (e.g., identifying areas at risk, available resources on the territory, etc.) to improve their response capacity;
4. the accurate assessment of risks, vulnerabilities, potential impacts and damages from extreme events;
5. the sharing of early warnings, emergency management instructions and remote assistance in the organisation of operations and coordination of on-field activities.

These functions are mainly implemented through the application of innovative enabling technologies, such as the Internet of Things and Big Data management.
In the light of these ICT-enabled functions, it is possible to outline optimisation scenarios of some actions that enhance the resilience of urban systems and their capacity to adapt to climate change such as:

1. the improvement of residents' behaviour. This category includes services aimed at optimising the management of resources (e.g. water, energy, etc.) through the use of ICTs, to outline consumption profiles of urban areas and users, and to provide solutions for waste reduction and efficiency improvement. The London datastore, for example, collects and stores data for the development of an inventory of air emissions, energy consumption, water use profiles, etc. Another example is the city of Santander which, thanks to the implementation of dynamic and shared dashboards, promotes the interaction between administration and residents to share data about energy consumption;
2. the improvement of organisational capacities in case of extreme events through the development of: condition-based services along with the definition of acceptance levels of critical parameters to be monitored in real-time (Paganin, 2018); real-time resource management services based on the integration of monitoring systems, dashboards and applications (web and mobile) capable of providing geo-referenced data about deployed/available resources on the territory; communication and alert systems to alert critical infrastructure managers to activate emergency services (firefighters, mobile teams, etc.). In Thailand, for example, the Department of disaster prevention and mitigation is equipped with a combined monitoring system (of data concerning as sea level, time, climate change, etc.) and multi-hazard early warning to improve preparedness and disaster management (e.g. tsunami).

Conclusions

The adoption of a soft approach to the issue of climate adaptation for urban systems is an effective strategy to overcome the main barriers to the implementation of adaptation-measures, opening up to solutions characterised by their flexibility, reversibility and cost effectiveness. The most up-to-date local climate plans include, alongside hard adaptation solutions, measures with characteristics that correspond to the definition of soft measures, revealing a growing interest in this approach.

The exploration of the urban services sector, in a perspective of climate change adaptation, opens up to several optimisation scenarios of the organisational and management practices of human systems, with the support of ICT applications to ensure the smartness of services.
The design of smart services for management and maintenance of urban facilities, understood as a strategy of adaptation to climate change, also gives back, as co-benefit, the enhancement of urban well-being and the attractiveness of public spaces in cities.
Research on soft adaptation solutions requires urgent advancements to encourage the adoption of this approach in planning the adaptation of urban systems to the potential impacts of climate change.
Lastly, it should be stressed that mitigation and adaptation are not alternatives, but complementary actions, and climate plans are the regulatory tools intended to ensure consistency and compatibility between the selected adaptation and mitigation measures.

NOTES

[1] National Adaptation Strategy

[2] National Adaptation Plan

[3] Criteria: 1) Capital cities of European states that are the forerunners in adaptation to climate change planning at a national scale, that is to say among the first countries to adopt a NAS (later transposed into a NAP); 2) Capital cities of European states that have made it mandatory to adopt local climate plans (Denmark, France, United Kingdom, Slovakia); 3) Covenant of Mayors signatories and members of the C40 cities network.

[4] Sources: Covenant of Mayors; EU scoreboard adaptation preparedness country fiches; ClimateADAPT; C40.

REFERENCES

Aguiar, F.C. *et al.* (2018), "Adaptation to climate change at local level in Europe: An overview", *Environmental Science and Policy*, Vol. 86, pp. 38-63.

Araos, M. *et al.* (2016), "Climate change adaptation planning in large cities: A systematic global assessment", *Environmental Science and Policy*, Vol. 66, pp. 375-382.

Cortekar, J. *et al.* (2016), "Why climate change adaptation in cities needs customised and flexible climate services", *Climate Services*, Vol. 4, pp. 42-51.

EC – European Commission (2013), *The European Strategy on adaptation to climate change.*

Füssel, H.M. (2007), "Adaptation planning for climate change: Concepts, assessment approaches, and key lessons", *Sustainability Science*, Vol. 2, pp. 265-275.

IPCC - Intergovernmental Panel on Climate Change (2014), "Adaptation needs and options", in: *Climate Change 2014: Impacts, Adaptation, and Vulnerability,* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 833-868.

Paganin, G., *et al.* (2018), "Knowledge management and resilience of urban and territorial systems", *Techne, Journal of Technlogy for Architecture and Environment,* Firenze University Press, Firenze, p.124-133.

Pietrapertosa, F. *et al.* (2019), "Urban climate change mitigation and adaptation planning: Are Italian cities ready?", *Cities*, Vol. 91, pp. 93-105.

Preston, B.L. *et al.* (2016), "Is adaptation a local responsibility?", *Environmental Science and Policy*, Vol. 48, pp. 89-98.

Proag, V. (2014), "The Concept of Vulnerability and Resilience, Procedia Economics and Finance", Vol. 18, pp. 369-376.

Reckien, D. *et al.* (2018) "How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28", *Journal of Cleaner Production*, Vol. 191, pp. 207-219.

Sovacool, B. (2011), "Hard and soft paths for climate change adaptation", *Climate policy*, Vol. 11, pp. 1177-1183.

WEC - The World Energy Council (2018), *World Energy Issues Monitor 2018. Perspectives on the Grand Energy Transitio*n.

WMO - World Meteorological Organization (2016), *Climate Services for Supporting Climate Change Adaptation, Supplement to the Technical Guidelines for The National Adaptation Plan Process,* WMO.

Woodruff, S.C. and Regan, P. (2019), "Quality of national adaptation plans and opportunities for improvement", *Mitigation and Adaptation Strategies for Global Change*, Vol. 24, pp. 53-71.

Weaving artificiality and nature. Architecture, context and techniques as interacting agents

Francesco Spanedda,
Department of Humanities and Social Sciences, University of Sassari, Italy
francesco.spanedda@uniss.it

Abstract. At the start of this century, a discussion took place with regard to humankind as an Earth-shaping force and the beginning of a new geological epoch, the Anthropocene. This paper investigates how this condition, where nature and artificiality are considered mutually influencing agents, could concern the field of architecture. It sums up the interdisciplinary background behind the main threads on the topic, and discusses the main implications for architectural design, a discipline traditionally concerned with the relationship between the artificial human habitat and the surrounding nature.Several case studies back up these speculations and show different design concepts that try to work on a fluid relationship between artificial and natural elements.

Keywords: Urban regeneration; Architectural design; Rehabilitation of existing buildings; Design for sustainability; Technological design culture.

Introduction

Currently, settlements, buildings, infrastructures and agriculture spread over 75% of land free of ice (Sanderson *et al.,* 2002). The resulting global artificial layer and the ensuing human ecosystem brought Earth scientists to speculate about a new geological epoch, the Anthropocene, in which humankind became an earth-shaping force, as strong as other natural forces (Crutzen and Stoermer, 2000). Human scientists drew on the concept to investigate the evolution in the relationship between culture and nature.

Under this point of view, the debate on Anthropocene is also an opportunity to reframe the discourse about sustainability, which until recently largely focused on the reduction of human impact on the environment. Thus, the role of architecture shifted from sheltering people from natural agents to protecting nature against human actions (Raman, 2007) by means of techniques, typologies, and components aimed at reducing energy and materials depletion.

This approach, however, leaves several open questions. The increasing demand in resources required by the growing world population and their need for a higher and equal quality of life (Sachs, 2015) requires a rather drastic reduction of impact. Moreover, minimising impact is not a radical cultural change, since it basically confirms a dualistic separation between culture and nature, the first still exploiting the latter, just more respectfully.

The Anthropocene helps to build a consistent frame around these two topics, since it acknowledges the increasing role of human-induced transformations and takes the separation between nature and culture as an epistemological assumption and not a given fact (Latour, 2015), thus paving the way to reconsider common views on sustainability issues.

The discussion about Anthropocene is gaining foothold in the architectural discourse, where authors highlight its importance in reconsidering the relationship between culture and nature (Turpin, 2014), breaking the disciplinary boundaries (Neveu, 2017), or reframing the discourse about sustainability (Spanedda, 2018). However, Earth sciences and humanities went further in investigating the relationship between societal organisation, space production, technology deployment, and natural environment. At present, analytical disciplines dominate the discussion, but they appear to lack the tools to envision possible positive futures, something that is at the core of architectural design and its related disciplines. Architects could, therefore, step into the debate by contributing with their knowledge about physical transformations, and at the same time by critically reviewing several basic concepts in their disciplines, with a view to findings in the discussion on Anthropocene.

Three takes on anthropocene

There are several discussion threads about Anthropocene, each with a different focus.

The first strand opened the debate, as Crutzen and Stoermer (2000) raised the hypothesis that human activity began at some point to significantly alter the planet's surface, thus initiating a new geological era. This led to a flourishing branch of studies describing how artificial and natural processes pervasively concur in developing complex ecosystems. A second strand in human sciences criticises the modernist way of relating nature and society, taking the opportunity to part from the Cartesian dualism between nature and culture and to, instead, connect them in a fluid relationship (Latour, 2015).

The third strand refuses to consider Anthropocene the product of humanity as a whole, but a consequence of the exploitation of natural resources by a culture centred on the production and marketing of commodities (Moore, 2018).

All these strands contribute to the general debate, and offer critical vantage points on the transformation of the physical environment. The following paragraphs will then summarise each of them and focus on their possible meaning for architectural design.

Earth as artefact

The first thread focuses on the relevance of human-induced changes on Earth's surface. By analysing the stratigraphic layers and the extension of land under human control, it emphasises the pervasive, long-lasting impact of human activities in geology and ecology (Rockström *et al.,* 2009), which eventually blur the boundaries between natural and artificial. In 2005 the USDA survey team classified the soil profile for Freshkills Landfill, which is largely made out of trash, coming to the conclusion that it has much in common with the soil from the slopes of North Carolina's Appalachian Mountains (Denizen, 2014). Through humanity, technology has irreversibly become a part of nature with no chance of radical mitigation or restoration to a previous condition (Grosz, 2014).

Architectural and urban design should then deal with this new kind of context, working on the combination of natural and human processes, instead of drawing boundaries between the two spheres.

As an example, "Urban Metabolism", a IABR–2014– Project Atelier by Field Operations and FABRICAtions, investigates the substance flows within the city of Rotterdam: goods, people, waste, plants and animals, energy, food, fresh, water, sand and clay, and air (Fig. 1).

The work envisions flow optimisation by transitioning to a circular economy enabled by four spatial design strategies.

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The first, "Collecting Resources", examines options for recovering raw materials from waste, which result in redesigning households (to collect waste), marketplaces (to gather reusable commodities), and infrastructures (to distribute phosphates or host urban farming).
"Creating Biotopes", considers steering the natural process of silting to form a new dyke, build new biotopes around unused docks, and increase the surface for land farming. The high voltage lines are reworked as ecological corridors, linking new and existing biotas. Rainwater storage sites provide freshwater throughout the year, preventing ground salinisation and configuring new public spaces.
"Channelling (Energy) Waste" mostly focuses on geothermal heat and CO_2 treatment at a regional and city level.
Finally, "Catalyzing Re-Industrialisation" envisions new forms of manufacturing and crafts settling within the gaps in the urban fabric left by retail, along with mobility optimisation. Working places could thus be located where people live, instead of forcing employers to commute.
By shifting the focus from objects to flows, this proposal entwines natural and artificial processes through different scales. Although it lacks detailed quantitative information, the study offers a positive view of Anthropocene thanks to an interdisciplinary inquiry. It visualises a physical environment, which is hard to divide into artefacts and natural elements, in an attempt to build a better living environment for humankind and all the other species.

Environment as diffuse agency

The second trend on Anthropocene offers a more philosophical stance on the blurring of artificial and natural.
The planetary ecological crisis reveals that nature is not just a static background for human actions, a passive provider of energy and resources. Instead, the environment reacts showing humans that their agency is shared with other agents in a mutual limitation of each other's autonomy (Latour, 2014).
As nature becomes a tangle of agents responding to human behaviour, it ceases to be a predictable subject to immutable laws, therefore disrupting any technological determinism and dissolving the old Cartesian dualism between artificial and natural.
These circumstances shed a different light on the idea of context, a fundamental notion in architectural design.
Context is often seen as a background provided by a specific site, carrying information about types, functions, evolutive rules, materials, and social behaviour. Designers actively react to it, choosing to take this information into account in terms of continuity or opposition.
However, the figure/background opposition might evolve into a broader, dynamic interpretation of context as an interactive set of agents working at different scales.
To explain such an extensive vision, Moe (2007) visualises the role of contextual agents in the design process by borrowing the concept of "epigenetic landscape" from developmental biology. An epigenetic landscape is a virtual topography in an abstract, multidimensional space, whose shape influences the developmental pathways along which a physical entity evolves. All contextual agents (political, economic, historical, technical, ecological, social, cultural, material) dynamically deform this virtual topography, producing minor or major inflections at different times through mutual influences, even if the inflecting force is the same. Designers should strategically lead the formation of the abstract epigenetic landscape in order to steer the design process and thus the formation of the spatial organism.
An example of such a strategic lead can be found in Elemental's plan for the reconstruction of the coastal town of Constitución, close to the Maule estuary in Chile (Fig. 2). In 2010, the site was hit by a tsunami. Elemental was tasked with the master plan to rebuild the town, including the infrastructure for tsunami mitigation. The participatory phase of planning revealed both a historical lack of public space within the town, and the need to keep a direct access to the river, which led to three solutions.
The first was leaving a fallow strip along the coast, with the risk of prospective illegal occupancy.
The second was building a protective wall, massive and tall enough to withstand the impact of tsunami waves, and then houses behind the wall. Local building firms backed up this proposal.
The third was planting a forest along the estuary to dissipate the impact of future tsunamis. This also provided a public space between the town and the river, and direct access to the latter. Instead of deploying "hard" techniques against a natural threat, the forest embodies resilience, a concept which is gaining foothold in the current debate about sustainability (Cumming and Collier, 2005).
Citizens opted for the forest.
The different contextual natural, social, and economic issues (one of the town's main employers is a forestry company) are clearly similar to the drivers tugging Moe's epigenetic landscape. The designers' ability in assessing, questioning, and combining social and natural issues, the integration of natural and artificial elements in the final design, and their refusal to jump straight into a predefined outcome allowed them to effectively steer the design process, even in a complex task like rebuilding a town under emergency conditions.

Entropy reversal

The third thread refers to the current exploitation of natural resources as the mark of a consumerist society, and not of humanity as a whole.
According to Moore (2018) the origins of Anthropocene trace back to the conquest of the Americas, the first great expansion of European logistic chains. Stigler (2017), drawing from Lévi-Strauss and Georgescu-Roegen, argues that, in order to optimise the transformation of resources in commodities, Western civilisation promoted

01 | Urban Metabolism, Rotterdam (2003), FABRICations, James Corner Field Operations, Environmental Assessment Agency, Havenbedrijf Rotterdam. Scheme of the ecological corridors along the high-voltage lines. A) Avifauna corridor, B) High voltage line, C) Agricultural land, D) Urban area, E) Terrestrial fauna, F) Water storage. Drawing by the author

02 | PRES – Sustainable Post-Tsunami Reconstruction Plan (2010-2016), Elemental and Arup, Constitución, Chile. A) New forest, B) Waterfront housing on pilotis, C) Emergency housing. Drawing by the author

03 | Zollverein School of Management and Design (2006), SANAA, SANAA, Heinrich Böll, Transolar, Bollinger + Grohmann, Horstmann + Berger, Essen. A) Emscher river, B) Pumping station, C) Passive insulation (red dotted lines, only partially drawn), D) Dismissed mine shaft. Drawing by the author

a specialised but very fragmented knowledge, mirrored by a landscape scattered with mono-functional buildings and infrastructures. He states that, in the Anthropocene, industrialisation reorganises the world into closed, entropic systems. Thus, a response to Anthropocene requires some negentropic work to instate a new order among the dispersed knowledge and the material remains of commodification.

Although Stigler's concept of negentropic work could seem rather vague and undefined, the principle of working by establishing relationships, both in space and among disciplines, is a specific, essential quality of architectural design. Since the late '70s, some authors focused on collecting "the scattered fragments of the essence of our present and awkwardly re-build with them our new churches" Gregotti (1987) and on dealing with the "density of history and nature" (Maciocco 2011). Promoting architecture as a way to re-organise systems of relationship through physical actions, they paved the way to work on the entropic landscape of Anthropocene, articulating space to synthesise contradictions, make order and unfold relationships.

Therefore, architectural design may become Stigler's negentropic work.

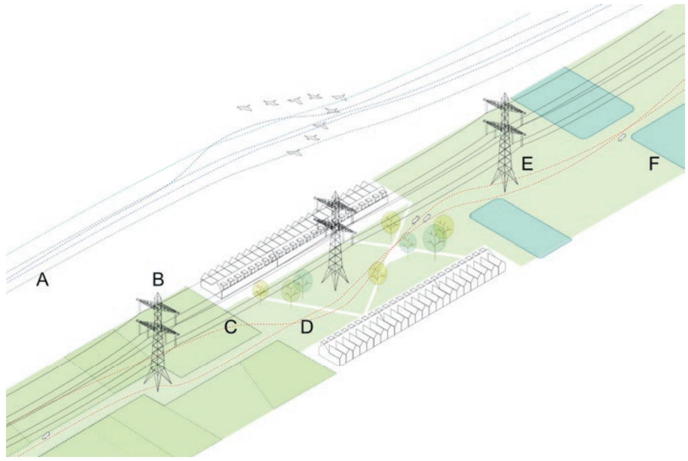
On the physical plane, it recombines in a new order obsolescent buildings, settlements, infrastructures, fragments of nature, and the broken loops of materials and energy. This post-production process (Bourriaud, 2002) still needs to find its own aesthetics, but is required to give sense to the intricate legacy of fossil capitalism.

On the plane of knowledge, design has the opportunity to gather the sparse knowledge of different specialists, prompting collaborations around specific issues. A process of problematisation that should allow every single specialist, and better than abstract specialities, to contribute to a much needed "politics of hyper-complexity" (Turpin, 2014), overcoming the blurred boundaries between natural and artificial, waste and resource.

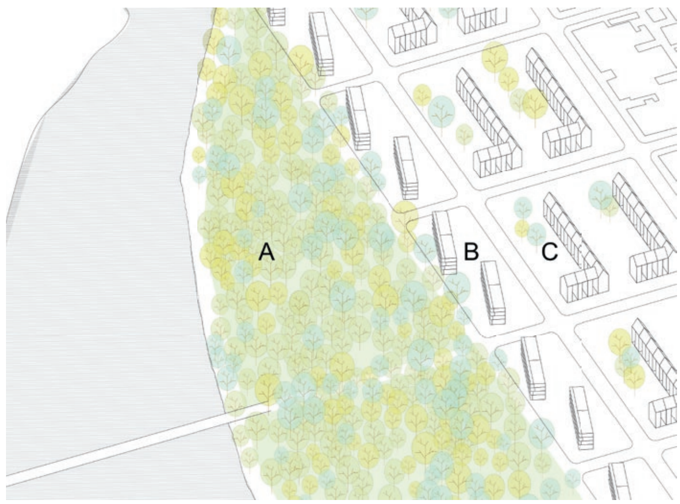
An example for this is the Zollverein Essen Design School by SANAA, part of the reclamation of a former industrial site in Germany (Fig. 3).

After close inspection of the site, the designers opted to provide the building with an active insulation layer made by warm water circulating through pipes cast inside the concrete shell. Although this solution seems detrimental in terms of energy efficiency, the reason for this peculiarity lies in the abundant waste warm water coming from an unused flooded mine. In fact, a pumping station extracts water from the nearby mine shafts with a temperature of approximately 28°C, and discharges it into the River Emscher. The water goes through a heat exchanger, heats the building just at the cost of the pump consumption, and chills before returning back to the riverbed, thus decreasing pollution. The system provides a CO_2-free energy consuming 75% less energy than a reference building (Moe, 2010).

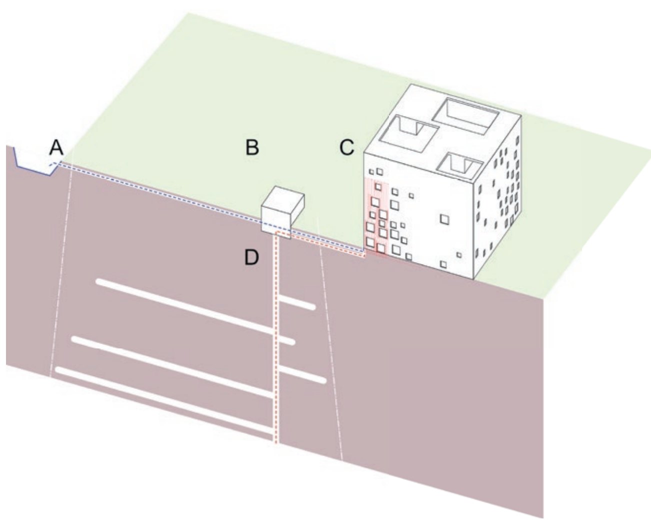
| 01



| 02



| 03



The designers reframed the thermal performance issues by considering the context as a part of the building's energy system. The different remnants of industrial activity are recombined in a new entity, blurring the boundaries between artificiality and nature, since the wastewater is used just like a "natural" geothermal source.
This context-aware technological solution deliberately disrupts the usual concept of optimisation, like the well known "Passivhaus" model that reduces the energy exchange with the environment through sealed envelopes and closed energy flows. Instead, the building becomes permeable to energy flows from the outside, closing the loops at a bigger scale, an unintentional proof of Stigler's concepts.

Conclusions

This paper argues that the fundamental issues raised by the current debate on Anthropocene directly concern architectural design disciplines. The relationship between culture and nature, the physical transformations of the planet's surface, and the ability to intervene in existing systems of relationships, traditionally fall into the disciplinary fields of architecture. In spite of their potentially relevant contributions, architects are mostly absent from the debate. But, in order to effectively tackle these issues, design disciplines should expand their scope, developing, along the design of objects, ways to design processes and enable complex systems of relationship between natural and artificial, existing and new, waste and resource. This implies reconsidering the way we look at techniques, examine context, choose whether to building anew or to renovate and, last but not least, a steady process of interdisciplinary problematisation to challenge obsolete assumptions.
Although it might seem a steep and winding path, it could be a challenging way to bring architecture back to its role, which Price (2003) described so concisely, of "a socially beneficial distortion of the environment".
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REFERENCES

Bourriaud, N. (2002), *Postproduction: culture as screenplay: how art reprograms the world*, Lukas & Sternberg New York, USA.

Crutzen, P. J. and Stoermer, E.F. (2000), "The `Anthropocene'", *Global Change Newsletter*, Vol. 41, pp. 17-18.

Cumming, G.S. and Collier, J. (2005), "Change and identity in complex systems", *Ecology and Society*, 10(1):29, [online] http://www.ecologyandsociety.org/vol10/iss1/art29/.

Denizen, S. (2014), "Three Holes: In the Geological Present" in Turpin, E. (Ed.), *Architecture in the Anthropocene: Encounters among design, deep time, science and philosophy*, Open Humanities Press, pp. 29-46.

Gregotti, V. (1987), "Alta manutenzione / High maintenance", *Casabella*, n. 539, pp. 2-3.

Grosz, E., (2014), "Time matters: On temporality in the Anthropocene" in "Time matters: On temporality in the Anthropocene" in Turpin, E. (Ed.), Architecture in the Anthropocene: *Encounters among design, deep time, science and philosophy*, Open Humanities Press, pp. 129-138.

Maciocco, G. (2011), "Scenarios for a territorial future of the city" in Maciocco, G., Sanna, G., and Serreli, S. (Eds.), *The Urban potential of External Territories*, Franco Angeli, Milan, Italy, pp. 10-79.

Latour, B. (2015), "Fifty shades of green", *Environmental Humanities*, Vol. 7, Vol. 1, pp. 219-225.

Moe, K. (2007), "Compelling Yet Unreliable Theories of Sustainability", *Journal of Architectural Education*, Vol 60(4), pp. 24-30.

Moe, K. (2010), *Thermally Active Surfaces in Architecture*, Princeton Architectural Press.

Moore, J.W. (2018), "The Capitalocene Part II: accumulation by appropriation and the centrality of unpaid work/energy", *The Journal of Peasant Studies*, Vol. 45, N. 2, pp. 237-279.

Neveu, M. J. (2017), "The Design of Environmental Design", *Journal of Architectural Education*, Vol. 71, Vol. 2, pp. 135-135.

Price, C. (2003), *Cedric Price: the square book*, Wiley-Academy, Chichester.

Raman, M. (2007), "Sustainable?" *Part 3 : A Quarter Century of Environmentally Conscious Design*, https://www.cca.qc.ca/en/issues/19/the-planet-is-the-client/221/sustainable, (accesse 3 Jenuary 2019).

Rockström, J. *et al.* (2009), "A safe operating space for humanity", *Nature*, Vol. 461, Vol. 7263, pp. 472-475.

Sachs, J.D. (2015), *The age of sustainable development*, Columbia University Press, New York, USA.

Sanderson, E.W., Jaiteh, M., Levy, M.A., Redford, K.H., Wannebo, A.V. and Woolmfer, G. (2002), "The human footprint and the last of the wild", *BioScience*, Vol. 52, n. 10, pp. 891-904.

Stiegler, B. (2017), "Escaping the anthropocene", in Magatti, M. (ed.), *The crisis conundrum: How To Reconcile Economy And Society*, Springer, Dordrecht, pp. 149-163.

Spanedda, F. (2018), *Architecture and Anthropocene*, Franco Angeli, Milan, Italy.

Steffen, W. *et al.* (2015), "The trajectory of the Anthropocene: the great acceleration", *The Anthropocene Review*, Vol. 2, Vol. 1, pp. 81-98.

Turpin, E. (2014), *Architecture in the Anthropocene: Encounters among design, deep time, science and philosophy*, Open Humanities Press, Ann Arbor.

Ecological-thinking and collaborative design as agents of our evolving future

Erminia Attaianese, Marina Rigillo,
Department of Architecture, University of Napoli Federico II, Italy
erminia.attainese@unina.it
marina.rigillo@unina.it

Abstract. The paper depicts emerging scenarios of environmental design, in connection to the paradigm shift brought about by digital technologies, and awareness of future challenges. It reviews selected researches and projects applying ecological thinking principles. It aims at raising awareness on heuristic approaches in research and design. The paper focuses on collective design as a way to improve the governance of complexity in the current anthropogenic era. The main conclusion highlights cultural marks depicting contemporary research trends, with a view to translate theoretical insights into practical experiences.

Keywords: Environmental Design; Heuristics; Digital technologies; Emergent Ecologies; Hybridization.

Background

A common sense of astonishment characterises our present time. The manifold challenges of our age call upon humankind to quickly adapt to new habitats – both physical and digital – within its lifetime. Such adaptation should not be really different from those which occurred in history. However, two new factors come into play: digital technologies, which reshape relationships among humans, machines and culture, and the tremendous impact of humans on the Earth, which has led to name the current geologic era "Anthropocene" (Crutzen and Stormer, 2000).

The combination of cultural and technological implications has produced an all-time shift in the scientific paradigm, notably in the relations between Artifice and Nature. The distinction between the two terms has become blurred, as the emergent capacity to produce hybrids offers a creative ground that merges biotic and abiotic systems (Gere, 2004; Brawnell & Swackhamer, 2015; Cantrell & Holzman, 2016). The fascination in hybridizing technologies and nature has been celebrated by the artistic avant-gardes since the 1970s[1], that considered the digital innovation potential as a cross-fertilization field between art and science, and more recently by artists as Eduardo Kac, or Kelly Jazvac or Aki Inomata, to name a few[2]. Indeed, the unprecedented alliance between humankind and technology supports the odds for improving both health and wealth, thus reducing the impact on finite natural capital. The failure of such alliance can accelerate the depletion of natural capital, bringing the Planet close to a real prospective of disaster: «It was the best of times, it was the worst of times» (Dickens 1859 quoted in Naam, 2013).

In light of such a large availability of technologies and devices, a new theoretical ground is required to foster creativity toward the achievement of common goals of well-being and prosperity. Furthermore, creativity and imagination can enlarge the borders of traditional research areas, thus establishing new domains inspired by collaborative problem-solving (Brian Arthur, 2011; Naam, 2013; Manzini, 2015). There is no need to substitute typical patterns of vertical research, rather we need to implement new cognitive habitats, resulting in shared knowledge and understanding. This is, indeed, the challenge of merging insights from the Anthropocene and Digital Revolution: leveraging a fast-growing demand for innovation in research border areas. These "cross-cutting fields" – as named in sciences – may generate unprecedented living conditions (Tagliagambe, 1997). The "cross-cutting fields" can produce new objects, new spaces and new behaviours, addressing anthropogenic habitats in which biotic systems interact with abiotic ones. This will establish a new leading position to which humans will commit: the «designer's role [*is evolving*, Ed.] as manipulator and carer of processes - considering both biotic and abiotic factors as equally engaged in shaping environment» (Cantrell and Holzman, 2016). This is, in a nutshell, the cognitive ground of Ecological-Thinking.

Ecological thinking and heuristics as paradigms for approaching cross-cutting fields in design theory

The awareness of living in a complex, inter-connected world has led to define new scientific fields of study. These are no longer limited to single disciplines; rather new fields are inspired by an epistemological approach rooted in the exceptional role of digital culture and data management; the latter produce a creative and pervasive framework of action. Acceptance of new fields allows to overcome the "obsolescence" of deterministic sciences (as per Bateson's terms), and to achieve advances and the integration of new fields, such as «the systems theory, the cybernetics, the ecology and the Gestalt psychology» (Bateson, 1978).

From this starting point, Ecological Thinking seems to be the proper experimental ground to develop new approaches. Ecological Thinking allows to develop design methods that provide effective and integrated knowledge that can shape the anthropogenic environment. We primarily refer to the term "Ecological Thinking" as this «seeks to eliminate the traditional dichotomy separating humanity (as subject) and nature (as object) as a route to understanding diverse, complex, multiply interconnected milieu»[3] (Code, 2006). Based on this definition, the key point for introducing Ecological Thinking among design fields is the idea of «Adaptation, appropriation and flexibility […] as the hallmarks of "successful" systems» (Reed and Lister, 2014). Moreover, ecological thinking moves ecology «away from classical determinism and the reductionist Newtonian […], in favour of more contemporary understanding of dynamic systemic change and related phenomena of adaptability, resilience and flexibility» (Reed and Lister, 2014). Additional outcomes of assuming ecological-thinking into the design method are further access codes to understand emerging socio-technical contexts, such as our contemporary milieu, that is «the site, habitat or medium of ecological interactions and encounter» (Code, 2006).

This insight is inspired by a complete revolution of the point of view, which is now centred on reducing the extreme specialisation and strengthening tolerance to contextual constraints (Lazlo, 1985), and on the technique known as "Muddling Through". This is specifically designed to investigate contextual (and progressive) changes of complex *milieu*, and it is based on both incremental progresses and small, pondered steps. Muddling Through has proven to be more

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convenient than tackling problems in one single step (Flatch, 2012). In the framework of the Design X experience, Donald Norman, of the Design Lab of the University of California, San Diego, underlines that changes in the operating pace of design processes accommodate indeterminacy and complexity as key points of design thinking: «with sociotechnical systems, it is seldom possible to follow the Independence Axiom: two-way or even n-way interdependencies are common. Moreover, these interdependencies are often unknown, discovered only after the fact»[4] (Norman and Stappers, 2016).
These advances are not limited to the design discipline, rather they define a fertile ground of innovation for many research fields, including social sciences and ecology. The "muddling through" technique is indeed similar to the trial-and-error mode (typically used in the digital culture) and to adaptation strategies of biological systems. In both cases, processes are based on incremental steps of opportunistic behaviour, which select potential solutions based on a "Darwinian evolution" of ideas (Naam, 2013).
Such cognitive patterns directly refer to the heuristics, which are, by definition, a tactical approach to problem-solving (Dale, 2015). The heuristic approach allows to overcome the ambitious goal of the "exact solution", which is somewhat aprioristic; while orienting cognitive processes toward potential solutions (or scenarios) that emerge from the process itself. Furthermore, the heuristic approach evokes terms, such as "plural" and "collaborative", whose practices also take advantage of digital technologies, and involve users in handling large data sets that describe local and site-specific habitats[5]. Access to digital tools - mainly those that embed sequences of sensing, visualisation, processing and returning feedback - moves projects beyond the borders of conventional design methods. It highlights an unprecedented capacity to forecast science-based scenarios, which feature new relations between users, technologies and nature (Cantrell and Holzman, 2016). The opportunity to monitor and adjust designs applies throughout the life cycle of projects, and makes projection tools suitable for managing the evolving nature of sites.The heuristic approach also activates collaborative processes, continuously involving different stakeholders in design, who can participate by defending their theories, while sharing embedded abilities and providing training about them.

New methods/ new processes/ new projects

The scenario proposed so far requires a different vision of the forthcoming future (Naam, 2013; Floridi, 2014; Di Biase, 2016). Work carried out by leading research centres, reviewed in the last section, shows the importance of introducing ecological thinking and the heuristic approach as scientific methods. Among research centres, it is worth mentioning the most trendy within the scientific community. First, the Institute for the Future (IFF), Palo Alto, California, which implements "narration" as a further research field. Second, the Santa Fé Institute (SFI), New Mexico, which merges deterministic and creative approaches with a view of tackling complexity as a primary research topic. Third, the Ann Wrigley Global Institute of Sustainability – a private branch of the Arizona State University – which particularly focuses on use-inspired research to advocate for sustainability, particularly in urban areas. Last, but not least, in Europe, the Institute for Advanced Architecture of Catalunya (IAAC), Barcelona, Spain, which works on collective urban design practices, whereby communities are key elements for problem-solving, and it applies digital technologies to facilitate knowledge transfer.
These leading institutions are characterised by a common interest in investigating multidisciplinary research areas with the aim to push the frontier of scientific knowledge. In order to achieve this goal, all these institutions share the view that education is a key field of action for expanding social empowerment and envisioning a sustainable future.
Altogether, three main elements emerge[6]:

- a growing interest in merging biotic with abiotic systems;
- the need to adopt collaborative design methods as "muddling through" practices;
- the need to implement digital technologies into design practices.

The IFF working philosophy posits the idea that non-deterministic creativity is an agent of innovation, ensuing selected "data points" and "signals of change" that serve as indicators of future socio-technical trends. Focus is on forthcoming lifestyles and on their high dependence on emerging technologies. The IFF philosophy emphasises both trial-and-error and self-education as collective attitudes for enhancing problem solving and defining the borders of research fields (www.iftf.org/home/) (Fig. 1).
Similarly, the vision of the Santa Fè Institute for Complexity moves beyond the rational-deductive approach (usually based on *a priori goals*, as in linear models), to leverage new cognitive patterns based on collaborative processes. In such patterns, every participant incrementally negotiates goals and results within the process itself (https://www.santafe.edu/; Flatch, 2012). Innovation applies to both research topics and to the model adopted. In the introduction to one of the basic courses of the Institute, participants are required to learn about «dynamics, chaos, fractals, information theory, self-organization, agent-based modeling, and networks. [*Students*, Ed.] also get a sense of how these topics fit together to help explain how complexity arises and evolves in nature, society, and technology». Courses do not require specific expertise, such as science or math background; rather students are expected to show «an interest in the field [*of complexity*, Ed.] and the willingness to participate in a hands-on approach to the subject» (https://www.santafe.edu).
Complexity and peer-to-peer collaboration also feature among the activities sponsored by the Julie Ann Wrigley Global Institute of Sustainability (ASU Wrigley Institute). In particular, the activities

focused on the advances in education and business opportunities for an urbanising world. In this case, the attention is mainly devoted to the evolution of the natural environment. The concept of sustainability is cast within adaptive and systemic processes promoting education, biodiversity, long-term ecological research, politics and economics (https://sustainability.asu.edu/about/). This approach emphasises the interaction of social, technological, and ecological domains in the transition towards sustainability, and the merger of socio-ecological and socio-technical systems.

Direct outcomes of this approach are also found in the projects of the IAAC, many of which are funded by EU research programmes. Education and digital culture are drivers for understanding the complex socio-technical environment of contemporary cities. Project typologies are not scale-dependent; thus they can accommodate both top-down and bottom-up initiatives, as inspired by adaptation practices and data management. Like in the ASU Wrigley Institute, also in the IAAC vision, education plays a key role in enabling local communities to manage complexity on their own, capitalising on cognitive abilities and emerging knowledge embedded within the community itself. The value added of the IAAC experience is in the implementation of collaborative digital platforms. These are devoted to projects, specifically designed for improving skills and knowledge of non-expert users. The stream of actions aims at empowering the community, and defines virtuous circles that help governing sustainability locally, while boosting social awareness.

Additional applications of heuristics within ecological thinking are in landscape design, which has discussed the importance of the systemic approach in shaping the environment since its theoretical foundation. In this area, the main scientific advance is the concept of "emergent ecologies", that is «the combination of intentional and unintentional futures shaped by ecology and human intervention» (Cantrell and Holzman, 2016). The term was first used in the title of James Corner's and Stan Allen's proposal to the 1999 Downsview Park Competition in Toronto. The project offers a paradigmatic example of indeterminacy as a part of the design outcomes, in which forms and performances strive to adapt to the new specific ecosystem, populated by humans and their socio-technical features[7](Corner and Allen, 2001).

The concept of "emergent" has also inspired a number of experiences with collaborative design. An example is the "Urban Circulatory System" project, which is founded on ecological thinking, and aims at empowering informal fragile communities in Brazil by improving their sanitation systems. The project has explored the potential of low-tech design to generate "emergent communities". Here, the combination of living-machines and collaborative design has driven small-scale actions that made people aware of how to manage the sewage remediation system, making users active subjects in the design proposal.

The heuristic approach also informs the New York competition "Re-Built by Design", which specifically calls for integrated solutions to reduce climate change risks. One of the five design teams involved, led by Kate Orff, presented a project titled "Living Breakwaters", which represents a clear example of collaborative design to achieve multiple objectives within a single design proposal (Rigillo & Tolla, 2016). The project aims at generating new marine habitats through the application of innovative concrete blocks built with oysters and other biological elements. These hybrid materials are used as seeding to support the new marine habitat. The Living Breakwaters project will reduce flood risks, restore habitats, and provide social education and urban renewal. Also in this case, education is a key part of the project, which mediates the transfer of technological innovation (both products and process) with the social awareness of the ecological potential of the coast.

Common marks (in form of conclusion)

The application of ecological thinking and of the heuristic method brings about major advances in design, especially in terms of the nature of creative processes, social education and enhanced anthropogenic environments. The new research fields result from a growing awareness of the need for specialised and generalist scientists to work together (Lazlo, 1985). This collaboration highlights concepts, such as socio-technical environments, emergent ecologies and responsive ecologies. These are new frontiers for shaping the environment, which allow to consider both biotic and abiotic systems in the design process. More reactive and responsive performances, as required by the anthropogenic environment, will enhance the heuristic method as the proper cultural framework, where the conventional dichotomy between artifice and nature disappears. Similarly, pairs such as "high tech/low tech", or "global scale/local scale", or "Big Data/on-field data" have lost their inherent traditional opposition, and become part of new integrated strategies to design sustainability.

In this framework, the socio-technical-ecological systems are recognised as cognitive structures allowing to better understand interfaces and interactions between different systems. They are effective means for developing new research areas, which facilitate the emergence of the risk of uncertainty (Ahlborg *et al.*, 2019).

Incremental design and the "muddling through" strategies involve the use of heuristic methods. In turn, these provide a new cultural model, which allows for the emergence of the wide potential of collaborative practices. Here the term "collaborative" is not meant as a mere substitute of "participative" (as per the Latin etymology of the term, collaboration results from *cum*, which means with, together, and *laborare*, labour, to work). Collaboration, in this sense, can be intended as a practice of responsible sharing, which contributes to create an updated "sense of community". Examples are co-working and co-housing experiences, which demonstrate a widespread adoption of collaborative dimensions within current lifestyles. Peo-

ple do share not only physical spaces, but also perspectives and expectations. The implementation of such design methods implies assigning growing importance to education, such as life-long training on technological and social advances. Education emerges as a key element for improving the ethical dimension of the human technical power on the environment. The concept of "culture of limits" (Dierna, 1994) anticipated this perspective.
Collaborative design is also meant to be an attitude, geared towards renovating the problem-solving approach through dialogue among stakeholders and common experiences and expertise in the form of embedded knowledge. The semantic renewal of the concept of "collaborative" within design processes calls for an active engagement of users and communities. Stakeholders should configure innovative solutions of co-production and co-government, encompassing material and immaterial dimensions in cognitive and operational terms.
Finally, the findings of ecological thinking operationalise the notion of "emergent" as a tool to understand new habitats and communities shaped by the project. The term hinges around the two dimensions of potential and unpredictability, which result from the complexity of the current socio-technical and environmental *milieu*. The term "emergent" considers digital aptitude as opportunity for implementing the design ability to sense and respond to natural processes. The "emergent" represents the cognitive (and operational) tool for applying a new ethical view, to shape the Anthropocene as our current era.

NOTES

[1] See the 1966 exhibitions "*9 Evenings: Theatre and Engineering*", and the 1968 "*The Machine as seen at the End of the Mechanical Age*" and "*Cybernetic Serendipity*", respectively held at the MOMA, New York and at the ICA, London, United Kingdom (Gere, 2004).

[2] We refer to the Alba Rabbit made by Eduardo Kac with the scientists Louis-Marie Houdebine e Patrick Prunnet, the series titled *Plastiglomerate* by the sculptor Kelly Jazvac with the geologist Patricia Corcoran and the oceanographer Charles Moore, the video *Think Evolution #1: Kiku-ishi (Ammonite)* by Aki Inomata.

[3] Similarly, Felix Guattari: «Ecology must stop being associated with the image of a small nature-loving minority or with qualified specialists. Ecology in my sense questions the whole of subjectivity» (Guattari, 1989, pp. 52).

[4] «These designs satisfice rather than optimize, and are related to the techniques of making progress by "muddling through"» (Norman and Stappers, 2016).

[5] Design process has strongly implemented its capacity of feedbacking the temporal and spatial evolution of the project, thanks to initiatives as crowd sourcing and crowd sensing, by which people comes into play and works as a virtual community for sharing and generating knowledge at the site scale.

[6] The analysis has been conducted through the review of the products feeding the dissemination areas of the institutional web-sites of the centres.

[7] Corner and Allen wrote: «We propose […] a matrix of interacting systems […] (where) the park identity will subsequentially evolve and be re-shaped as users inscribe their own traces […] We do not determine or predict outcomes; we simply guide or steer flows of matter and information. Thus we present the park as a precisely engineered matrix, a living groundwork for new forms» (Corner and Allen, 2001, pp.58)

REFERENCES

Ahlborg. H., Ruiz-Mercado, I., Molander, S. and Maser, O. (2019), "Bringing Technology into Social-Ecological Systems Research - Motivations for a Socio-Technical-Ecological Systems Approach", *Sustainability*, Vol.11(7), 2009.

Arthur, B. (2009), *The nature of technology. What it is and how it evolves*, Ed it. *La natura della tecnologia. Cos'è e come evolve*, Codice Editore, Turin, Italy.

Bateson, G. (1978), "Il tempo è fuori squadra", in Bateson G. (ed.), *Mente e Natura*, Adelphi.

Brawnell, B. and Swackhamer, M. (2015), *Hyper-natural. Architecture's New relationship with Nature*, Princeton Architectural Press, New York, USA.

Cantrell, B. and Holzman, J. (2016), *Responsive landscapes. Strategies for responsive technologies in landscape architecture*, Routledge.

Code, L. (2006), *Ecological Thinking: the Politics of Epistemic Location*, Oxford University Press, New York, USA.

Corner J. and Allen S. (2001), "Emergent Ecologies" in Czerniak J. (Ed.), *CASE: Downsview Park Toronto*, Prestel, Munich.

Crutzen, P. and Stoermer, E. (2000), "The Anthopocene'", *Global Change Newsletter*, Vol. 41, pp. 17-18.

Czerniak, J. (Ed.), *CASE: Downsview Park Toronto*, Prestel, Munich.

Dale S. (2015), Heuristics and Biases - The Science of Decision-Making, in *Business Information Review,* Vol. 32 Second Edition.

Di Biase L. (2016), *Homo pluralis. Essere umani nell'era tecnologica*, Codice Edizioni, , Turin, Italy.

Dierna, S. (1994), "Innovazione tecnologica e cultura dell'ambiente", in La Creta, R. and Truppi, C. (Eds.), *L'architetto tra tecnologia e progetto*, Franco Angeli, Milano.

Flatch, J.M. (2012), "Complexity: Learning to Muddling Through", *Cognition, Technology & Work, Vol.* 14 (3), pp. 187-197.

Floridi L. (2014), *La quarta rivoluzione. Come l'infosfera sta trasformando il mondo*, Raffaello Cortina Editore, Milan, Italy.

Gere, C. (2004), "New Media Art and the Gallery in the Digital Age", *Tate Papers*, Vol. 2, available at: www.tate.org.uk/research/publications/tate-papers/02/ (accessed 12 December 2019).

Guattari, F. (1989), Les trois Ecologies, Edition Galilé, Paris, France.

Lazlo E. (1985), "L'evoluzione della complessità e l'ordine mondiale contemporaneo", in Bocchi G. and Ceruti, M. (Eds.), *La sfida della complessità*, Feltrinelli, Milan, Italy.

Linbloom, C.E. (1959), "The Science of "Muddling Through", *Public Administration Review*, Vol. 19(2), pp. 79-88.

Manzini, E. (2015), *Design, When Everybody Designs*, MIT Press Cambridge, USA.

Naam, R. (2013), *The Infinite Resource. The Power of Ideas in a Finite Planet*, University Press of New England.

Norman, D.A. and Stappers, P.J. (2016), “Design X: Complex Sociotechnical Systems”, *She Ji: The journal of Design, Economics and Innovation*, Vol.13, pp.1-24.

Rigillo, M. and Tolla, A. (2016), “Riduzione del rischio e design eco-orientato per il waterfront di N.Y.: il progetto Living Breakwaters” in D’Ambrosio, V. and Leone, M. (Eds.) *Progettazione ambientale per l’adattamento al climate change. Modelli innovativi per la produzione di conoscenza,* Clean, Naples, Italy, pp. 240-248.

Reed, C. and Lister, N.M.(2014), *Projective Ecologies*, ACTAR, Harvard Graduate School of Design.

Tagliagambe, S. (1997), *Epistemologia del confine*, Il Saggiatore, Milan, Italy.

WEB SITES

Institute for Advanced Architecture of Catalunya:https://iaac.net/.

Institute For the Future: http://www.iftf.org/home/.

Julie Ann Wrigley Global Institute of Sustainability: https://sustainability.asu.edu/about/.

Sante Fè Institute: https://www.santafe.edu.

Silvano Tagliagambe: https://silvanotagliagambe.wordpress.com/epistemologia-del-confine/.

Towards urban transition: implementing nature-based solutions and renewable energies to achieve the Sustainable Development Goals (SDG)

ESSAYS AND VIEWPOINT

Valentina Oquendo Di Cosola[ab], Francesca Olivieri[abc], Lorenzo Olivieri[abd], Jorge Adán Sánchez-Reséndiz[ab],
[a] Department of Construction and Technology in Architecture, Universidad Politécnica de Madrid, Spain
[b] Innovation and Technology for Development Center (itdUPM), Universidad Politécnica de Madrid, Spain.
[c] ABIO UPM research group
[d] GEDIRCI research group

valentina.oquendo@upm.es
francesca.olivieri@upm.es
lorenzo.olivieri@upm.es
adan.sanchez@upm.es

Abstract. Cities today are the scene of major problems linked to air pollution, resource consumption, and inequality. The Agenda 2030 for Sustainable Development proposes a roadmap for the transition to more resilient and sustainable city models. This challenge can only be met through systemic innovation, which produces technological, social, environmental, and cultural changes. The integration of nature-based technologies is a tool for the transformation of the current city model. This essay analyses the international context of sustainable development in cities, and the different possibilities for transforming urban space, with the final aim of making a concrete contribution to solutions that guarantee the fulfilment of the Sustainable Development Goals (SDGs), decarbonise the current model, and ensure the participation of citizens in the process.

Keywords: Cities; Nature-Based Solutions; Renewable energy; Sustainable Development Goals; Systemic approach.

Research and innovation to achieve the Sustainable Development Goals (SDG's)

The United Nations ensures a population growth from 55% today to 75% in 2050, which means that vulnerability to the consequences of climate change will increase and there will be a greater need to ensure economic productivity, social inclusion and resilience (Nations, 2015b).

The importance of the social, economic and environmental effects of urbanisation, such as the lack of education and equality in access to services; the gap between the health and well-being of people linked to population growth; the energy consumption and the emissions associated, among others, are evidence of the challenges we face. Against this background, cross-cutting measures are needed, with emphasis on the multi-stakeholder approach.

These challenges are addressed in the Agenda 2030 through the 17 Sustainable Development Goals (SDGs) (Nations, 2015a) and the Paris agreement, in which members of the United Nations have developed a framework for action and international cooperation to achieve sustainability through a systemic approach that encompasses prosperity, people, the planet, peace, and partnerships. This will require profound changes and the participation of all sectors of society: governments, universities, businesses and civil society. Jeffrey Sachs, in his work *"Six transformations to achieve Sustainable Development Goals"*, argues the importance that SDGs have over global development, and how the goals set can achieve a complex model beyond mere objectives. However, for this to happen it is necessary to promote deep structural changes (Sachs *et al.*, 2019).

Along these lines, on 3 December 2013 the Horizon 2020 Programme (H2020) was approved, the main source of European funding for research and innovation in the European Union (European Commission, 2014) with a mission-oriented approach. Theorised by Mariana Mazzucato (Mazzucato, 2018), Professor of Economics of Innovation and Public Value at the University College of London (UCL), the approach is based on an innovative policy, which must be oriented towards one or more specific missions, in order to define an ambitious objective and long-term policies.

Sustainability-oriented missions in urban environment will require investments in energy, transport, health, water management, and waste reduction. Cities, because of the complexity involved and the crucial role they play in the transition towards a more desired future, offers an extraordinary opportunity for experimental research based on interdisciplinary approaches, aimed at finding solutions to the complex problems we face.

It is well known that the urban space and the energy model we have must change. In this sense, we should reflect on lines of action that generate visible and permanent changes. On the one hand, the decarbonisation of the current energy model requires holistic approaches to the generation, transmission and use of energy, which is framed by three different levels of action: the substitution of fossil fuels by zero carbon sources (solar photovoltaic, wind, geothermal), energy efficiency in the final use of energy (heating and cooling of buildings and transport) and the electrification of motorised mobility and industrial processes (Irena, 2018). On the other, achieving resilient and sustainable cities requires investment and development of urban infrastructure, services and technologies, in which nature-based solutions can play a key role.

Hence, research through the scientific community plays a key role in this process, as it can take up the challenge of developing, monitoring and quantifying tools, methods and technologies that demonstrate the technical and economic feasibility of certain actions in the medium and long term.

It is, therefore, the aim of this paper is to define the framework for international action in terms of innovation and sustainable development in cities, and to analyse the lines of action that are being implemented today in the field of nature-based technologies, in order to finally make a concrete contribution to urban space design models that meet the global agenda and demonstrate that the design of isolated actions does not produce a genuine transformation.

Fostering nature and energy values

Urban space is made up of a complex network of actors and elements that require a broad integration approach when thinking about transforming it into a sustainable model. Some authors, such as Tara Mothtadi, call this systemic approach "hedonistic sustainability" (Mohtadi, 2016). Addressing climate change issues will highlight the role of architects and urban planners in shaping the city and building resilience.

Urban space, nature and people are interconnected, which is confirmed by the proven benefits of nature in cities, ranging from mitigating the urban heat island effect, to absorbing sound waves, improving air quality, managing rainwater, increasing biodiversity and reducing carbon emissions. In addition, they provide psycho-

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perceptual benefits that improve people's well-being and health (Lee *at al.*, , 2015).
Considering that cities must work to mitigate climate change and, at the same time, taking into account the relationship with the urban landscape and citizens, it is necessary to devise solutions that provide cross-cutting values, such as nature-based solutions and the use of renewable sources.

Green infrastructure

The changes that cities are undergoing today mean that Nature-Based Solutions can have a fundamental role to play through the implementation of green and blue infrastructures, due to their capacity to restore ecosystems and at the same time provide benefits to society.
In 2015 the European Commission published the report "Towards an EU Research and Innovation Policy Agenda for Nature-Based Solutions and Re-Naturing Cities", a document that presented the opportunities for innovation and research in the use of nature as an instrument for urban planning for sustainability. This highlights the growing value that nature has acquired in facing the environmental, social and economic challenges we face, defining them as «solutions inspired and supported by nature, which are cost-effective, provide simultaneous environmental, social and economic benefits and help build resilience» (European Commission and Union, 2015).
The term Nature-Based Solutions (NBS) arises through the concept of ecosystem, used by the scientific community since 2000, considered as a tool to solve social and environmental problems. Through the European Commission's new approach, the economic dimension is increasingly part of this concept, thus becoming part of European policies and strategies based on biodiversity conservation, climate change adaptation, natural disaster reduction, and human well-being (Lafortezza and Sanesi, 2019).
The quantification and evaluation of the benefits provided by the NBS to address the challenges we face is part of current research. It is important to identify not only benefits and costs, but also interactions with social, cultural, economic, biodiversity and climate factors. Cities, therefore, need to be rethought through sustainable planning that takes into account these complex interactions. Under this approach, NBS can be seen as a technological innovation focused on nature and on the objective of improving the natural capital of cities (Frantzeskaki, 2019).

Energy infrastructure

To achieve the main objective of decreasing the temperature of the earth below 2 ºC in relation to the pre-industrial levels fixed by the Paris Agreement, renewable energies must develop six times faster than what has been done so far.
The urban model is the inflection point on which the parameters, dimensions, and methodology necessary for a large-scale energy transition can be established, allowing the current energy model to be modified.
The concept of the energy transition, in addition to being technological, places the citizen at the centre of the system, transforming his or her role as a passive consumer into an active actor, capable of rationalising, self-producing and managing his or her energy needs. This transition must consist of aligning public policies with private investments in a framework of cross-cutting action.

The growing role of cities in climate action

The introduction of sustainable solutions in cities depends largely on new models of governance, through which innovation is encouraged, whether through long-term funding programmes in collaboration with businesses; the creation of an economic framework; or the monetisation of the benefits offered by nature.
Some indicators such as: the rate of growth of jobs related to green infrastructure; access to energy from renewable sources; the percentage of total surface area of green spaces; reduction of the rates of insecurity linked to the recovery of degraded spaces; levels of population exposed to outdoor air pollution; waste water treatment; the proportion of renewable energy produced and investment capacity, can be public policy instruments for quantifying the effectiveness of these solutions.
The value of green infrastructure and the reconfiguration of the current energy model are increasingly recognised by civic authorities and local citizens. Evidence of this is the growing number of local, national and international initiatives for the sustainable use of natural capital in urban areas, among which some priority lines of action have been developed, linked to the points listed below.

- Enhancing sustainable urbanisation through new technologies and business models: sustainable urban planning requires the development of technologies focused on human well-being and public health. An example of this is green roofs, which are capable of providing benefits in reducing energy consumption, contributing to rainwater management, reducing the urban heat island effect, creating opportunities for work and social interaction, as well as improving public health (Xing, Jones and Donnison, 2017).
- Restoring degraded ecosystems by environmental restoration: as a result of human activities, some ecosystems have been degraded or lost, especially due to air and soil pollution, the modification of water bodies and the intensity of forestry practices, resulting in the interference of the functions that nature exercises in urban environments such as water purification, carbon sequestration, flood and drought prevention, among others (Kabisch *et al.*, 2016).

  Some NBS, such as Sustainable Urban Drainage (SUD), can contribute to flood mitigation and water quality, as well as reduce the risk of flooding in cities.

Some solutions, such as plant façades, can contribute to generating economic and environmental value. The opportunities to green the grey infrastructure, the design of exterior and interior spaces, the development of business models around spaces, such as urban gardens, can guarantee a positive and multiplying effect in the search for sustainability and urban resilience (Nesshöver *et al.*, 2017).

- Power grid decarbonisation: energy transition must be drawn inside and out from the cities, from their different consumer sectors, buildings, industry, and services. The transport sector is one of the most influential, and the promotion of electrification of mobility can be one of the strategies that can help decarbonisation.

  Some estimates claim that a combination of solar, wind and hydropower by 2030 would capture between 35% and 45% of the sector's total emissions. Therefore, this will not be possible without promoting demand for renewables and energy efficiency through utilities and policymakers (McKinsey Center for Business and Environment, 2017).
- Promote the expansion of distributed renewable energies: solar energy is considered one of the main strategies for sustainability in cities and forms part of only 0.1% of the world's electricity mix. Despite development and innovation, there are still barriers in the renewable energy market, such as lack of legislation, tax incentives and the exhaustion of available areas adaptable to solar energy production.

Photovoltaic technologies are a potential contributor to both small- and large-scale energy in response to the challenges of 2050. Unlike centralised renewable energies, smaller and more distributed installations can be more economical for public services and can be faster to implement. Energy resilience is important, not only at the scale of buildings but also in urban space (Renewable and Agency, 2018).

In the building sector worldwide, heating and cooling accounts for 35% to 60% of total energy demand, and is expected to increase by 70% by 2050, despite the energy efficiency measures that have been implemented. Several opportunities, such as Building Integrated Photovoltaics (BIPV), offer the possibility of reducing emissions from buildings (Kiss, 2012).

Building the urban transition: the holistic aspect of urban space

A great deal of the scientific research developed so far has focused on identifying the causes of urban social inequality and the unsustainability of the current urban model, and on understanding the connections between these problems.

While certain tensions in cities are considered to be connected, the loss of biodiversity, air quality, the impact this has on water quality, climate, and human health, are part of a chain of consequences that lead us to reflect on the need for holistic and cross-cutting solutions that can address these interconnected problems.

We are convinced that NBSes are a tool that can contribute to the improvement of urban environments in vulnerable neighbourhoods. Among other ways, through citizen participation and attention to the specific needs of disadvantaged groups. Evidence is provided by the European project CLEVER Cities, which proposed the rehabilitation of an area of the city of Madrid through the creation of "habitable itineraries" in the Usera neighbourhood.

Similarly, projects such as Nature4Cities, Naturvation, or Think Nature, investigate the new political and economic models of NBS to provide evidence at European level of the scalability potential of NBS, as well as to provide a sound assessment framework for spreading the value of nature in cities. Such projects contribute to synthesising current knowledge and influencing local and European policies towards more sustainable and resilient cities.

Likewise, if we look at the field of renewable energies, nowadays there is a significant disproportion between population density, the energy intensity this entails, and the surfaces available for the installation of technologies, such as solar photovoltaic. This scenario raises the question that beyond the installation of systems on roofs and façades, it is necessary to promote another type of innovation and technology in the field of distributed energy offering alternatives to the current market under the premise of more production and efficiency with less surface area.

The incessant growth of the cities requires a commitment to the development of new systems that can be adapted to the territory, not dependent on the surface area of the buildings, and which can also offer different systemic and transversal solutions, including light, urban furniture, charging points for electric vehicles, contact with nature, and recovery of the sense of belonging to a community.

The design of complex and interconnected urban spaces that have solutions based on nature and energy production technologies from renewable sources can become tools, among many others, capable of activating a series of social, ecosystemic and economic mechanisms and processes, valuable for the transformation of the cities of today and tomorrow.

Addressing the current complexity of urban spaces requires the definition of spaces that, on the one hand, define strategic actions in cities, and on the other, involve cross-cutting solutions to address current challenges. Considering the city as an ecosystem allows us to achieve models of efficient, complex, interconnected, and socially cohesive cities.

Conclusion

This study reflects on distinct aspects that characterise the current urban scenario. It starts with the awareness that urban settlements have the most important environmental impact in terms of energy consumption, natural resources, and CO_2 emissions. For this reason the challenge of climate change must be met by promoting economic, social, environmental, and political initiatives, involving society and government in co-creation models aligned with the SDGs. Through this work, the aim is to provide a strategic and interdisciplinary vision in the transformation of urban space, giving rise to concrete actions focused on processes of an ecosystemic and social nature.

The creation of an innovative model requires the creation of spaces for debate and consultation processes that are the basis of collaborative design. This requires, on the one hand, promoting solutions compatible to achieve zero net emissions, preserve biodiversity, and improve citizens' well-being in the short term. On the other hand, it is necessary to promote the integration of renewable energies through innovative technologies required to reduce emissions. As architects, we are called upon to promote urban planning approaches that allow citizens to enjoy the benefits and services that nature offers, without prejudice to the environment.

Indeed, one of the main challenges of our time is to achieve sustainable urban ecosystems. Although much progress has been made in recent years, we can consider that we are only at the beginning of a long journey. In this sense, the study supports the hypothesis that the combination of nature-based solutions and renewable energy production technologies can give rise to integrated urban spaces, potential activators of social, ecosystemic, and economic processes functional to the transformation of today's and tomorrow's cities.

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REFERENCES

European Commission (2014), "Horizon 2020", available at: https://ec.europa.eu/programmes/horizon2020/en.

European Commission and Union (2015), *Nature-based solutions & re-naturing cities. Final report of the horizon 2020 expert group on 'Nature-based solutions and re-naturing cities'* (full version), Brussels.

Frantzeskaki, N. (2019), "Seven lessons for planning nature-based solutions in cities", *Environmental Science and Policy*, Vol. 93, pp. 101-111.

Kabisch, N. *et al.* (2016), "Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action", *Ecology and Society*, Vol. 21 (2), p. 39.

Kiss, G. (2012), "19 - Solar energy in the built environment: powering the sustainable city", in Zeman, F.B.T.M.S. (Ed.) *Woodhead Publishing Series in Energy*. Woodhead Publishing, pp. 431-456.

Lafortezza, R. and Sanesi, G. (2019), "Nature-based solutions: Settling the issue of sustainable urbanization", *Environmental Research*, Vol. 172, pp. 394-398.

Lee, A.C.K., Jordan, H.C. and Horsley, J. (2015), "Value of urban green spaces in promoting healthy living and wellbeing: Prospects for planning", *Risk Management and Healthcare Policy*, Vol. 8, pp. 131-137.

Mazzucato, M. (2018), *Mission-Oriented research and Innovation in the European Union*, Brussels.

McKinsey Center for Business and Environment (2017), "Focused acceleration: a strategic approach to climate action in cities in 2030".

Mohtadi, T. (2016), "The Complementarity of Improving Quality of Life and Reducing Environmental Footprints in Urban Spaces: The Argument of 'hedonisitic Sustainability'", *Consilience*, Vol. 16(1), pp. 20-22.

Nations, U. (2015a), *Sustainable Development Goals (SDG)*.

Nations, U. (2015b), *Transforming our world: The 2030 agenda for sustainable development*.

Nesshöver, C. *et al.* (2017), "Science of the Total Environment The science, policy and practice of nature-based solutions: An interdisciplinary perspective", *Science of the Total Environment*, Vol. 579, pp. 1215-1227.

IRENA (2018), *Opportunities to accelerate national energy transitions through enhanced deployment of renewables (Report to the G20 Energy Transitions Working Group)*, International Renewable Energy Agency, Abu Dhabi.

Sachs, J.D. *et al.* (2019), "Six Transformations to achieve the Sustainable Development Goals", *Nature Sustainability*, Vol. 2(9), pp. 805-814.

Xing, Y., Jones, P. and Donnison, I. (2017), "Characterisation of nature-based solutions for the built environment", Sustainability (Switzerland), Vol. 9(1), pp. 1-20.

Urban retrofit of the Leipzig-Grünau District. A screening LCA to measure mitigation strategie

ESSAYS AND VIEWPOINT

Elisabetta Palumbo[a], Monica Rossi-Schwarzenbeck[b], Marina Block[c], Marzia Traverso[d],
[a] Institut für Nachhaltigkeit im Bauwesen, RWTH Aachen University, Germany
[b] Institut für Hochbau, Baukonstruktion und Bauphysik, HTWK Leipzig University of Applied Sciences, Germany
[c] Department of Architecture, University of Naples Federico II, Italy
[d] Institut für Nachhaltigkeit im Bauwesen, RWTH Aachen University, Germany

elisabetta.palumbo@inab-rwth-aachen.de
monica.rossi@htwk-leipzig.de
marina.block@unina.it
marzia.traverso@inab.rwth-aachen.de

Abstract. The work proposes and verifies an integrated approach to the redevelopment of the disadvantaged Grünau district in Leipzig, combining microclimatic mitigation strategies on buildings and urban scales with Life Cycle Assessment screening. The application of the LCA showed that, compared to an increase in the impact of retrofitting solutions, the strong reduction of energy consumption (-58%) during the use stage leads to an overall decrease of the total GWP. Nonetheless, some major issues connected to occupant comfort were not totally captured by the environmental dimension. Consequently, it is crucial to develop new approaches and schemes based on combining LCA with other appropriate performance criteria in order to more broadly assess the sustainability of a district.

Keywords: City transformation; Urban retrofit; Life cycle assessment; Environmental impacts; Outdoor and indoor comfort level.

Achieving an environmentally friendly and habitable urban district

Climate change can have devastating consequences. To mitigate them we must start drastically reducing anthropological greenhouse gas (GHG) emissions. Many studies (Birgea and Bergera, 2019; Albino *et al.*, 2015) point to cities as one of the main contributors to climate change. While their sprawl only covers 2% of the world's landmass, urban areas are the leading hotspots of resource usage and environmental impact (Lotteau e*t al.*, 2015). Around 70% of global primary energy is consumed by urban areas, accounting for over 70% of global CO_2 emissions (Mauree *et al.*, 2019). Furthermore, more than half of the world's populations live in cities, and this figure is expected to grow in future decades due to rapid urbanisation and to the increase in populations migrating from rural to urban societies (Xu *et al.*, 2019). However, cities can also become sites of environmental efficiency and have the potential, through energy, building, mobility and planning mitigation strategies, to reduce major GHG emissions and energy consumption (Milhahn, 2019).

As a result, the United Nations has periodically debated the need for urban planning activities to explore new models and integrated growth strategies for a resilient environment. In 2016, the New Urban Agenda was collectively adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III), as a contribution to the application of the 2030 Agenda for Sustainable Development. Its purpose was to consider the multiple impact levels of urban areas and their short and long-term consequences with a view to achieving a sustainable environment, a competing economy and a better quality of life (Milojevic, 2018). Consequently, many German cities have developed new initiatives in an attempt to enhance their adaptive and urban resilience abilities. One of these cities was Leipzig, which since 2016 has updated the concept of integrated urban development through the 2030 INSEK-Leipzig plan, encompassing the idea of sustainability. While developing this plan, the Grünau district was identified as one of the most disadvantaged areas of the city, having heavily suffered the consequences of population decline resulting from German reunification, which left the neighbourhood with half of its pre-reunification population (Stadt Leipzig, 2016).

The crucial issues that need to be addressed to make this district sustainable are principally those concerning the ageing of buildings, along with rising environmental and energy-related values and improving the urban quality.

As a result, our study first analyses the main issues at the urban scale and proposes several mitigation strategies that seek to enhance the sustainability of the district. Accordingly, with the aim of evaluating the suitability of the defined urban retrofit strategies, the Life Cycle Assessment (LCA) methodology was applied at two different scales. While LCA was used to conduct quantitative assessments of buildings in order to identify and measure the environmental impact produced over the course of their entire life cycle, its application at urban level is so far limited and being studied by LCA specialists (Lotteau *et al.*, 2015; Palumbo *et al.*, 2019). A secondary objective of the research was to identify whether this method could provide strong scientific grounds to evaluate the environmental issues of urban districts.

Description of the case study: issues at district and building scales

After a period of depopulation following the German reunification, Leipzig is currently the city of the former GDR with the highest population growth. This trend leads to an urgent need for new housing and the redevelopment of existing buildings. A district particularly affected by this phenomenon is Grünau. This working-class neighbourhood was built between the 1960s and the 1980s with 38,000 housing units for about 85,000 inhabitants. Therefore, Grünau has big potential for urban and housing development and has been the focus of several studies and integrated development plans.

In order to identify the principal issues of this district and to develop some appropriate mitigation strategies, several analyses and measurements at district and building scale have been carried out.

Four-lane streets divide Grünau into "green pedestrian islands", where there are large residential buildings. Noise analyses (Fig. 1) have shown that the main sources of noise are vehicle traffic as well as tram and metropolitan trains. Air quality surveys, conducted by the municipality of Leipzig, have shown that the values of air pollution (in particular PM10 and PM2.5, NO, NO_2, SO_2 and volatile organic compounds like benzene toluene/xylene) are higher near the main roads but in any case below the maximum permissible values. In order to evaluate the microclimatic conditions of the site,

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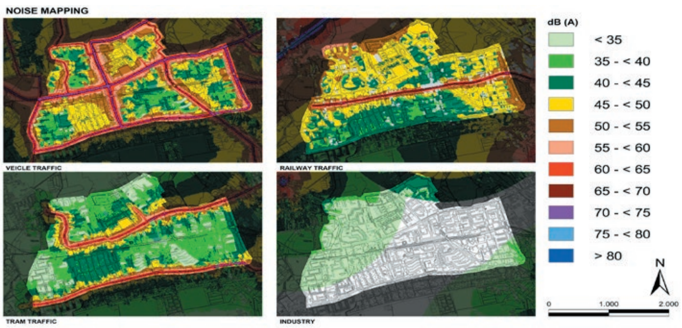
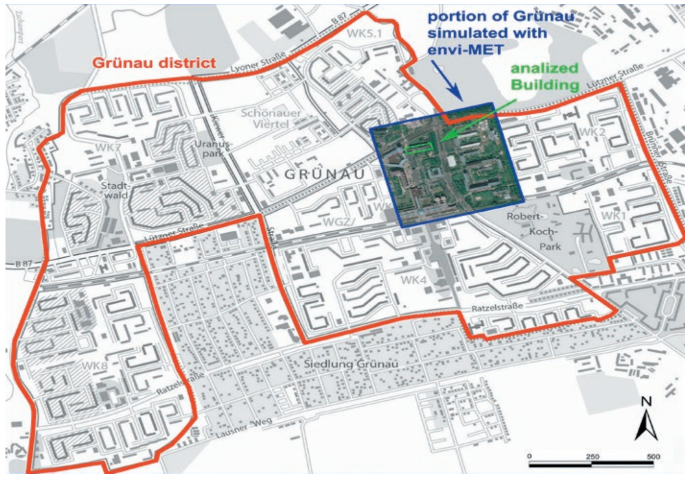
01 | Noise mapping, showing the different forms of noise

02 | Identification of the analysed areas

01 |





| 02

the climatic data of the last 30 years was generated with the software Meteonorm and verified with that of local meteorological stations. Based on these values (station and interpolated data), hourly values for a "typical meteorological year" and a "representative summer and winter day" were calculated with Meteonorm using a stochastic model, resulting in a climate data input file for the simulations. These analyses have shown a constant increase in temperature and humidity during summer months and the intermediate seasons over the last 15 years. Analyses of the shading of the buildings as well as of the outdoor spaces are carried out through the elaboration of solar diagrams. The comfort level of the outdoor spaces was simulated with ENVI-met, a three-dimensional non-hydrostatic computational fluid dynamics software for analysing interactions between buildings, surfaces, plants and air within urban environments. The part of the district chosen for the environmental simulation measures 500x500 metres and is quite heterogeneous in order to assess different situations, such as a road with heavy traffic, multi-story residential buildings and green areas, among others (Fig. 2). The outdoor comfort conditions in the districts were simulated for two separate days: one in summer (21st June - summer solstice) and one in winter (21st Dec. - winter solstice) as these are the days with the lowest and the highest level of sun radiation. The simulations calculated a period of time from 6:00 a.m. to 6:00 p.m. The analysed microclimate parameters are: air temperature [K], relative humidity [%], wind velocity [m/s], wind direction [deg], surface temperature [K] at the building surfaces and the ground flooring. The analysed comfort parameters are: physiologically equivalent temperature (PET), Predicted Mean Vote Index (PMV), Predicted Percentage of Dissatisfied Index (PPD), and Universal Thermal Climate Index (UTCI).
The simulation results (Fig. 3) show the values of PMV and PPD on 21st June at 2:00 p.m. (the "longest day" at the "hottest hour"). The figure highlights that in summer, especially in areas that are directly exposed to the sun, there are situations of discomfort and that the presence of greenery (lawn) is not sufficient to mitigate the increase in temperature due to climate change in recent years.
Following a detailed analysis of all the above mentioned environmental parameters, it was found that the discomfort phenomena, measured with PMV and PPD values, derive mainly from direct radiation and low air movement. In fact, the operating temperature is not extremely high (max 26 °C) and the relative humidity is acceptable (average value of 45%).
The objects of this study at the building scale are two 11-storey blocks (48 m long and 33 metres high) built with mass-produced prefabricated concrete panels based on a regular grid and located in the Grünau-Mitte district (Fig. 2, 4). The analysis of their building characteristics and energy efficiency (using onsite tests and thermography surveys) showed inadequate energy efficiency (poor thermal insulation, inefficient solar shading and presence of thermal bridges), acoustics and fire protection.

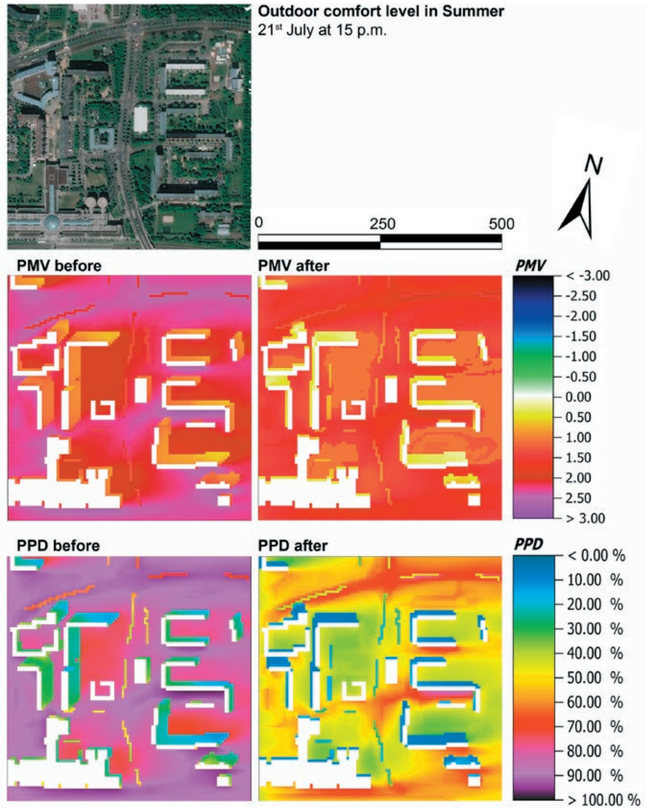
The mitigation strategies adopted

On the basis of the highlighted issues, mitigation strategies were identified to improve the level of outdoor comfort and building quality (Fig. 5).
Urban-scale strategies were based on an overview of the whole district, seen in its complexity (Rossi, 2017).
In order to improve acoustic comfort, the installation of green acoustic barriers or evergreen trees near main roads is planned. These barriers, in addition to limiting noise, help to improve air quality, reduce pollution, provide shade and enhance the local outdoor comfort level with increased humidity through evaporation. To reduce the heat island effect, mainly occurring in the square in front of the shopping mall, the use of appropriate cool paving materials and solar shading systems, such as sun sails, has been planned. Public lighting, at times poor and inefficient, will be replaced with high efficiency LED lamps, and limited accessibility will be improved through the redevelopment of pedestrian paths and the construction of ramps.
The ENVI-met simulations (Fig. 3) show how mitigation strategies at the urban scale (Fig. 5) significantly improve both the PMV-index and the PPD-index.
At the building scale, the intervention strategies aim to complete the previous renovation project through work on the systems and on the envelope to improve the general energy efficiency conditions. In order to reduce significant energy losses caused by obsolete concrete panels and single-glazed wooden window frames in the envelope, the window frames will be replaced with double-glazed and thermal-cut PVC frames, and mineral wool thermal insulation (10 cm thick) will be attached to the outside walls.

03 | Analysis of the outdoor comfort level in summer before and after the application of mitigation strategies

04 | BIM-Model of the analysed building with information on its energy efficiency. Issues and mitigation strategies at district and building scale

| 03

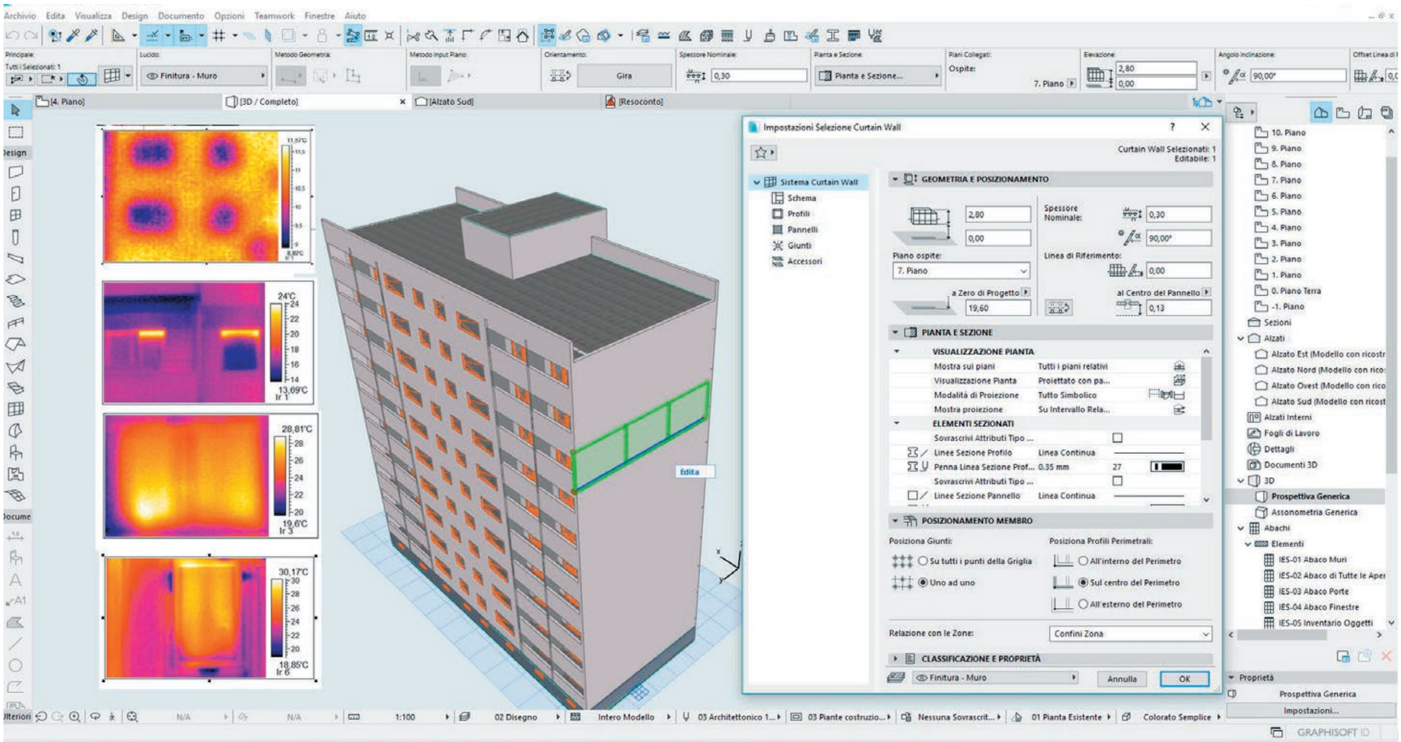


The use of high efficiency LED lamps and appliances should reduce energy consumption, while the inclusion of rainwater recovery systems and renovation of the sanitary water system will reduce water consumption.

Investigating sustainability in an urban retrofit with a life cycle approach

With the intention of properly assessing the effectiveness of the retrofitting solutions proposed in Grünau from a sustainable development perspective, it was decided to apply LCA. The LCA excels as a methodology capable of measuring sustainability as it is the most reliable framework for verifying the potential environmental impact of a product (Schlanbuscha *et al.*, 2016), in addition to being standardised by ISO 14040:2006 and 14044:2018, and more specifically for buildings and construction products by ISO 15978:2011 and EN EN15804:2012+A2:2019. In recent years, LCA has been increasingly recognised and used by several stakeholders in various economic sectors, also becoming a reference methodology to support policy decisions. In the EU context, the Single Market for Green Products (EC, 2013) or the EU Better Regulation Toolbox (EC, 2015) are two important community initiatives that reflect this trend (Zampori *et al.*, 2016).
In practice, many Green Building Rating Systems (GBRSs) have developed new planning tools to support the measurement of sustainability at the urban level. Some of them, for instance the German Sustainable Building Council (DGNB Urban Districts), have also implemented the LCA with their own approaches and assumptions to assess environmental performance. As such, approximately 30% of the environmental quality score in the DGNB (UD) depends on the completion of an LCA. However, only the basic performance data of the building, mainly energy, water and waste management, is considered in the LCA.

04 |



05 | Issues and mitigation strategies at urban and building scale

06 | Comparative assessment related to Global Warming Potential (kg CO_2 equivalent) between existing status and mitigation strategies of Grünau in 1 year

07 | Comparative assessment related to Global Warming Potential (kg CO_2 equivalent) between existing status and mitigation strategies of Grünau during the entire Life Cycle of the Building (60 years)

The identification of factors that act as significant contributors within the LCA of an urban district is first dealt with by Popovici (2006), and then broadly taken over by the framework developed by Lotteau et al. (2015). Popovici's model considers four main elements of the neighbourhood: buildings, open spaces, network and mobility. However, due to the considerable number of variables and interactions in a district model, a set of adaptations and assumptions is required to make the methodology implementable.

Consequently, this study conducts a screening LCA, following the indications described in the Operational Guidance for Life Cycle Assessment Studies of the Energy Efficient Buildings Initiative (EeB Guide, 2012) and focusing on the environmental dimension. The EeB Guide describes screening LCA as an assessment that provides an approximate evaluation of the environmental performance, with an initial examination of the potential environmental impact. However, the results obtained do not provide detailed information on the environmental performance, nor, according to ISO 14044, can the screening LCA be used to make comparisons.

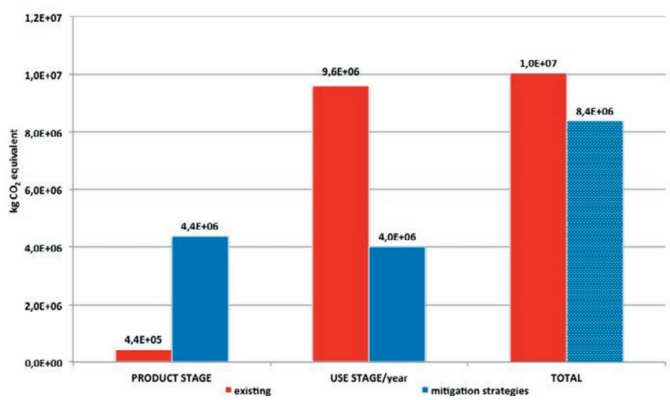
More specifically (Tab.01) the following assumptions were made in this study: i) only five crucial mitigation strategies were assessed; ii) only two stages of the LCA were considered: production and use stage; iii) only one life cycle environmental indicator was evaluated: Global Warming Potential (GWP).

In order to facilitate a comparison between the two LCA scales, the equivalent functional unit (FU) must be specified, defined by LCA criteria as the quantified performance of a product system used as a reference unit whenever a comparison between assertions is made (ISO 14040-14044). Literature highlights the need to adopt a per capita FU (m² of living space/inhabitant) when applying LCA at neighbourhood scale. Nevertheless, the assessment also considers the dimensional aspects of the block located within the area studied and it is evaluated for 60 years in accordance with the European Framework Level(s) (Dodd *et al.*, 2017). Our FU includes precisely 2,700 m² of open area, 28,203 houses with 1,013,603.1 m² of living space and 43,904 inhabitants.

The LCA was approached first at building scale, focusing on the retrofitting solutions proposed: windows and insulation improvements, as well as the reduction of water consumption and heat energy demand. Secondly, the LCA related to the Open Spaces field was carried out, focusing on three mitigation strategies: the installation of green acoustic barriers, the use of high efficiency LED lamps, and the replacement of paving in the square.

The software used to perform the LCA of most of the physical elements was Simapro© and the Ecoinvent database v.3.5 (2019), while the environmental profile of replacing the windows, thermal insulation in the building envelope and cool paving materials was derived through the impact indicators contained in the specific Environmental Product Declarations of manufacturers.

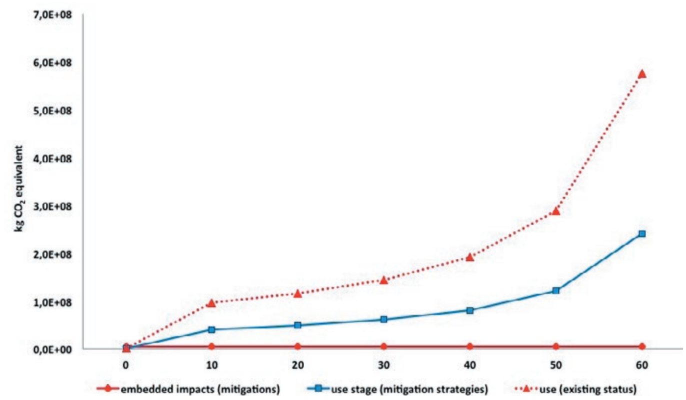
| 06



05 |

	Issues	Mitigation strategies
DISTRICT SCALE	Noise near the train tracks and main roads	- Application of green acoustic barriers - Planting of Tree
	Heat island effect in the square close to the to the shopping mall	- Replacing the flooring
	High PMV values in Summer in the green outdoor spaces	- Tree-planting - construction of roofs or solar shading systems such as sun sail
	Sometimes poor and inefficient public lighting	- Use of high efficiency LED lamps
	Sometimes limited accessibility	- Redevelopment of pedestrian paths - Construction of ramps
BUILDING SCALE	Partly low level of renovation (1990)	- Joints sealing - Fire prevention system regulation
	High energy consumption	- Replacement of heating systems - Use of high efficiency LED lamps
	High water consumption	- Insertion of rainwater recovery systems - Update of the sanitary water system
	Thermal dispersions of the envelope	- Replacement of windows - External insulation of the facade
	Under-sizing of rooms	- Insertion of new balconies - Replacement of existing balconies

| 07



Tab. 01 | Assumption adopted in the Screening LCA in accordance with the EeBguide (Gartner *et al.*, 2015)

| Tab. 01

	Assumption at Urban level	Assumption at Building level
Purpose	• Noise pollution reduction; • Heat island effect reduction; • Public lighting improvement	• Energy efficiency improvement • Water consumption reduction
Indicator analysed	Global Warming Potential (GWP)	
Data Requirements	• Open spaces (roads, sidewalks, parking lots and green areas); • Public lightning consumption District heating; • Dimensional characteristics; (e.g., open spaces, surface inhabitants, no. of dwellings)	• Building (two 11-storey blocks); • Natural gas consumption; • Heating energy demand; • Water consumption; • Dimensional characteristics (e.g., windows and walls surface, type and insulation)
Mandatory Life Cycle Stages	• A1-A3 (Product stage) • B6 (Operational energy use), B7 (Operational water use)	
Scope of the assessment	• Green acoustic barriers installation; • Replacing of the flooring. LED lamps implementation	• Improving energy efficiency of envelope (e.g., wall insulation, replacement of old windows); • Rainwater recovery systems and sanitary water system improvements; • Heating systems replacement

Discussion and future scenarios: the vision of technology experts

The LCA results relate to just one indicator: Global Warming Potential, expressed by equivalent kg of CO_2. In particular, Figure 06 shows the GWP related to the environmental impact of the LCA applied to retrofitting a block in Grünau in one year, associated with two life cycle stages: product and use stage. The product stage refers to the impact generated during the manufacturing of the products used. Consequently, the GWP of the product stage indicates, for example, the kg CO_2 emitted to produce the thermal insulation and the windows used in the retrofitting of the envelope, or the cool paving material used to reduce the heat island in the square. The use stage, on the other hand, considers, respectively, the operational energy usage (heating and water) and energy consumption from outdoor lighting in the open space.

The LCA results highlight that, against an increase in the impact owing to the materials and products used in the retrofitting solutions (product stage), the strong reduction of energy consumption (-58%) during the use stage leads to an overall decrease in the total GWP.

Figure 07 shows the outcomes related to the entire life cycle, considering 60 years in line with the indications of the European Framework Level(s).

More specifically, in the applied mitigation strategies the 52% increase in GWP generated in the manufacturing of the materials and products used is offset by the reduction (roughly 58%) of energy consumption in the building's use phase: heating, tap and hot water. Although the comparative assessment reveals only one of the LCA indicators (GWP), and is limited to only two life stages, there is a clear improvement thanks to the mitigation strategies. The decrease in kg of CO_2 equivalent is about 58% of the total value. However, while carrying out the LCA, it was identified that some environmental impact cannot be fully evaluated due to the necessary limitations. For instance, although environmental impact from the construction of the acoustic green barriers could be determined, in order to evaluate the sustainability of the district after the application of the analysed mitigation strategies, a broader approach should be taken. With the aim of evaluating the potential environmental impact associated with the mitigation strategies at the urban scale and measuring the effectiveness in terms of the reduction of carbon emissions before and after, this research has combined retrofitting solutions adopted in the Leipzig-Grünau district with a screening LCA.

In fact, the LCA results have provided a better understanding of the environmental impact on the whole intervention during the main life cycle stages (product and use stage, respectively), making it possible to conduct an initial and quick estimate of the environmental impact, and to determine the significant stages that need to be addressed to enhance sustainability.

Likewise, it was identified that some mitigation strategies proposed at urban level to improve sustainability, such as enhancing acoustic well-being or lessening the heat island effect, were not entirely captured or quantified by adopting a single approach.

For instance, improved sound insulation through the inclusion of acoustic green barriers can be determined as an environmental impact ("embedded impact" during the manufacturing stage), while the benefits obtained by increasing sound performance comfort can be better achieved at the level of social performance criteria, for example by including an EN 16309 "Sustainability of construction works Assessment of social performance of buildings-Calculation methodology" (Dolezal, Spitzbart, 2017) evaluation in the LCA.

Although the GBRS protocols already include central aspects, such as indoor air quality, thermal characteristics and all performances related to "health and comfort", there is no procedure to systematise them that would perceive the results, impact and benefits, and really connect with the LCA issues.

However, even though the application of LCA methodology at the urban level involved making a large number of assumptions, and consequently some results might not be as accurate as they should be, the analysis successfully identified the potential environmental impact related to the main urban issues, as well as specific mitigation strategies proposed to enhance the sustainability of the district and to identify the most relevant Life Cycle stages that need to be addressed in order to improve the environmental sustainability of Grünau. Furthermore, it provided a recognisable comparison between different statuses of the same neighbourhood (existing vs. mitigated). Therefore, it is thought that further development of this methodology could play an important role in the transition to low-zero carbon societies.

Consequently, it is crucial to develop new approaches and schemes based on combining LCA with social performance criteria in order to properly assess the sustainability of a district. A first step in this direction could certainly be to combine the results of the LCA with those inferred from the adoption of criteria and assessments on improved comfort performances in the use phase.

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REFERENCES

Albino, V., Berardi, U. and Dangelico, R.M. (2015), "Smart Cities: Definitions, Dimensions, Performance, and Initiatives", *Journal of Urban Technology*, Vol. 22, pp. 3-21.

Birgea, D. and Bergera, A.M. (2019), "Transitioning to low-carbon suburbs in hot-arid regions: A case-study of Emirati villas in Abu Dhabi", Building and Environment, Vol. 147, pp. 77-96.

Dodd, N., Cordella, M., Traverso, M., Donatello, S. (2017). *Level(s)-A common EU framework of core sustainability indicators for office and residential buildings - Part 3: How to make performance assessments using Level(s).*

Dolezal, F. and Spitzbart, C. (2017). "Relevance of acoustic Performance in Green Building Labels and social Sustainability Ratings", *Acoustics in Practice*, Issue 6.

EeBGuide Project (2012), "2.4.1 Screening LCA", available at: https://www.eebguide.eu/eebblog/?p=913.

EC European Commission (2013), *Building the Single Market for Green Products Facilitating better information on the environmental performance of products and organisations*, European Commission, Brussels.

EC European Commission (2015), "Better regulation: guidelines and toolbox", available at:https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox/better-regulation-toolbox_en.

Gartner, J. *et al.* (2015), *EeBGuide Guidance Document Part B: Buildings Paperback*, Fraunhofer Verlag.

Lotteau, M., Loubet, P., Pousse, M., Dufrasnes, E. and Sonnemann, G. (2015), "Critical review of life cycle assessment (LCA) for the built environment at the neighborhood scale", *Building and Environment*, Vol. 93, pp. 165-178.

Mauree, D., Naboni, E., Coccolo, S., Perera, A.T.D., Vahid, M.N. and Scartezzini, J. (2019). "A review of assessment methods for the urban environment and its energy sustainability to guarantee climate adaptation of future cities", *Renewable and Sustainable Energy Reviews,* Vol. 112, pp. 733-746.

Milhahn, K. (2019), "Cities: a 'cause of and solution to' climate change", available at https://news.un.org/en/story/2019/09/1046662.

Milojevic, B. (2018), *Integrated urban planning in theory and practice*.

Norman, J., MacLean, H.L., M.ASCE and Kennedy, C.A. (2006). "Comparing high and low residential density: life-cycle analysis of energy use and greenhouse gas emissions", *J Urban Plan Dev*, Vol. 132, Issue 1.

Palumbo, E., Traverso, M., Antonini, E., Boeri, A. (2019), "Towards a sustainable district: a streamlined Life cycle assessment applied to an Italian urban district", IOP *Conf. Ser.: Earth Environ*. Sci., pp. 1-12.

Popovici, E., (2006), *Contribution a l'analyse de cycle de vie des quartiers. PhD dissertation*, Ecole Nationale superieure des Mines de Paris, Paris, France.

Rossi, M. (2017), "Efficient and Nice - Urban Metabolism and Urban Comfort", in Sargolini, M., Cocci Grifoni, R., D´Onofrio, R. (Eds.) *Quality of Life in Urban Landscapes. In Search of a Decision Support System for Orienting Urban Transformations*, Springer, S., pp.125-130.

Schlanbuscha, R.D., Fufaa, S.M., Häkkinenb, T., Varesb, S., Birgisdottirc, H. and Ylménd, P. (2016), "Experiences with LCA in the Nordic building industry – challenges, needs and solutions", *Energy Procedia*, Vol. 96, pp. 82-93.

Stadt Leipzig (2016), STEK – *District Development Concept. Vision for Grünau 2030.*

Stephan, A., Crawford, R.H. and de Myttenaere, K. (2013), "Multi-scale life cycle energy analysis of a low-density suburban neighbourhood in Melbourne, Australia", *Building and Environment*, Vol. 68, pp. 35-49.

Xu. L., Wang, X., Liu, J., He, Y., Tang, J., Nguven, M. and Cui, S. (2019), "Identifying the trade-offs between climate change mitigation and adaptation in urban land use planning: An empirical study in a coastal city", *Environment International*, Vol. p. 133, 105162.

Zampori L., Saouter E., Castellani V., Schau E., Cristobal J. and Sala S. (2016), *Guide for interpreting life cycle assessment result JRC technical reports*, Luxemboug.

Teaching to dexign futures in cities

ESSAYS AND VIEWPOINT

Anna Barbara[a], Peter Scupelli[b],
[a] Dipartimento Design, Politecnico di Milano, Italy,
[b] School of Design, Carnegie Mellon University, USA

anna.barbara@polimi.it
pgs@andrew.cmu.edu

Abstract. Global challenges, such as Climate Change and Sustainable Development, require the design of sustainable lifestyles, products, services, and cities that reduce carbon intensity by at least 50% before the year 2030 and 100% by the year 2050 to avoid long-term climate catastrophes.
Short-term action is needed to accomplish long-term sustainability goals. We work on the 2030 deadline with every tool available to us: new course development combined with new pedagogy to effectively and efficiently deliver time-based design. We made our courses available online as open source resources within a global network of universities.
In this paper, we describe a project called "Dexign Futures" initially developed at the School of Design at Carnegie Mellon University. This open source learning project is being locally adapted and evaluated with three global partners: at the School of Design, Politecnico di Milano, Italy; Tsinghua University in Beijing, China, and Georgia Tech University in Atlanta, Georgia, USA. In this paper, we describe the general project Dexign Futures and, specifically, the case study workshop conducted at the School of Design, Politecnico di Milano. We briefly describe the general Dexign Futures project and focus on the seminar conducted at the School of Design of the Polytechnic of Milan to show the possible variations to adapt the global model to specific and local contexts.

Keywords: esign-thinking; futures-thinking; open-source-learning; scenarios; time-based-design.

Introduction

Dexign Futures runs in the tradition of global initiatives, such as CUMULUS, DESIS Network, the INDEX Project already engaged in challenges, such as Climate Change, Sustainable Development Goals, Social Innovation, and so forth.
In this paper, we focus on the challenges introduced when design educators are concerned with teaching students to align short-term design action on a temporal dimension to accomplish long-term vision goals. Global problems, such as sustainable development (United Nations, 2015), climate change, climate mitigation and climate adaptation (United Nations, IPCC, 2018), and now the coronavirus pandemic, are among the possible areas of experimentation.

Shifts in design pedagogy

The new issues and transformations that emerged on a global scale entail radical rethinking of the issues on which design teaching has always questioned itself: what (content design); why (Ethical Design on values), when (Time-based design) and how (e.g. pedagogy).
First, for "design what" we assume that Climate Change, Sustainable Development, and Global Pandemics are the most pressing societal challenges about which designers and consequently design educators need to teach new design methods.
Second, with regard to value issues, we consider that an exclusively human-centred Design Thinking process (Brown, 2009) often leads to focusing the vision on the end users, missing broader values like design in the present for collective futures (Fry, 2009); therefore on the short-term needs of an individual, and cannot frame the challenges on a planetary scale, such as the environmental and health ones we want to deal with.
The third point is temporal. Increasingly there is a shortening of time horizons in the present through rapid prototyping techniques (Chuaet *et al.,* 2010), lean (Ries, 2011), agile (Beck *et al.,* 2001) and so forth at the expense of broader time horizon approaches (e.g., Baghai *et al.,* 2000) or time-based design approach (Barbara, 2018) careful to consider time as an energy, economic and social resources of design.
Fourth, post-human-centred design methods inspired by Futures Studies are urgently needed to augment design thinking methods to overcome limiting human-centred worldviews, epistemologies, and ontologies (Inayatullah, 1998). Design students can learn greater agency within time-based design from Futures Studies pedagogy (Slaughter, 2008). Blended-learning pedagogies involve both online and classroom learning activities (Graham, 2006).
Through the project we explore four research questions:

1. How might a time-based design pedagogy that aligns short-term design action with long-term future vision goals be distributed globally?
2. How might open-source teaching materials developed for one university be adapted by professors and students in a different university, country, language, and local culture?
3. What kind of support do university professors and students need to take on such challenges?
4. How might new local solutions become global open-source learning resources?

Design Pedagogies

Until a few years ago, much of the teaching of design was based on four pedagogical methods: study/laboratory, lecture, and seminar (Lawson and Dorst, 2009; Lyon, 2012; Tovey, 2015; Boling *et al.,* 2015; Farías and Wilkie , 2016; Davis, 2017).
The digital age has introduced new providers of courses and educational formats into the educational landscape, ranging from the traditional classroom to entirely online courses. The scene is extremely varied, ranging from online courses and degree courses (e.g., SCAD, COURSERA, UCSD); online master class (e.g., masterclass); post-graduate education courses; to new suppliers (eg IDEO U, IDEO.org, Luma Institute, Cooper Interactive University, Acumen.org).
The Dexign Futures course was taught with a novel flipped classroom pedagogy to support design based reflective practice (Schön,1990). Reflective practice is critical in design education to embed new ideas and methods firmly into practice. Therefore, the flipped-classroom pedagogy we used has three components: online interactive pre-work with immediate correctness feedback, in-class hands-on workshop activities with instructor feedback, and weekly reflective assignments followed by in-class group discussions to encourage reflective practice (Scupelli and Brooks, 2018).

Dexign Futures

"Dexign" is an experimental form combining design thinking with futures thinking. The term "Dexign" was coined by Arnold Was-

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serman in 2013 for the title of a course called "Dexign the Future" (Wasserman *et al.,* 2015).
Given the urgency to rapidly decarbonise by year 2030, it was decided to make the Dexign Futures course materials available globally as open source learning materials with a creative commons license on https://dexignfutures.org for university professors worldwide to use, modify, and adapt to their own cultural, social, and national contexts.
The Dexign Futures project originated at Carnegie Mellon University involves global collaborations through a series of pilot studies with professors and students from three universities.
The pilot study at Tsinghua University involves translating the Dexign Futures courses into Chinese on the https://next.xuetangx.com/ online learning platform. The course materials are being piloted in existing taught design courses. Revised versions of the courses are being translated and modified to be culturally appropriate. The video content is being reshot and will be placed on platforms visible in the Chinese Internet (Scupelli *et al.,* 2019).
The pilot study at Georgia Tech involved introducing graduate level students to the futures thinking method called Causal Layered Analysis (CLA)(Inayatullah, 1998). CLA can augment designers' creative responses to behavior change challenges by thinking through four layers (e.g., litany, systems, worldview, myths/metaphors). Typically, design students are challenged to apply such theory laden approaches to concrete design problems (Scupelli, 2020).
The pilot study we describe in this paper is organized with the School of Design at the Politecnico di Milano. It was focused on exploring Dexign Futures methodology and the case study.

Challenges of adapting course materials

There are tradeoffs to teaching design related subjects as studio type courses and flipped classroom pedagogy (Scupelli, *et al.,* 2019).
Four differences emerged from adapting course materials developed from one university to another: (a) student types and cultural traditions; (b) professor pedagogy and teaching preferences; (c) teaching infrastructure differences and (d) schedule, time, curriculum, and course constraints. In this paper, we compare exercises created for a flipped class and the same materials adapted to a one-day workshop.

Masdar city: a case-study

We used the case study of Masdar City as a forcing function to have students explore a utopian technology driven sustainable city future. We chose Masdar City as a case study precisely because it was very different from the life experiences of the students. The contrast to their life experience allowed students to critically question the underlying assumptions of Masdar City (Fig.1).
In this paper, we describe the teaching materials from four units of futures studies methods on Masdar City located near Abu Dhabi, in the United Arab Emirates. Given Masdar's focus on sustainability, design students are asked to envision new design products, services, spaces, and experiences within Masdar City (Fig.2).

Case 1. Masdar city - flipped pedagogy - Carnegie Mellon University-School of Design

The Masdar assignment was broken up over 4 weeks focused onfour key futures studies ideas. The materials available online focus on four futures thinking methods: STEEP forces (Social, Technological, Economic, Ecological, Political) (ARUP, 2018), common errors in futures scenarios (Cascio, 2012), obligations to future generations (Dator, 2007), and alternative futures (Dator, 2009).

Reflections

The purpose of choosing Masdar City was to challenge students to use the STEEP framework (social, technological, economic, environmental, and political aspects) as lenses to brainstorm new design opportunities. Students were focused on the design outcome and less on learning a new design process.
Most students had never visited the United Arab Emirates, Abu Dhabi or Masdar City. They lacked understanding the UAE society, culture, economy, or climate. The sustainability focus of Masdar City and the innovative technological design choices were unfamiliar to students. They watched documentaries and read online articles.
Binary thinking led students to be perplexed. How could Masdar City, such an amazing example for sustainable living, be created in a country, whose national economy was mostly based on fossil fuel extraction? Some students reasoned that Masdar City must be a sustainability public relations operation; they struggled to navigate apparent contradictions.
Masdar City forced students to notice that no single paradigm, worldview, or ideas can fully explain the present times. Opposing ideas co-exist in the present and futures. William Gibson said «The future is already here, just not evenly distributed» (Spenser, 1994). Students needed to learn to reconcile apparently opposing ideas, worldviews, and paradigms and design for desirable futures.

Case 2. One-day Workshop at Politecnico di Milano - School of Design

The Dexign Futures workshop held at the Politecnico di Milano involved the graduate students of the Ephemeral Design course of the School of Design. It lasted a day and was divided into several didactic phases, both traditional and frontal, both flipped and digital. The method of interaction between teachers and students was deliberately left free in the ways and means, therefore the workshop took on, from the very beginning, the character of a community workshop, in which groups of students freely aggregated, arranged in the classroom according to new postures and layouts. The form of

01 |

01 | View of Masdar City pedestrian spaces

interaction also changed significantly pro-actively up to a lively final debate among all, including in connection with prof. Scupelli video conferencing from Carnegie Mellon (Fig. 3).

Aim of the workshop

The workshop held at the Politecnico di Milano had an investigative character, aimed at this publication, for a better understanding of how to teach:

- to consider the future as a tool and not as a destination;
- to understand at what distance / proximity from the present, the future must be located;
- to design other methodologies to include the climatic emergency in the project horizons at any scale;
- to study all sources of knowledge and information: human, paper, digital;
- to create a choral narrative of the possible scenarios;
- to check what and who to believe;
- to improve relationship, interaction and empathy between the inhabitants.

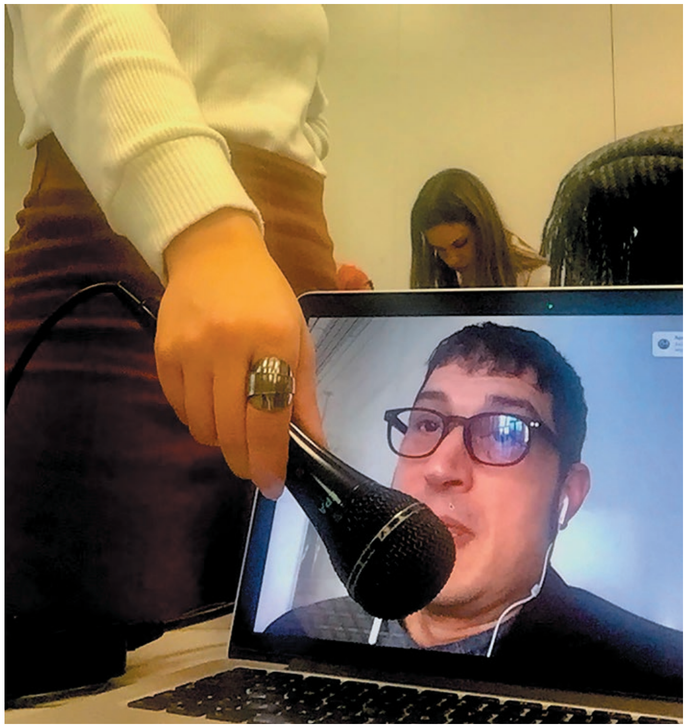
Teams

The composition of the class is varied in geographical terms, over 20 different nationalities. This adds to the idea of the future, a multi-cultural dimension that makes the comparison, and debate on the meaning and values of the future, more interesting. Different questions emerged about the value of history and memory, which in the projection seem to become the strength of the project's range,

| 02

02 | View of Masdar City with a self-driving transport

| 03



03 | Dexign Futures: flipped classroom

especially in a newly founded city like Masdar. Instead, a homogeneity of vision and values is achieved where the future is viewed through the lenses of the climate and its transformations, a topic that seems to make any national distinction inappropriate. Therefore, if the theme of futures is placed in a climatic framework, the concept of country of origin fades before a unitary environmental framework.

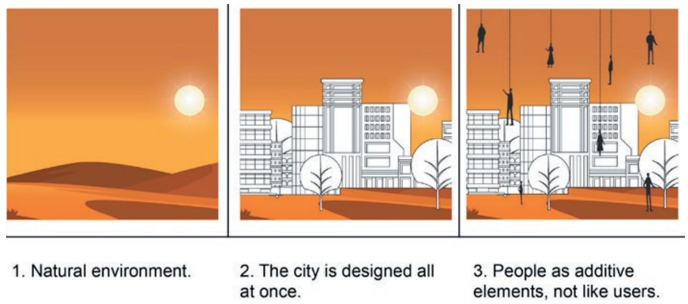
Ephemeral and future design

The theme of futures, within the Ephemeral Design course, seems an oxymoron, because it needs to force the temporal projection beyond the temporary deadline of the project. For the purpose of the teaching methodology, the time-based dimension becomes a fundamental axis on which to slide the projection of the visions.

04 | Dexign Futures: scenarios (designed by students of Ephemeral Design Lab at Politecnico di Milano, School of Design)

05 | Dexign Futures: concepts (designed by students of Ephemeral Design Lab at Politecnico di Milano, School of Design)

| 04



It becomes essential to understand: how far to go, to ask them: how far is their future? What are their concerns and expectations? What future to include in the vision of their projects? What perspective besides the anthropocentric one remains possible? How many futures are possible?

The relationship with futures that students try to establish becomes more strategic than the future itself. It is no longer intended as a forecast, but as a construction and tool for the project.

Masdar city

The choice of Masdar City, in the UAE, as the case study, becomes extremely interesting because through the 5 STEEP forces (social, technological, economic, environmental, political) emerged proposals and critical issues, very coherent between the different groups.

- Social: homogeneity and elitist community. Lack of history. Instant culture. Absence of cars but alienation from new media.
- Technological: overvaluation of technologies. Lack of relationships. Technological pollution
- Economic: not completely independent. Dependence on external supplies.
- Environmental: positive but insufficient for the number of inhabitants expected in the future.
- Political: gated community risk. City branding. Who is the owner of the city?

Discussion

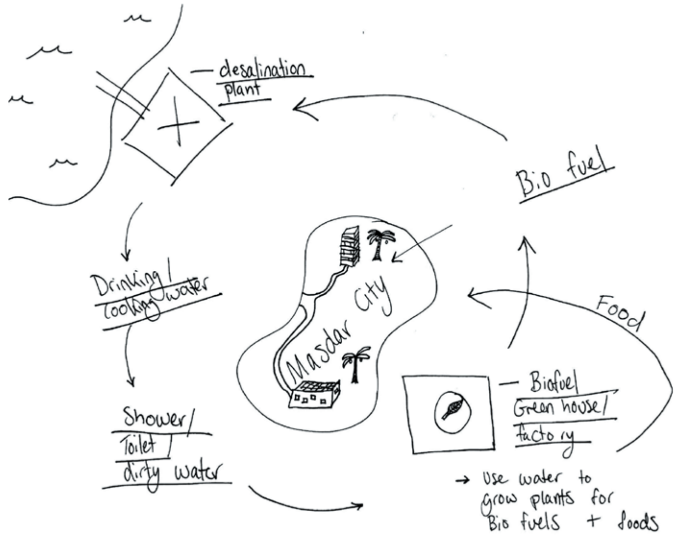
The study of the Masdar, as case study, presents critical issues related to a limited history of the place, since it is a newly founded city. In this sense, students from countries with thousands of years of urban histories (e.g., Europe, China, Middle East) were far more critical than students from countries with more recent urban histories (e.g., America, Australia, New Zealand).

Another interesting factor is linked to the social composition of the inhabitants who are considered too elitist and homogeneous, making the social structure very similar to that of a "gated city" and not to a realistic and complex city. The everyday lives of workers that make Masdar services run were invisible in the online videos.

An evaluation also emerges from the role of the technologies used both in the construction and management of the city, both in the interaction between the inhabitants, and in the control of behaviour and safety. The technological pervasiveness was considered to be extremely invasive in the quality of living and too essential as a medium of relationships. The absence of cars, located on the ground floor of the city, which would allow greater pedestrian interaction between the inhabitants, is likely affected by an excessive presence of digital connection (Fig. 4).

The people themselves are perceived as subsequent "additions" to the project.

| 05



Masdar's environmental plan was considered the absolute positive value, as an extraordinary response to the design of energy-efficient environments.

The identified critical issues then became concept, proposals in which, spaces of relationship and greater social and generational diversity, are strengthened (Fig. 5).

Conclusions

We wrote this article before the COVID-19 pandemic gripped the world. We were focused on earth-centred sustainability by aligning short-term design action with long-term sustainability vision goals. We described our challenges translating and adapting design methods and pedagogies from one university reality with the flipped classroom pedagogy to another university focusing with a workshop pedagogy. The realities of social distancing imposed by COVID-19 now force us to think about transitioning to an all-online design pedagogy to teach time-based design. The world has become united by the environmental challenges and new roles to reinvent. Due to the COVID-19 pandemic, the Dexign Futures Open Source Learning project is shifting to an all online offering that may facilitate global learning. Futures are tricky to predict with much accuracy.

REFERENCES

ARUP Foresight Consulting (2018), http://www.driversofchange.com/

Baghai, M., Coley, S. and White, D. (2000), *The alchemy of growth: Practical insights for building the enduring enterprise*, Mass Perseus Books, Cambridge, United Kingdom.

Barbara, A. (2018), *Sensi, tempo e architettura*, Postmedia Books, Milan, Italy.

Barnosky, A.D. *et al.* (2011), "Has the Earth's sixth mass extinction already arrived?", *Nature*, Vol. 471(7336), pp. 51-57.

Beck, K., Beedle, M. *et al.* (2001), "Manifesto for agile software development", available at: https://agilemanifesto.org/.

Bergmann, J. and Sams, A. (2012), *Flip your classroom: Reach every student in every class every day*, International Society for Technology in Education.

Boling, E., Schwier, R., Campbell, K., Smith, K.M. and Gray, C.M. (2015), *Studio teaching in higher education: Selected design cases,* Routledge, London, United Kingdom.

Brown, T. (2009), *Change by design: How design thinking creates new alternatives for business and society*, Collins Business, New York, USA.

Buchanan, R. (2001), Human dignity and human rights: Thoughts on the principles of human-centered design, Design issues, Vol. 17(3), pp. 35-39.

Cascio, J. (2012), "Bad Futurism", Retrieved May 4, 2020, available at: https://www.youtube.com/watch?time_continue=1&v=oYb9mZh90r4&feature=emb_logo.

Chua, C.K., Leong, K.F. and Lim, C.S. (2010), *Rapid prototyping: Principles and applications*, New Jersey, World Scientific.

Crutzen, P.J. (2006), *The "Anthropocene"*, in: Ehlers, E., Krafft, T. (Eds.), *Earth System Science in the Anthropocene,* Springer, Berlin, Germany.

Dator, J. (2009), "Alternative futures at the Manoa School", *Journal of Futures Studies*, Vol. 14(2), pp. 1-18.

Dator, J. (2007), "Caring for future generations", available at: http://www.futures.hawaii.edu/publications/future-generations/Caring4FutureGenerations2007.pdf.

Davis, M. (2017), *Teaching design: A guide to curriculum and pedagogy for college design faculty and teachers who use design in their classrooms*, Allworth Press, New York, USA.

Farías, I. and Wilkie, A. (2016), S*tudio studies: Operations, topologies and displacements,* Routledge, Taylor & Francis Group, London/New York.

Fry, T. (2009), *Design futuring: Sustainability, ethics and new practice.* Oxford: Berg.

Spenser, S. (1994), "Job opportunities along the information superhighway – experts tell how not to get frozen out of the new, ice' age", *The Seattle Times*, available at: http://community.seattletimes.nwsource.com/archive/?date=19940403&slug=1903605.

Graham, C.R. (2006), "Blended learning systems", *The handbook of blended learning*, pp. 3-21.

Inayatullah, S. (1998), "Causal layered analysis: Poststructuralism as method", *Futures*, Vol. 30(8), pp. 815-829.

Jones, J.C. (1992), *Design Methods*, Wiley, United State.

Lawson, B. and Dorst, K. (2015), *Design expertise*, Architectural Press, Oxfordshire, New York, USA.

Lyon, P. (2012), *Learning and teaching through design: An anthology of models, approaches and explorations,* Burlington Gower Pub. Co.

Manzini, E. (2015), *Design, when everybody designs: An introduction to design for social innovation*, The MIT Press, Cambridge, USA.

Norman, D.A. and Stappers, P.J. (2015), "DesignX: Complex Sociotechnical Systems", *The Journal of Design, Economics, and Innovation*, Vol. 1(2), pp. 83-106.

Pellegrino, J.W. and Hilton, M.L. (2012), *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*, The National Academies Press, Washington.

Ries, E. (2011), *The lean startup*, Crown Business, New York, USA.

Scupelli, P. (2020), "Teaching to Find Design Opportunities for Behavior Change Through Causal Layered Analysis", *Proceedings of the 2020 Human-Computer Interaction International Conference. 2020 HCI International Conference*, Copenhagen, Denmark.

Scupelli, P., Candy, S. and Brooks, J. (2019), "Teaching Futures: Trade-offs Between Flipped Classroom and Design Studio Course Pedagogies", *IASDR 2019: Design Revolutions*, Manchester, United Kingdom.

Scupelli, P., Fu, Z., Zheng, Y and Brooks, J. (2019), "Teaching to Dexign Futures in China: A Vision for a Blended Learning Pedagogy to be Deployed at Scale", *9th International Conference the Future of Education*, Florence, Italy.

Scupelli, P. and Brooks, J. (2018), "What Features of a Flipped Course Improve Design Student Learning Experiences?" *Next Wave Design Management Institute Academic Design Management Conference*, August 1-2, Ravensbourne, London, United Kingdom.

Schön, D.A. (1990), *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*, Cal Jossey-Bass, San Francisco.

Slaughter, R. (2008), "Futures Education: Catalyst for Our Times", *Journal of Futures Studies*, Vol. 3, pp 15-30.

Tovey, M. (2015), *Design Pedagogy,* Taylor and Francis Ltd.

United Nations (2015), "Sustainable Development Goals", available at: https://sustainabledevelopment.un.org

United Nations, IPCC (2018), "Global Warming of 1.5 °C", available at: https://www.ipcc.ch/sr15/.

Wasserman, A., Scupelli, P. and Brooks, J. (2015), "Learn! 2050 and Design Futures: Lessons learned teaching design futures", *Design Educators IDSA International Conference 2015: Future of the Future*, August 19-22, Seattle, WA.

Heritage buildings towards the future: conservation and circular economy for sustainable development

RESEARCH AND EXPERIMENTATION

Ernesto Antonini, Giulia Favaretto, Marco Pretelli,
Department of Architecture, University of Bologna, Italy

ernesto.antonini@unibo.it
giulia.favaretto2@unibo.it
marco.pretelli@unibo.it

Abstact. Keywords: The issues of energy efficiency and climate change belong to a complex scenario to which contemporaneity is called upon to answer. Architecture can contribute by promoting practices that look at the environment with a view to building the future. As an architectural activity, restoration of heritage buildings can actively participate in this fundamental challenge within the perspective of a circular economy proposing a globally sustainable model. Starting from a state-of-the-art investigation, this paper aims to enucleate the BECK project's contribution in this field, as well as to underline how careful strategies of conservation and contemporary use can have positive effects on sustainable future scenarios.

Keywords: Heritage Buildings; Conservation; Reuse; Circular Economy; Sustainability.

The worrying effects of climate change are increasingly evident. If, as far back as the past century, the United Nations highlighted that they constitute a common concern for the whole of humanity (UN, 1987; UN, 1992; UN, 1997), the most recent documents confirm the urgent need to identify practices that can be useful to contrast the increase of this phenomenon.
The United Nations Framework Convention on Climate Change reaffirmed the need for a common effort to reduce greenhouse gas emissions into the atmosphere (UNFCCC, 2019). Nevertheless, the seriousness of the current situation requires substantial interventions against the increasingly climate change acceleration, such as emissions from manufacturing, transports and building heating and cooling. These measures outline a radical change of perspectives and priorities, compared to the current linear economic model. This leads to shifting the focus to the structural causes of the climate balance perturbation, aiming at correcting the route, not just to replace the vehicle. In this regard, circular economy proposes a globally sustainable model that jointly addresses multiple dimensions, including environmental, energy, social, economic, production, architectural and cultural ones (Mickaityte *et al.*, 2008).
While it may seem inconsistent at times, this approach works best when the hierarchical model is abandoned and a circular perspective is adopted instead (ICOMOS, 2017), assuming that meeting the present needs must not compromise the ability to satisfy those of the future (UNISDR, 2009).
This perspective leads to increasing the values awarded to the heritage inherited from the past (UNESCO, 1972) in its both tangible and intangible contents. Enhancing the heritage tangible values requires reducing the resources needed for its use, slowing down its ageing, preserving its material substance and efficaciously recycling the residues left at the end of each operational cycle of the artefact. Instead, the crucial issues for the intangible heritage address safeguarding and protecting its contribution toward strengthening the specificities and identity of local communities, the transmission of collective memory, and the social sustainability.
Along these lines, «the changes made in contemporary age forced the scientific community to face the challenges of the sustainable growth even within the historical Cultural Heritage, tangible or intangible» as they are fully involved within that «crucial issue for human activity and behavior» (Magrini *et al.*, 2015).
In this sense, taking care is not only intrinsically coherent with the principles of circularity, but is also positive in cultural and economic terms, as it favours the creation of heritage communities and, in so doing, it feeds a virtuous circle assuring an effective conservation of the assets.
Furthermore, this generates job opportunities and hence well-being, rewarding the development of knowledge, skills and autonomy stimulating the capacity for initiative of both individual and communities.
There is, therefore, an evident need to jointly address the many aspects which are connected to the social, economic and environmental sustainability, by adopting an approach for which the existing heritage represents a physical and cultural resource to be preserved and enhanced.
Having been recognised as a driver for sustainable development, cultural heritage has thus become an essential object of global agendas and guidelines: its protection not only allows the transmission of material and immaterial values, but also fosters the sustainable development, acting as one of its driving forces (ICOMOS, 2011; UN, 2012; MARSH, ICCROM, ICOMOS-ICORP and UNESCO, 2013).
The topicality of the issues connecting climate, energy and heritage emerges in this scenario. Among the actions to achieve the UN Sustainable Development Goals (SDGs), the 2030 Agenda for Sustainable Development requires taking urgent measures on climate change, also considering heritage as an enabler of sustainability (UN, 2015; UNESCO, 2015; ICOMOS, 2017) and its conservation as a climate positive action (ICOMOS CCHWG, 2019). Moreover, several international conferences call for an interface between conservation and energy efficiency issues (López *et al.*, 2014; De Bouw *et al.*, 2016; Broström *et al.*, 2018).
Within this framework, a common challenge to all fields of action is the intervention on human resources (UN, 1987). In this regard, the need for actions in capacity building regarding the development policies has been highlighted, involving within them cultural heritage as a driver for sustainable development. In fact, a capacity building programme aimed at increasing expertise constitutes a strategic means to strengthen collaboration and to develop new skills (Della Torre *et al.*, 2020).
This task rests with universities and research organisations, which are called upon to consolidate programs promoting technical and scientific cooperation on these issues. In parallel, a key role is up to local communities, which contribution is crucial in implementing solutions adapted to the individual specificities. Universities can contribute to this synergy also by their teaching activities provided to both students and professionals, while institutional bodies involvement may strongly help in supporting global policies and fostering cooperation between the various concerned players. In turn, local actors not only acquire training, but can actively contribute

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through the knowledge of their local region, as well as of its specificities and heritage.
In this scenario, the promotion of a multicultural (ICOMOS CIVVIH and ICOMOS-Korea, 2017) and multidisciplinary approach (UNESCO and UNDP, 2013) is of great relevance, although the potential inherent in these fruitful relationships still appears to be under-exploited.

Internationality/ interdisciplinarity: synergistic encounters towards the future

Within the aforementioned worldwide reference framework, BECK Project[1] represents a case study of a possible capacity building strategy, particularly focusing on enhancing motivations and target definition.
The project goal, indeed, is integrating the consumer behaviour relevant to energy efficiency and climate change within the education programs of some Universities of Russia, Sri Lanka and Bangladesh. This transdisciplinary scientific project has two main purposes: on the one hand, to support research on energy efficiency for combating climate change and, on the other hand, to promote capacity building in academic education and third level training.
The project promotes an action of third mission in Eastern European and Far East Asian countries which aims at strengthening the local expertise of teachers, students and future professionals by exploiting the longer experience of European countries in these topics[2].
Especially, the investigations carried out by the European partners focus on energy efficiency and climate change issues, also deepening the relationship between preserving heritage buildings and improving their energy behaviour[3]. Since acting on new buildings only is not sufficient to achieve the environmental targets (Battisti, 2016), the heritage buildings conservation is also needed to reach this goal, in addition to the social and cultural needs it meets. In this regard, the aim is to fill technical capacity gaps in energy efficiency improvement and climate change effects mitigation, to stimulate cultural sensitivity for heritage protection, and to integrate the historical buildings conservation strategies according to the most recent international guidelines, including the Faro Convention, the Nara+20 and the Leeuwarden Declaration (Council of Europe, 2005; Nara+20, 2014; Leeuwarden Declaration, 2018).
The third partner countries have been selected accordingly, among those where these actions are needed and appear to be promising. However, the long term expected benefits are not just local.
Specifically, the analysis of the current situation revealed:

- the need to spread awareness of the importance inherent in improving the energy behaviour of historical heritage, which is not yet reached within those contexts;
- the need for operator training in architectural restoration field, including the skills enhancement in intervention planning and management of heritage buildings;
- the strategic role played by capacity building in cultural field for the countries with poor experience of the most up-to-date approaches on this.

The project addresses these issues targeting on the knowledge transfer process strengthening in this specific field, and recognising the pivotal role of consumer, whose continuous interaction with the built environment makes him – more than other players – the spokesperson of a co-evolutionary logic (Pianezze, 2009-2012).
Since the action on human resources thus emerges as an essential leverage for capacity building, the project is oriented to actively increase the design, executive and management capabilities of local realities that can, in turn, feed processes of community involvement (Göttler and Ripp, 2017).
Especially, the project focuses on human resources by addressing the different actors of the process, from the workers to the technicians and specialists, through the development of innovative learning schemes for training the skills needed for the purpose. In particular, the adopted approach couples actions providing people suitable technical contents and measures to support the entrepreneurship centred on offering those knowledge as services. In so doing, the project aims at achieving the double goal of building specialised skills and making them a resource for both heritage and local economy.
In this perspective and with the awareness of the need to interpolate complementary competences (Morin, 2000), several different skills have thus been brought together in the most synergistic way possible. Namely:

- Architectural Restoration, targeting heritage conservation, its effective maintenance and the compatible retrofitting to host contemporary functions;
- Architectural Technology, to provide suitable methods in improving the existing buildings energy behaviour and the environmental profile of the activities needed for their protection and enhancement;
- Business Management, to supply efficient entrepreneurial approaches suitable in promoting the entrepreneurship centred on providing services to the sector.

Involving teachers and researchers of different disciplines ensures multidisciplinary and further project development based on complementary knowledge, as well as the selection of case studies where the different aspects merge and interact.

Global/local: global challenges for innovative approaches to local human resources

In addressing the global challenge of increasing energy efficiency and mitigating the effects of climate change, the project identifies practices and outlines methodologies empowering the knowledge transfer process in a dual direction.

Firstly, by assuring that information and experiences can be effectively exchanged among the teachers belonging to the different institutions. The means for this are periodic meetings useful to facilitate the transfer of medium- and high-level technical expertise to the involved universities.

The second action line concerns dispensing innovative and distance learning modules[4] able to reach people within and beyond the limits of academic education.

The compatibility between the building heritage preservation and the improvement of the environmental profile of the activities needed for the purpose is the first scientific problem raised by the research, with the aim to establish a basic set of criteria useful in framing the issue.

The following basic concepts have been identified as the key theoretical pillars in addressing the topic, so representing the core notions to transfer:

- if conservation of cultural heritage allows preserving and transmitting both the tangible and intangible values of a community, the asset protection has significance and generates benefits going beyond the local dimension;
- the intervention on the built heritage is a sustainable operation in itself, as the reuse of existing buildings well complies to the circular economy principles;
- the energy efficiency improvement can act as a protection tool for heritage (Carbonara, 2015) as it leads to the adoption of practices considering climate change, thus preventing its negative effects on the asset too. Additionally, more energy performant buildings are cheaper to maintain and manage, which makes easier their conservation;
- since the needs of architecture conservation, user comfort and energy saving must be suitably balanced when designing an intervention on a heritage asset, a preliminary deep study must be always carried out on the use-related calling of the buildings and the individual spaces inside them;
- a logic of development intended as improvement (Daly, 2001) must drive the building technological and plant engineering integration, avoiding solutions that are totally extraneous to it. The Italian regulations on building consolidation provide a suitable reference for this, suggesting improving the efficiency of the existing architecture instead of forcing it to fully meet the performance requirement (De Santoli, 2015). This approach is less impacting on the building and it also often allows downing both the intervention and management costs;
- a more correct and balanced assessment of the whole intervention environmental impact can be performed by adopting a life cycle perspective. The adoption of LCA (Life Cycle Assessment) and LCC (Life Cycle Costing) tools is thus strongly recommended, as well as the training of skilled technicians needed to apply those protocols;
- the preliminary analyses on the character, conditions and needs of the building must identify the possible interferences between conservation objectives and improvement of energy behaviour, using the former as a limit to evaluate the compatibility of the latter.

  Based on this set of criteria, the project identified a methodology to follow in designing and executing the heritage building energy retrofitting, tailoring the whole process according to the local specificities.

The first step aims at acquiring a deep knowledge of the building, especially concerning its energy behaviour and indoor microclimate conditions, as well as at identifying the transformability levels of its main elements and constituents.

The requirements in terms of thermo-hygrometric comfort can be then established, targeting to the preservation of both the asset and the objects it hosts, as well as, possibly, to the comfort of those living and working inside, too.

Examples in which the same approach and methods have been successfully applied (Boriani et al., 2011; Lucchi and Pracchi, 2013; Pracchi, 2014) are make available by the research project, which also provides to third country partners a collection of the regulations and guidelines on the topic that are in force in Europe and internationally.

The case studies selected by the project refer to buildings of different locations, age (ranging from ancient times to the 20th century) and designated use. Material, morphological and microclimatic characteristics of each building are identified, then an analysis is made of the interventions performed on them over time, by assessing their compatibility. This leads to the classification of the case studies in categories based on the possible actions that can be envisaged on them:

- interventions on opaque envelope, window and door frames, and technical installations;
- interventions on outdoor and surrounding spaces, such as courtyards, green areas and terraces;
- actions of preventive conservation, monitoring and maintenance planning, with an assessment of the impact on climate change (Cassar, 2005).

The further step concerns the skills mapping of the professional profiles to train. The analysis of the expertise needed to plan, realise, manage and promote the envisaged activities has thus allowed to identify the skills to be developed and strengthened.

Regarding the technical capabilities, the main target is the reinforcing of the theoretical and cultural background of designers and builders, in order to provide them a basic knowledge for conscious and responsible actions. Guided exercises on the case studies are useful means to make people understand the connection between theory and practice, as well as good sources from which retrieving the needed operational tools. This aims at raising the awareness that accurate and creative projects are crucial in enhancing the quality of the work, reducing environmental impacts and optimising costs and time.

On the entrepreneurial skills side, builders and technicians are the core target for capability empowering actions. Due to their intermediate position within the process, they play as a collector for the information coming from the designers upstream and as disseminators towards the workers downstream. This allows them acquiring suitable knowledge and useful experience in implementing specific activities related to the heritage conservation and retrofitting. The project stimulates them to enhance this heritage by becoming entrepreneurs, thanks to the additional skills that it makes available to them in management and marketing within local contexts.

Circular economy and sustainable development are the reference scenarios with respect to which the research has developed both contents and possible methodologies of knowledge transfer to the builders operating in the heritage conservation sector within the third party countries.

At this stage, the approach is accurately defined based on a robust scientific background which has been established in cooperation by the European and third party academic partners of the research. The main strategies have also been shaped and implemented, as well as the practices to disseminate them.

The next steps will concern the launch of the innovative distance learning actions regarding the various above-mentioned scopes.

The more challenging expected result of the project is the building of a double virtuous circle. The first one is that in which the European solid knowledge in heritage conservation and sustainability is shared with less experienced countries, where this transfer both feeds effective asset preservation actions and builds capabilities and skills allowing to practice conservation in the future. The second virtuous circle, closely related the first one, aims at triggering a socio-economic positive dynamic in local communities thanks to the development of entrepreneurial activities in heritage conservation, thus also reinforcing the inhabitant commitment to share and protect the heritage cultural values.

(Provisional) conclusions

The scientific implications of this research involve two main issues. From a technical point of view, the core topics are the assessment of the impacts related to the operations of existing heritage conservation – in terms of environmental and social sustainability – and the definition of efficient strategies and intervention methods for their reduction. From a socio-economic point of view, the optimisation of the capacity building processes in this specific field is the more challenging topic, especially regarding the development of effective tools able to provide suitable technical skills, as well as to generate forms of entrepreneurship suitable to enhance them.

The collaboration between the different expertise involved in this scientific path highlighted the opening of scenarios of great relevance, starting from the stage of project definition. The result is an approach that has assigned a crucial role to the context analysis, extending its object to a plurality of phenomena present in the local situation and finalising it not only to achieve a knowledge increase, but also to identify strategies for its improvement. The barriers hindering the strategy implementation have also emerged as topic to address, as well as the possible actions to mobilise and increase the local capabilities and resources which can facilitate it.

The first package of actions carried out within this framework showed the need to include specific measures to raise the awareness of the combined cultural, environmental and economic benefits of heritage conservation, as part of the training paths for local capacity building of both individuals and communities.

Finally, a crucial issue is worth mentioning (Fabbri, 2013): as energy saving is a major challenge for sustainable development impacting on global dynamics, this represents a priority for the heritage buildings too, but it must integrate – not compete with – the primary need to preserve the heritage of humanity.

In this perspective, sprawling the awareness of the heritage potential can contribute to sustainable development and climate change effects mitigation. If managed according to the concepts of conservation and reuse and by promoting careful practices of energy saving and environmental impacts downing, heritage is, indeed, an added value within the circular economy perspective, leading towards the future the witnesses of our past.

NOTES

[1] BECK - Integrating education with consumer behaviour relevant to energy efficiency and climate change at the Universities of Russia, Sri Lanka and Bangladesh is a project co-funded by the Erasmus+ Programme of the European Union. Project Reference no. 598746-EPP-1-2018-1-LT-EPPKA2-CBHE-JP. Grant Agreement no. 2018-2489/001-001. Key Action 2: Cooperation for innovation and the exchange of good practices. Action Type: Capacity Building in the field of Higher Education. 2018-2021. See: http://beck-erasmus.com (accessed 11 January 2020).

[2] The BECK project coordinator is the Vilnius Gediminas Technical University (Lithuania). The European partners involved come from Italy (University of Bologna), United Kingdom and Estonia, while the Asian partners come from Russia, Sri Lanka and Bangladesh.

[3] The contribution of the University of Bologna is related to this precise aspect.

[4] The reference is to the Massive Open Online Courses (MOOCs).

REFERENCES

Battisti, A. (2016), "Guidelines for energy efficiency in the cultural heritage", *Techne, Journal of Technlogy for Architecture and Environment,* Vol. 12, Firenze University Press, Firenze, pp. 65-73.

Boeri, A., Antonini, E., Gaspari, J. and Longo, D. (2015), *Energy Design Strategies for Retrofitting. Methodology, Technologies and Applications*, WIT Press, Southampton.

Boriani, M., Giambruno, M. and Garzulino, A. (2011), "Studio, sviluppo e definizione di schede tecniche di intervento per l'efficienza energetica negli edifici di pregio", avaiable at: https://www.enea.it/it/Ricerca_sviluppo/documenti/ricerca-di-sistema-elettrico/risparmio-energia-settore-civile/rds-64.pdf (accessed 13 January 2020).

Broström, T., Nilsen, L. and Carlsten, S. (Eds.) (2018), *The 3rd International Conference on Energy Efficiency in Historic Buildings*, Conference Report, Visby, September 26-28, 2018, Uppsala University, Department of Art History, Visby.

Carbonara, G. (2015), "Energy efficiency as a protection tool", *Energy and Buildings*, Vol. 95, pp. 9-12.

Cassar, M. (2005), *Climate Change and the Historic Environment*, UCL Centre for Sustainable Heritage, University College London, United Kingdom.

Council of Europe (2005), *Council of Europe Framework Convention on the Value of Cultural Heritage for Society*, Faro.

Daly, H.E. (2001), *Oltre la crescita: l'economia dello sviluppo sostenibile*, Edizioni di Comunità, Turin, Italy.

De Bouw, M., Dubois, S., Dekeyser, L. and Vanhellemont, Y. (Eds.) (2016), *Energy Efficiency and Comfort of Historic Buildings*, Proceedings of the Second International Conference, Brussels, October 19-21, 2016, Belgian Building Research Institute, Brussels.

Della Torre, S., Cattaneo, S., Lenzi, C. and Zanelli, A. (Eds.) (2020), *Regeneration of the Built Environment from a Circular Economy Perspective*, Springer, Cham, Switzerland.

De Santoli, L. (2015), "Guidelines on energy efficiency of cultural heritage", *Energy and Buildings*, Vol. 86, pp. 534-540.

Fabbri, K. (2013), "Energy incidence of historic building: Leaving no stone unturned", *Journal of Cultural Heritage*, Vol. 14, n. 3, supplement, pp. 25-27.

Göttler, M. and Ripp, M. (2017), *Community Involvement in Heritage Management Guidebook*, OWHC Regional Secretariat Northwest Europe and North America, Regensburg.

ICOMOS (2011), *The Paris Declaration on heritage as a driver of development adopted at Paris, UNESCO headquarters, on Thursday 1st December 2011*, Paris, France.

ICOMOS (2017), *ICOMOS Action Plan: Cultural Heritage and Localizing the UN Sustainable Development Goals (SDGs)*, Istanbul, Turkey.

ICOMOS CCHWG (2019), *The Future of Our Pasts: Engaging Cultural Heritage in Climate Action. Outline of Climate Change and Cultural Heritage*,Paris, France.

ICOMOS CIVVIH and ICOMOS-Korea (2017), *Urban Heritage and Sustainability.*

Leeuwarden Declaration (2018), *Adaptive Re-Use of the Built Heritage: Preserving and Enhancing the Values of our Built Heritage for Future Generations*, Leeuwarden, Netherlands

Lefevre, R.A. and Sabbioni, C. (Eds.) (2010), *Climate Change and Cultural Heritage*, Edipuglia, Bari, Itay.

López, M., Yánez, A., Gomes Da Costa, S. and Avellà, L. (2014), *Energy Efficiency in Historic Buildings*, Proceedings of the International Conference, Madrid, September 29-30, Fundación de Casas Históricas y Singulares y Fundación Ars Civilis, Madrid, Spain.

Lucchi, E. and Pracchi, V. (Eds.) (2013), *Efficienza energetica e patrimonio costruito. La sfida del miglioramento delle prestazioni nell'edilizia storica,* Maggioli, Santarcangelo di Romagna (RN), Italy.

Magrini, A., Franco, G. and Guerrini, M. (2015), "The Impact of the Energy Performance Improvement of Historic Buildings on the Environmental Sustainability", *Energy Procedia*, Vol. 75, pp. 1399-1405.

MARSH, ICCROM, ICOMOS-ICORP and UNESCO (2013), *Heritage and Resilience. Issues and Opportunities for Reducing Disaster Risks*, Geneva , Italy.

Mickaityte, A., Zavadskas, E.K., Kaklauskas, A. and Tupenaite, L. (2008), "The concept model of sustainable buildings refurbishment", *International Journal of Strategic Property Management*, Vol. 12, n. 1, pp. 53-68.

Morin, E. (2000), *La testa ben fatta. Riforma dell'insegnamento e riforma del pensiero*, Raffaello Cortina, Milan, Italy.

Nara+20 (2014), *Nara+20: on heritage practices, cultural values, and the concept of authenticity*, Nara.

Pianezze, F. (2009-2012), *L'obiettivo del miglioramento dell'efficienza energetica nel processo di conservazione del costruito storico*, Tesi di Dottorato in Progetto e tecnologie per la valorizzazione dei beni culturali, Politecnico di Milano, XXIV Ciclo, Tutor Prof. S. Della Torre, Prof V. Pracchi.

Pracchi, V. (2014), "Historic Buildings and Energy Efficiency", *The Historic Environment*, Vol. 5, n. 2, pp. 210-225.

Pretelli, M. and Fabbri, K. (2018), *Historic Indoor Microclimate of the Heritage Buildings. A Guideline for Professionals who care for Heritage Buildings*, Springer, Cham, Switzerland.

UN (1987), *Report of the World Commission on Environment and Development: Our Common Future*, Oslo, Norway.

UN (1992), *United Nations Framework Convention on Climate Change*, New York, USA.

UN (1997), *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, Kyoto, Japan.

UN (2012), *Resolution adopted by the General Assembly on 27 July 2012. 66/288. The future we want*, Rio de Janeiro, Brazil

UN (2015), *Resolution adopted by the General Assembly on 25 September 2015. 70/1. Transforming our world: the 2030 Agenda for Sustainable Development*, New York, USA.

UNESCO (1972), *Convention Concerning the Protection of the World Cultural and Natural Heritage. Adopted by the General Conference at its seventeenth session,* Paris; France.

UNESCO (2015), *Policy Document for the Integration of a Sustainable Development Perspective into the Processes of the World Heritage Convention as adopted by the General Assembly of States Parties to the World Heritage Convention as its 20th session.*

UNESCO and UNDP (2013), *Energy Efficiency and Energy Management in Cultural Heritage. Case Studies Guidebook*, Venice/Zagreb.

UNFCCC (2019), *UN Climate Change Annual Report 2018.*

UNISDR (2009), *Terminology on Disaster Risk Reduction*, Geneva, Italy.

THE FUTURE NOW: An adaptive tailor-made prefabricated Zero Energy Building

Antonella Violano, Lorenzo Capobianco, Monica Cannaviello,
Department of Architecture and Industrial Design, University of Campania "L. Vanvitelli", Italy

antonella.violano@unicampania.it
lorenzo.capobianco@unicampania.it
monica.cannaviello@virgilio.it

Abstract. How much space do we need for living? In a backcast vision, the living scenario is inscribed in spaces for short stays, concentrates functions strictly necessary to the daily needs of its occupant, and takes the archetypal shape of the "refuge", naturally inspired but technologically advanced. (Robinson 1982). The contribution proposes results of an experimental technological design conducted by the "ZEBtwdZEEB" research group of the University of Campania "L. Vanvitelli", in collaboration with industrial partners, which led to the construction of a prototype of a zero energy building (3x3m single user residential unit), built with the innovative LGS Construction System in cold-formed steel. Various envelope solutions, which ensure high energy performance, have been designed for it.

Keywords: Zero Energy Building; Adaptive Technology; Embodied Carbon; Light Construction; Human-centred Design.

La Petite Cabane: the design approach

A consolidated tradition of scientific studies, in modernity, traces the evolutionary lines of the theme of minimal housing, driven by the need to provide answers to the basic needs of human living. The instinctive search for protection and shelter, points out Marc-Antoine Laugier in his description of the *cabane rustique*, is on the other hand an archaic and primordial action, which in becoming construction and translating into a refuge gives rise precisely to architecture: «Man wants to make himself an accommodation that covers him without burying. Some branches cut in the woods are the materials suitable for his design. He chooses four of the strongest, and raises them perpendicularly, arranging them in a square. Above, it has four more sideways; and on these other sloping slopes, which point together in the middle inclined and joined to form a sort of roof covered with foliage [...] The small rustic hut that I have described thus is the model on the basis of which all the magnificence of Architecture» (Rykwert, 1972).

Imagining a "minimal house" today, in the inevitable tension to the essential that guides the project and with a view to a backcast vision (Robinson, 1982), confronts us with scenarios in which the choices we made must refer to a renewed and extended vision of sustainability, well-being, awareness of the territory, protection of the landscape as well as having to interpret the changing needs of contemporary living. It is not a question of providing only a practical solution to a need but also of trying to graft, through the project, processes and practices that can act as a reference for the whole community in the direction of reduced and more aware consumption of energy and space resources of our territories. Imagining the minimal functions of domestic life, studying their arrangement and reciprocal relationships, imagining the nature and characteristics of the space of the home, also means taking into account its "essential" equipment, its performance, its aesthetic qualities, its economic and environmental costs, and the possibilities related to the ease and immediacy of its construction (Ishida and Furukawa, 2013).

An innovative light steel bending technology, in this experimental design, makes available to the project, after a phase of careful engineering, a "new" construction system substantially based on assembly techniques. The lightness and speed in the production and subsequent assembly of the structures built with this technology are such as to go well beyond the times with which we are accustomed to dealing in the world of construction, and determine a drastic reduction in costs also with regard to the transport logistics of materials needed for construction. Basically we are faced with a modular frame system that allows large free spans, very small thicknesses and unimaginable plant and design flexibility.

A very small space (3x3 m) is the minimum surface necessary to create a technologically advanced envelope experimenting the design of an archaic space, natural inspiration, through the intersection of simple volumes that define one internal space "flooded" with natural light. A bright, comfortable and performing shelter describes the minimum measures for sleeping, eating, studying, taking care of yourself, and also for spending leisure time.

The *Petite Cabane* (Fig. 1) develops on two levels in height. It is precisely the design of the section of the house, in its configuration of a double height, which conceals the minimum footprint of the internal space to give its occupants an unexpected sensation of amplitude. The house is slightly raised above the ground, and its shape recalls the archetypal image of the hut in the inclination of the roof. This research was also developed through the creation of a prototype on which performance tests are currently underway. The use of innovative technologies for its construction refers to multiple areas of investigation, study and further experimentation. In particular, the possibility of resorting to self-construction and achieving energy independence outlines scenarios of great interest as a response to the social and environmental emergencies with which we daily measure ourselves.

The technological design experimentation: method and results

Petite Cabane is the result of research project experimentation entitled "3X3 Zero Energy Building", which is part of the activities of the Research Group " ZEB towards ZEEB " of the DADI Department of the University of Campania "L. Vanvitelli". It has been established with an agreement with LSF Italia srl and the participation of ten other industrial sponsoring partners in the prototype implementation phase. Considering the design process as a complex decision-making process, the principles of predictions and ordinary nature determined choices based on "general validity" and "probabilistic objectivity" criteria until the end of the last century. Such principles were considered immanent characteristics basically for the design choices made at time x, but they have been replaced by the predictive and proactive backcasting approach, due to the need to reverse the negative trend foreseen by visions of 2050, and change the paradigm by acting at time x with choices that are functional to the implementation of future scenarios (at time x + k) desirable through a "long-term technology" that focuses on the right choices in the individual steps of the "cradle to cradle" process. With the

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Tab. 01 |

	Wall Tipologies					
Codex[5]	WS_B.tlv	WS_B.wtl	WS_D.tl	WS_D.wtl	WS_F.tl	WS_F.wtl
Stratigraphy						
Thickness [cm]	15	11	16	13	17	15,5
Thermal Transmittance (U) [W/m²K]	0,318	0,400	0,272	0,281	23,7	0,234
Periodic Thermal Transmittance (Y_{ie}) [W/m²K]	0,100	0,362	0,062	0,23	0,055	0,160
Time Lag [h]	9h 15'	3h 16'	10h 10'	3h 60'	10h 40'	5h 30'
Decrement factor [n]	0,315	0,905	0,228	0,818	0,232	0,686
Superficial Mass [kg/m²]	74,45	41,85	66,55	26,5	58,65	33,05
Resistance [m²K/W]	3,15	2,50	3,68	3,56	4,21	4,28

Tab. 01 | Energy performance of different designed stratigraphies of prototype

Tab. 02 | Energy summer performance of the same stratigraphy with the different positions of layers

| Tab. 02

	Codex	Stratigraphy	Thickness [cm]	Thermal Transmittance (U)[W/m²K]	Periodic Thermal Transmittance (Y_{ie})[W/m²K]	Time Lag [h]	Decrement factor [n]	Dynamic analysis in summer check	Thermal penetration depth [m]	Tsupl/TsupE
Wall Tipologies	WS_B.tlv_1		15	0,318	0,095	9h 15'	0,315		0,0056	0,0113
	WS_B.tlv_2		15	0,318	0,145 ↑	7h 18' ↓	0,476 ↑		0,0390 ↑	0,0176 ↑

(EU) Directive 2018/844, the Union is committed to developing a sustainable, competitive, secure and decarbonised energy system by 2050. These elements are part of the design methodology of the "3X3 ZEB " research. The innovative Light Gauge Steel (LGS) Construction System (Fig. 2) has been the added value for decarbonising structural components of the planned building system, as illustrated in the following paragraph.

The research is divided into five phases:

- WP1 / KC_ knowledge and consciousness (1 / KC);
- WP2 / S_experimentation;
- WP3 / TC_theoretical check (3 / TC);
- WP4 / LT_laboratory test;
- WP 5 / E_enterprise[1].

In WP1/KC (the initial phases of the project), we referred to international research, the proposed process and product innovation it is based on. We, therefore, started by identifying the requirements of regenerative architecture, which proactively reverses the trend of all design choices generating environmental damage, and focuses on solutions that have a long-term positive net impact (Attia, 2018; Mang, 2016). The choice of products and materials follows the "Cradle to Cradle" approach (McDonough, 2010), considering their opportunity to be eco-friendly according to their possibilities of reintegration in the biological cycle (biosphere) or the technological cycle (techno-sphere) at the end of their service life. Finally, a Core set of Indicators evaluates the regenerative quality of architecture (Attia, 2018), ecological and carbon footprint (Solis-Guzman, 2015) and reduction of CO_2 emissions without energy sacrifice (Rovers, 2019).

In WP2/S, the design of building envelope components considered the following criteria:

a. optimisation of consumption and emissions during the operational phase (operational energy and carbon reduction);
b. optimisation of consumption and embodied emissions (embodied energy and carbon reduction);
c. recyclability/reusability of the components, also in relationship with the ease of disassembly;
d. choice of materials also in relationship with the embodied energy and carbon (Geiser, 2001);
e. basic component design according to the nZeBOX approach and identification of additional panels in relationship with specific needs (climatic context, regulatory requirements, integration of renewable sources, etc.);
f. design of the envelope system with interchangeable panels (study of the connection system among the panels), also integrating innovative bio-based materials;
f. design of thermal and electrical systems, optimising efficiency in order to reduce the need for non-renewable primary energy; the type of system chosen, the materials and the installation methods (level of separability) also considered the incorporated energy and the expected service life;
h. integration of renewable, thermal and electrical sources; choice of materials through a balance between energy benefits in the operational phase and embodied carbon.

The actual competitiveness of the final product on the market is given by the high performance eco-oriented envelope, which is able to meet the energy-environmental requirements. On a market based on C2C principles, economic growth is separated from the consumption of resources. This includes both the more strictly technical aspects, such as the design of modular products and innovative eco-design in the product stage, and the new reuse/recycling methods in the end of lifecycle stage, but also product traceability and alternative business models, which will redefine requirements (mandatory standards).

Particularly, in the WP3/TC phase, the designed wall solution allows high technological performance, even when it is less than 20 cm thick.

The performance evaluation of the envelope system (tab. 1) has been made in relationship with three different climate zones (B, D, F), both on the individual components, in relationship not only with the Italian standards in force, but also in relationship with the LEED certification system (this phase is contemporary to the WP2 phase), and on the building-plant system of the 3x3 prototype, not only in a steady state (using the calculation method adopted by the standard UNI/TS 11300 and calculating the values with the PAN 7.0 software), but also in a dynamic mode as adopted by the standards UNI EN ISO 52016-1 and 52017-1 on dynamic hourly calculation.

The minimum requirements laid down by Ministerial Decree of 2015/06/26 foresee a Maximum Thermal Transmittance (U) value of 0.43-0.40 W/m²K in zone B, 0.29-0.32 W/m²K in zone D and 0.24-0.26 W/m²K in zone F. This significant variation makes it impossible to design a single stratigraphy valid for all climatic conditions. In addition, since for zone B the duration of the heating season is 121 days, which becomes 166 days in zone D, and 200 days in zone F, with an increase of about 65% in heating days, homogenising performance to the most unfavourable condition means an unnecessary (not to say unfavourable) increase in costs. For an average irradiation of the month of maximum sunshine greater than 290 W/m², the summer check must also be carried out, depending on the surface mass excluding plaster (>230 kg/m²) or, alternatively, on Periodic Thermal Transmittance (Yie<0.1 W/m²K). Therefore, in cli-

01 | The *Petite Cabane*, ground and first floor plans, architectural project by L. Capobianco

02 | The construction system and assembly phases in the company

mate zones A-D, the stratigraphy of the vertical perimeter wall may need an additional stratigraphic element to increase the value of the Thermal Lag. Table 1 shows the main energy performance values of the different designed stratigraphies.
The only invariant element is the high performance thermal insulation layer, which is 9 cm thick and is placed in the C-element of the aluminium structure. Since the embedded carbon coefficients (ECC) are expressed in kg of Co_{2eq}($kgCo_{2eq}$) per kg of material (kgm), the technological solution must minimise the amount of material used. Therefore, the designed stratigraphies follow this concept.
The laboratory test for thermo-hygrometric and environmental performance on the designed individual components of the envelope, the patent for innovative elements and the Certification of performance are in progress, as well as the creation of a spin-off on the existing start-up for which funding is awaited.
Special attention was paid to the evaluation of the summer performance of the envelope components (Tab. 2). In such conditions, in fact, the thermal wave must be not only poorly conductive, but also very massive and with high specific heat, in order to allow the envelope system to transmit weakly. So, the heat received at each layer is stored inside the layer itself without determining a thermal gradient between the layers that favours diffusion. With an external finish made of a material with high conductivity (but also high density and specific heat), the heat flow would be high in the first layer but would not pass through the next. In this experimentation, considering the type of wall WS_Btlv, designed for the most unfavourable summer weather condition, the simple variation in the position of layer 1 (insulation) with layer 2 (wood cement) determines an increase in the depth of penetration of the thermal wave (from 5.6 mm to 39 mm) with a consequent increase of the decrement factor (from 0.315 to 0.476). But the most significant data is the reduction of the summer time lag value (from 9h 15' to 7h18') and the summer value of the periodic thermal transmittance (from 0.095 W/m^2K to 0.145 W/m^2K), which is no longer verified by law. Therefore, in addition to the alternation of layers (resistance and capacitance layers), the reciprocal position is also significant.

From Zero Energy target in the operational phase to embodied carbon reduction

The targets set by the Report of World Green Building Council in 2019 (www.worldgbc.org), according to which the construction sector emissions should fall to zero by 2050, are not limited to assess the amount of CO_2 emitted during operational life, but they also aim at limiting the amount of Embodied Carbon, which contributes to nearly 11% of all global carbon emissions. Particularly, the emissions associated with the initial Embodied Energy, also defined "*Upfront Carbon*", will be responsible for half of the whole carbon footprint of the new buildings between today and 2050.
Hence, a paradigm reversal in the choice of materials and the con-

01 |

| 02

Tab. 03 | Initial embodied carbon ("upfront" carbon) of the *Petite Cabane* structure

struction process becomes increasingly urgent, favouring the use of innovative materials and processes that effectively reduce the carbon embodied in buildings.

Particularly, the 3X3 Zero Energy Building is not only zero energy in the operational phase, but also net zero embodied carbon in the rest of its service life, with a low "upfront carbon" content.

It has been shown that most of the embodied energy and carbon in buildings is attributable to the load-bearing structure, especially when it is made of steel (De Wolf et al, 2017).

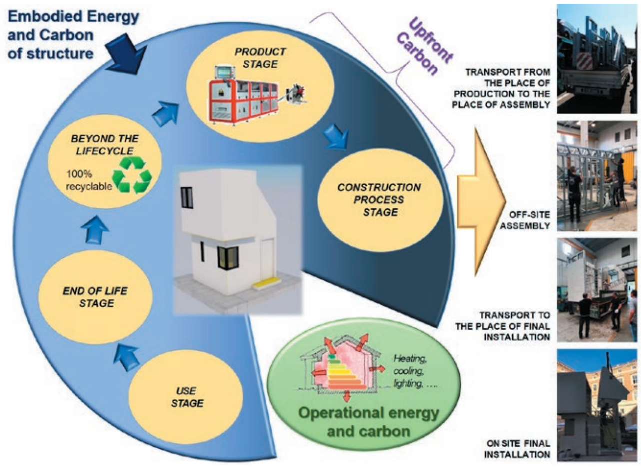
The first step was the analysis of the embodied energy and carbon in the load-bearing structure (Fig. 3), made with cold pressed galvanised steel (CFS) profiles with the LGS system. Galvanised sheets with a zinc layer 275 g / m^2 are used in production to create 140 mm thick profiles with 0.8 - 1.2 mm material thickness (source: http://lgs-montazne-kuce.com/lgs-materials).

Generally, one of the main rules for reducing embodied carbon in buildings consists in using less material (source: Cutting embodied carbon in construction projects - wrap.org.uk).

The use of cold-formed steel for small buildings can result in up to 30% less embodied carbon than hot-rolled steel because cold formed steel frames (for 18 m and 24 m span buildings) are lighter (Johnston et al. 2018).

The production system of the profiles used to carry out the *Petite Cabane* prototype used a Controlled Automatically Roll Forming Machine, which allowed to optimise the quantity of steel used, sizing the structure according to the specific dimensional, formal and structural needs. This avoided pointless oversizing of the middle section of the frames, generally indicated as one of the most frequent inconveniences in the design practice of steel structures (Moynihan et Allwood, 2014), and which increases unnecessary tons of CO_2 emitted. The machine is controlled through a software, which represents the system's core. It simultaneously performs static analysis and sizing. The software simplifies the traditional profile manufacturing process and reduces the additional cuts and relative energy consumption.

One of the main environmental advantages of this construction system is the optimisation of the relationship between resistance and weight of the structure, as this allows to reduce the initial embodied carbon: the whole structure of *Petite Cabane* weighs only 800 kg!



| 03

The profiles of the steel structure were carried out in Poland, preassembled in the company for partial spatial elements, and the various parts were assembled within the courtyard of the Royal Palace of Caserta in a very short time (Fig. 4).

In order to evaluate the upfront carbon of the load-bearing structure, in addition to the embodied energy in steel, the energy for transportation and assembly must also be added. The embodied carbon for assembly was nearly equal to zero, as the system does not require any heavy handling and it requires neither lifting equipment, nor welding, nor cutting, nor onsite drilling machinery also because the profiles are already made and equipped with the holes necessary for installation and with service holes for electrical, plumbing and other plant systems. So, it was sufficient to connect them according to the "Do-it-Yourself " principle.

The construction of the *Petite Cabane* prototype structure required 4 hours of work performed by 4 unskilled workers. This allowed to eliminate the energy connected to onsite construction processes.

The life cycle assessment (LCA) approach, used to evaluate the environmental sustainability of the Petit Cabane structure, helped to quantify associated embodied carbon.

The system boundary is from Cradle to Site:

- steel production phase (from cradle to gate);
- transport from the production site of steel profiles to the construction site:
  - -rom Poland to the pre-assembly site;
  - -from the pre-assembly site to the final destination (Caserta Royal Palace);
- off-site construction (pre-assembly in the factory shed);
- onsite construction (final assembly on the destination site).

Data used for the calculation:

| Tab. 03

Life-Cycle phase		System boundary	Embodied carbon [$kgCO_{2eq}$]
Extraction and manufacturing stage of steel production		From cradle to gate	2.024
Construction phase	*Transport to the site*	From gate to site	1.481
	Of-site construction		Negligible
	On-site construction		Negligible

04 |

04 | The transport and assembly phase of the prototype

- weight of the structure: 800 kg;
- distance travelled between the production site of the steel profiles to the construction site:1,740 km;
- number of trucks used: 1;
- number of trips: 1;
- diesel consumption: 0.325 L/km;
- emission factors of transportation by diesel truck: 2.62 $kgCO_{2eq}/L$ (Yan et al. 2010);
- embodied carbon of steel, cold rolled coil: 2.53 $kgCO_{2eq}/kg$ (ICE Database V3.0 Beta – 7 Nov 2019).

The calculation of the "upfront carbon" of the structure is shown in table 3.

As can be seen from the table, the embodied carbon attributable to transport has a high relevance in the calculation of upfront carbon. However, this criticality can be solved either by creating new production sites closer to the construction sites, or by identifying alternative modes of transport. The off-site construction of the prototype has also contributed to a reduction and better waste management, «On-site construction waste can account for up to 15% of the embodied carbon of a building; off-site construction can significantly reduce this by more than two-fold in most cases» (source: Cutting embodied carbon in construction projects - wrap.org.uk).

Finally, the *Petite Cabane structure* has the enormous advantage of being 100% recyclable at the end of its lifetime, with consequent benefits in terms of "beyond life carbon".

Wall cladding panels have been applied to the structure, suitably designed not only to optimise the primary energy requirement during the operational phase, but also to minimise embodied energy and carbon.

Conclusion

In a future vision of social and energy equity, the building system is designed to significantly reduce not only the energy needs and emissions in the operational phase (energy and carbon net zero in operational phase), but also the embodied energy and carbon. The structure, easily built in all world contexts, even in countries where skilled labour is not present, is designed to be assembled according to the "do-it-yourself" principle. In fact, it offers the advantages of prefabrication without being linked to the constraints that generally characterise prefabricated systems. However, the envelope system varies according to the context in order to optimise performance to the maximum and comply with the binding legislative requirements.

The real competitiveness on the market is given by the high performance eco-orientated smart envelope, which can satisfy significant energy-environmental requirements.

The results of the conception, design, feasibility study (technical, legal, administrative, economic and energy-environmental) phases have been positive. The study phase was followed by the production of the prototype, "3x3 ZEB ... la Petite-Cabane" which was presented at the event "The European Researchers' Night", held on 27-28 September 2019 at the Royal Palace of Caserta (Fig. 5).

The academic Spinoff is being defined. Its objective is to complete the experimentation in order to obtain certification of the system and individual components. At the moment, the main limitation of the research is the acquisition of adequate funding to build all typologies of designed components in order to start the "commissioning phase".

| 05

05 | The *Petite Cabane*, at the European Researchers' Night 2019

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NOTES

[1] The last two phases are being implemented.

[2] The stratigraphic code is defined as follows: Wall Stratigraphy_climate zone. time lag verify or Wall Stratigraphy_climate zone.without time lag verify.

REFERENCES

Attia, S. (2018), *Regenerative and Positive Impact Architecture: Learning from Case Studies*, Springer, Liege, Belgium, pp. 33-45.

Barucco, M.A. (2015), *Progettare e costruire in acciaio sagomato a freddo*, Edicom Edizioni, Bologna, Italy.

De Wolf, C., Pomponi, F. and Moncaster, A. (2017), "Measuring embodied carbon dioxide equivalent of buildings: A review and critique of current industry practice ", *Energy and Buildings*, Vol. 140, pp. 68-80.

Geiser, K. (2001), *Materials Matter. Toward a sustainable materials policy*, MIT Press, London, United Kingdom.

ICE Database V3.0 Beta - 7 Nov 2019, "https://circularecology.com/embodied-energy-and-carbon-footprint-database.html", (accessed 08 May 2020).

Ishida, E.H. and Furukawa, R. (2013), *Nature Technology: Creating a Fresh Approach to Technology and Lifestyle*, Springer Science & Business Media, Japan.

Johnston, R.P.D., McGrath, T., Nanukuttan, S., Lim, J.P.B., Soutsos, M., CheeChiang, M., Masood, R. and AfjalurRahmanc, M. (2018), "Sustainability of Cold-formed Steel Portal Frames in Developing Countries in the Context of Life Cycle Assessment and Life Cycle Costs", *Structures*, Vol. 13, pp. 79-87.

Mang, P., Haggard, B., Mang, P., Haggard, B. (2016), *Regenesis. Regenerative Development and Design: A Framework for Evolving Sustainability*, John Wiley & Sons, Incorporated.

McDonough,W and Braungart, M. (2010), *Cradle to Cradle: Remaking the Way We Make Things*, Farrar, Straus and Giroux, New York, USA.

Moynihan M. C. and Allwood, J. M. (2014), "Utilisation of structural steel in buildings", *Proceedings of the Royal Society* A, Vol. 470, Issue 2168.

Robinson, J.B. (1982), *Energy backcasting - A proposed method of policy analysis, in Energy Policy*, Butterworth & Co (Publishers) Ltd.

Rovers, R. (2019), *People vs Resources. Restoring a world out of balance*, Eburon Academic Publisher, The Netherlands, pp. 325-329.

Rykwert, J. (2005), *La casa di Adamo in Paradiso*, Adelphi, Milan, Italy.

Solis-Guzman, J. and Marrero, M. (2015), *Ecological Footprint Assessment of Building Construction*, Bentham Science Publishers.

Voss, K., Sartori, I and Lollini, L. (2012), "Nearly-zero, Net zero and Plus Energy Buildings – How definitions & regulations affect the solutions", *REHVA Journal,* pp. 23-27.

Yan, H., Shen, Q.P., Fan, L.C.H., Wang, Y and Zhang, L. (2010), *Greenhouse gas emission in building construction: A case study of One Peking in Hong Kong*, Build. Environ, Vol. 45, pp. 949-995.

Will artificial intelligence kill architects? An insight on the architect job in the AI future

Dario Trabucco,
Department of Architecture and Arts, Iuav University of Venice, Italy
trabucco@iuav.it

Abstract. Artificial Intelligence's (AI) impact is already visible in several aspects of our life: when we ask for a car insurance, when we consult the weather forecast or when we plan the best route on a car trip, we are actually using AI tools. Jobs are also being affected in many fields, and studies predict AI's dramatic impact will be clear in the near future. The present study analyses the application of AI to architecture by reviewing the most recent achievements in the automation of architectural design. The study then adapts existent methodologies to predict AI's impact on the work-related activities carried out by architects. The results show that some disciplines will experience a massive impact of AI technologies with the need to adapt the way architects are trained at universities.

Keywords: Artificial Intelligence; Architecture; Job Losses; Automated Design; Work Activities.

Background and statement of the research problem

The author of this paper is coordinating a research1 to investigate the evolution and prospected future developments of construction robots. While searching for such a definition, it appeared clear that many pieces of equipment labelled as such by their own producers do not meet the most advanced idea of robot as a 'free-willing' machine. According to the Japan Industrial Robot Association robots can be divided into 6 classes, but only the highest one, class 6, features "intelligent robots", i.e., a robot that has «the means to understand its environment, and to successfully complete a task despite changes in the surrounding conditions» (Coiffet and Chirouze, 1982).

In recent years, thanks to the evolution of Artificial Intelligence (AI), robots have evolved from extremely advanced and precise machines into machines that are capable of making decisions on their own, of self-adapting, and of anticipating events based on their perception of the external environment, thus integrating robotics and Artificial Intelligence. AI is thus significantly impacting manufacturing and construction sectors, and this aspect is being investigated as a focal point of the commissioned research. Changes in the way a building is constructed can only be implemented if the way it is being designed changes as well.

The scope of this paper is to understand the impact AI will have on the architect's job by analysing AI's possibility to replace the human architect in all the various aspects of the building process. A few studies described in the paper have focused so far on the possibility of AI to assist (or replace) architects during the design phase. This initial study will consider the architect's job with all its tasks, from design to construction and testing of the finished building. The objective of the research is to understand what parts of the profession are at risk to see a more pervasive automation of the various activities they include.

Artificial Intelligence

AI can be defined as «a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible ada tation» (Kaplan and Haenlein, 2019). In simpler terms, AI can be seen as a computer program that improves itself to perform a specific task, learning from previous experience to perform better at each iteration. Like humans, AI needs to 'practice' to achieve improvements and the more it practices, the better it becomes. When enough data is fed to the algorithm to optimise it, AI can become better than humans in a number of extremely complex tasks, such as image recognition[2], natural language recognition, etc.

Artificial Intelligence currently exceeds human capacity in playing difficult games, such as chess, go, recognising images, etc. but also in performing tasks such as calculating mortgage risks, diagnosing diseases or predicting weather.

Human jobs in the AI future

Several studies try to understand the impact AI will have on jobs. A job can be looked at as a sequence of tasks (Autor et al, 2003). The premises to understanding the possibility of AI substituting a human worker are set out by Levy (Levy, 2018) and they are based on two observations:

1. all human jobs involve acquiring and processing information;
2. a computer processes information by executing instructions.

Consequently, the capacity of computers to replace humans has to be found in their capacity to execute either deductive instructions (i.e., if-then operations) or data-driven instructions based on statistical analysis of large quantities of input data. A deductive set of instructions can be generated when it is easy to subdivide a task into conscious decisions and actions. If-then computer programs have existed for a long time, but they have been able to displace only a small range of human jobs. Artificial intelligence – through machine learning – is capable of automating tasks where the relevant information process rationale is unclear or happens unconsciously in the human brain (Levy, 2018). Thanks to this capacity to mimic the natural processing phenomena of the human brain, the possibilities of AI are far more impactful.

A comprehensive study was conducted at the Oxford University in 2013 (Frey and Osborne, 2013). The study analysed the likelihood of jobs being displaced by AI, resulting in an astonishing 47% of jobs currently (as of 2013) in danger of being substituted by AI in the foreseeable future.

A WPC study (Hawksworth et al., 2018) subdivided potential job losses across industry fields, professions and countries, distinguishing three technological waves (caused by major breakthroughs in AI and automation). Jobs at risk of automation range from less than 10% in "education" (where social relations and human-to-human communication are of the utmost importance) to a 50+% rate in the sector of "transportation and storage" (with autonomous driving vehicles disrupting most of the jobs) with "professionals" risking a marginal 15%.

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Artificial Intelligence in architectural design

The application of AI to the design of buildings is not new. Efforts to reproduce an architect's design capabilities with a computer date back to the late 1960's (Negroponte, 1970). However, AI research experienced various periods of brisk decay but it is now headed towards a prosperous future (Lee, 2019). Consequently, and thanks to the advanced abilities of present day computers, research into the possible use of AI to automate architecture is experiencing an unprecedented success rate. An extensive literature review of the technical possibilities and different methods offered by AI applied to architecture is presented by Newton (Newton, 2019). In general, the design of buildings is being treated by AI scientists using neural networks. Neural networks are good at comparing images, and at learning from this comparison with the goal of generating new images. For instance, a study conducted in 2018 (Huang and Zheng, 2018) uses a Generative Adversarial Network (GAN) to generate apartment floor plans. Two floor plans - a visual image and its labelled description - are entered in the GAN, and compared to understand if they are the same or not. After the algorithm is trained with hundreds of pairs, it can generate the second image when only one image of the pair is provided. The GAN generates the second image using the information learned during training, and then compares it again to the input image to improve itself. A thesis discussed at Harvard (Chaillou, 2019) uses GAN to process floor plans according to a building footprint in a building lot, creating windows and room subdivisions, and placing furniture. Architectural students are taught to look for design references and to understand the design pattern adopted by the creators of those examples to generate their own designs. GAN learns statistically significant patterns in the input data, mimicking the learning method of human brains with artificial capacity. It can look into as many references as it is fed with, and it can decipher relevant patterns (i.e., a dining room is always close to the kitchen, a dining room always has a natural source of light, the table is always present in the dining room, *sometimes* the table is close to the window, etc.) with analytical rigour.

Another field of application is the integration of AI with simulation software to create the feedback-loop described in a 2013 study on design optimisation (Gerber and Lin, 2013) consisting in the reiteration of design alternatives to identify the most effective one. By learning the consequences of a specific alteration, AI can quickly learn how to modify the input at the next reiteration, achieving optimum results in a short time and gaining a lifetime's worth of knowledge in a fraction of time.

What is missing (in the surveyed applications of AI to generate architectural drawings) is the connection that these drawings have with the future – human – inhabitants of the spaces themselves. AI can only learn from statistically significant phenomena found in the inputs used to train the machine learning model. Such inputs (i.e. building floor plans) were created by humans who had already 'digested' the aspects connecting a floor plan with the behaviour of the people who will occupy the space. Such a connection was achieved in the past by two factors, the human nature of the architect (and thus his implicit knowledge of the average desires of his own kind) and the architect's capacity to learn from de-structured data communicated by other humans.

Architects and Architecture

Architecture is the discipline, and architects are the professionals who practice architecture. Architectural design, despite being seen as the main focus of architects, is only one aspect of a profession that includes a broad number of very diversified tasks: from preliminary design to design and construction supervision, to testing of the finished building. A recent study on AI's capacity to take over humans in architecture (Mrosla *et al.*, 2019) uses the Honorarordnung fur Architekten und Ingenieure (fee structure for architects and engineers in Germany) to highlight the four main design phases that form architects' and engineers' daily job, reviewing literature in each segment. However, the referenced study especially focusses on the design aspect of architecture, providing evidence about how the progress made and expected in AI design abilities may quickly lead to the possibility of substituting human designers with AI algorithms, at least for the most recurrent projects. Conversely, aspects not related to design are not analysed in detail.

In order to understand the likelihood of architects (as humans practicing architecture) to be displaced by AI, one should look not just at the design phase of a building (though this is often regarded as the leading discipline, especially in academia), but at all the tasks an architect is required to carry out to master the entire construction process.

To achieve the study's goal, this paper proposes a methodology inspired by Frey and Osborne (2013), which consists in:

1. the 71 tasks an architect carries out during the entire building process (from inception to testing) of a public building are identified according to the Italian Ministerial Decree 140/2012;
2. each of these tasks is described using three of the "Work activities" the job of an architect is divided into, according to the O*net database (O*net, 2020), a public database that collects job descriptions, skills required and responsibilities for all jobs available in the United States of America; the database lists 41 work activities for architects; a panel of practicing architects was used in the present research to select the top three activities carried out to perform the tasks described in 1) thus resulting in an array of 213 possible work activities;
3. the same panel of architects was used to select the "Intelligence

Features" of the human brain involved in each work activity used in 1);

4. a score ranging from -2 and + 2 was assigned to each of the 213 identified Intelligence Features resulting from 3); scores are derived by a study that compares AI and Human intelligence (Komal, 2014) according to 19 categories; the study provides a table listing the level of human and artificial brains, pointing out and commenting on the advantages or drawbacks of each one; a score of -2 is assigned when the AI is a clear winner (i.e., Numerical Computation ability; Reaction Time/Speed), while +2 is assigned when the human brain is performing best (i.e., Creativity; Emotional Quotient) with proportionate mid-values;
5. average results are calculated to identify the likelihood of each of the 71 work activities from 1) to be automated;
6. work activities are subdivided according to the various disciplines taught in Italian universities for the "L-17 Scienze dell'architettura" and the "LM-4 Architettura e ingegneria edile – Architettura" courses held in an Italian University.

Limitations of the adopted methodology

The proposed study set the objective to quantify the impact of AI on the future of architects as practicing professionals by modifying the methodology used by Frey and Osborne (2013). Frey and Osborne worked on the possibility of AI displacing all sorts of jobs, while the present study focusses on the various tasks one single job (architect) is divided into. The reference methodology starts from manual labelling of 70 different US jobs, dividing them into those which are automatable and those which are not, and then using the O*net database and a scoring system to correct the previously made subjective assumptions. This study's methodology uses Ministerial Decree 140/2012 to objectively divide the architect's job into various tasks, and then to use a panel of volunteers to subjectively attribute the possibility for each task being done by AI.
The main limitations of the proposed methodology are:

- the comparison of AI and Humans is referred to a 2014 study (Komal, 2014); considering that computing speed is increasing two-fold every two years according to Moore's law, the current (as of January 2020) comparison may be much more favourable for computers;
- the work activities that describe an architect's job in the US job market may differ from those of an architect operating in Europe and, specifically, in Italy;
- moreover, the questionnaire took an average of 4 hours to complete (it consists in assigning the top 3 levels of intelligence needed by each of the 3 main skills of the 71 tasks the architect's job entails); it was, therefore, possible to involve only 10 volunteers. The involvement of a larger panel of architects in the description of their job in steps 2) and 3) of the proposed methodology may lead to different results.

Presentation and discussion of the results

The results of the study are summarised in the attached graph (Fig. 1). Work activities with scores in the left part of the graph are likely to be automated, while activities with positive values are less easily automated. An important result is the great variability of volunteers' judgements, as evidenced in figure 1 by the standard deviation bars. The scoring system adopted by the volunteers is subjective and thus the results emphasise this aspect. However, the volunteers used for the study were neither experts in AI, nor did they know much about the various tasks of an architect's job (despite all of them being registered architects in Italy). In a future phase of the research, it would be interesting to see if a volunteer's scores are affected by his/her knowledge level, for instance by attending a short seminar on AI or by selecting only senior practicing architects.
From a general perspective, architects are in a relatively calm area, with AI expected to have a marginal impact on the profession. This is likely caused by the fact that architects have very diversified tasks, involving a broad spectrum of intelligences. It is, therefore, difficult to automate the profession as a whole. On the other hand, some tasks are more likely to be transformed by AI, and the subdivision of the work activities into disciplines points out some interesting findings.
First, the disciplines related with the economic aspects of the profession are more likely to be affected by AI. Cost estimation is a practice where general trends, average costs and project-specific circumstances are mixed together. All the information pertaining to these three aspects are numbers and trends, which make the passage to a computer-controlled field of the discipline very easy. This aspect seems to be confirmed by the widespread application of AI in jobs that use the same "tools", such as banking and insurance.
Also building physics and the sector of law, despite being in the positive area, witness a certain degree of uncertainty due to the good performance of algorithms in these fields.
Unexpectedly, the activities pertaining to the core of the architectural practice (i.e. design), show some concerning results. This is in line with the successful examples of AI-generated architecture presented in the literature review.

Conclusions

AI will likely have a strong impact on all jobs. Architects and other professional figures may experience a weaker impact, if compared with more routine-based jobs. Still, it is important to start a debate within the profession and university professors on how AI will re-shape the future of practicing architects. Of course, the high variability and the artistic content of architecture defends the profession from sudden changes, but «another reason for underestimation of its importance (AI) is the interest (of the architects) in their self-preservation, which is inherent to all professions, therefore also architects. This auto-centric interest can cause general ignorance of one's own sub-

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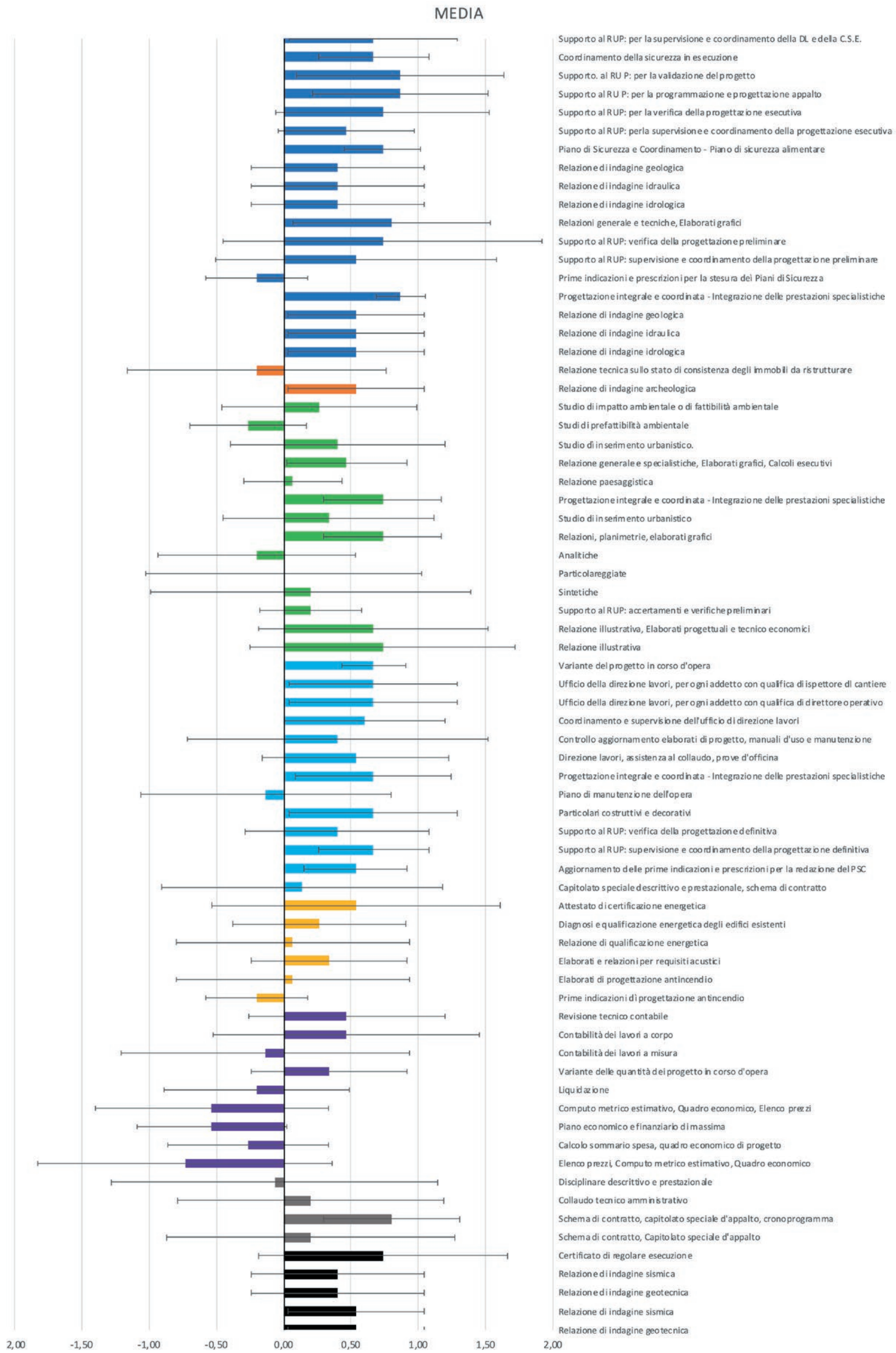

01 | Results of the research. Likelihood of the 71 work activities that form the job of an architect being replaced by AI

stitutability by machines» (Mrosla *et al.,* 2019).

Architecture universities can start looking into this future, modifying classes and the "spirit" of the profession to incorporate AI to achieve other results than the mere substitution of human intelligence with computer work. «Many computer-aided design studies are relevant only insofar as they present more fashionable and faster ways to do what designers already do. And since what designers already do does not seem to work, we will get inbred bad architecture, unresponsive architecture, even more Prolific» (Negroponte, 1970). This sentence, which dates back to 1970, is interesting to understand how AI and humans can work together in the future, rather than as alternative, competing elements. Computers have the capacity to analyse data in a more efficient, unbiased and much faster fashion than humans. This information can then be used to improve the architect's human capacities to interpret data to either predict trends or to access a variety of information that is not manageable by a human brain. However, it is the author's strong belief that future architects (and thus current programmes in architecture universities) should retain, and even improve, the choice of disciplines that form the current programmes of architecture as a technical-humanistic discipline. At the same time, the understating of the AI revolution, data analysis, ICT etc. has to be significantly enhanced.

NOTES

[1] The Author is the Principal Investigator of a 2-year research project commissioned by Schindler to the Council on Tall Buildings and Urban Habitat (CTBUH) to explore the present and future uses of robot technologies for onsite building construction activities. Total funds amount to USD 258,000 and the Iuav-based research unit's role is to create a taxonomy of the construction robots and to understand their future applications.

[2] A simple, though very effective, example of AI can be seen at https://quickdraw.withgoogle.com. This Google program uses a neural network to recognise sketches created with the mouse by the website user. As of today, each of the 345 possibilities has been drawn over one hundred thousand times. The neural network learned how humans design apples, paper clips, airplanes, etc. and now it is much faster than humans in recognising what is being drawn.

REFERENCES

Chaillou, S. (2019), *AI & Architecture - An Experimental Perspective*, Harvard University, Harvard.

Coiffet, P., Chirouze, M. (1982), *An introduction to robot technology*, Kogan Page, London, United Kingdom.

Decreto 20 luglio 2012, n. 140, "Regolamento recante la determinazione dei parametri per la liquidazione da parte di un organo giurisdizionale dei compensi per le professioni regolarmente vigilate dal Ministero della giustizia, ai sensi dell'articolo 9 del decreto-legge 24 gennaio 2012, n. 1, convertito, con modificazioni, dalla legge 24 marzo 2012, n. 27.

Frey, C.B. and Osborne, M. (2013 in press), "The Future of Employment", *Oxford Martin Programme on Technology and Employment.*

Gerber, D. and Lin, E. (2013), "Designing in complexity: Simulation, integration, and multidisciplinary design optimization for architecture", *Simulation*, 90(8), pp. 936-959.

Hawksworth, J., Berriman R. and Cameron E. (2018), *Will robots really steal our jobs? An international analysis of the potential long term impact of automation*, PWC.

Huang, W. and Zheng, H. (2018), "Architectural Drawings Recognition and Generation through Machine Learning", Wit, A.J., Del Signore, M. and Anzalone P., *Recalibration on Imprecision and Infidelity*, *Proceedings of the 38th Annual Conference of the Association for Computer Aided Design in Architecture*, Mexico City, Mexico, October 18 - 20, pp.156-165.

Kaplan, A. and Haenlein, M. (2019), "Siri, Siri, in my hand: Who's the fairest in the land? On the interpretations, illustrations, and implications of artificial intelligence", *Business Horizons*, Vol. 62, pp. 15-25.

Komal S. (2014), "Comparative assessment of Human Intelligence and Artificial Intelligence", *International Journal of Computer Science and Mobile Computing*, Vol. 3, pp. 1-5.

Lee, K.F. (2019), *AI Superpowers China, Silicon Valley, and the New World Order*, Houghton Mifflin Harcourt, Boston and New York, USA.

Levy, F. (2018), "Computers and populism: artificial intelligence, jobs, and politics in the near term", *Oxford Review of Economic Policy*, Vol. 34, pp. 393–417

Manyika, J., Lund, S., Chui, M., Bughin, J., Woetzel J., Batra, P., Ko, R. and Sanghvi S. (2017), *Jobs Lost, Jobs Gained: Workforce Transitions in a Time of Automation,* McKinsey & Company, Brussel.

Mrosla, L., Koch, V. and von Both, P. (2019), "Quo vadis AI in Architecture? - Survey of the current possibilities of AI in the architectural practice", in: Sousa, J.P., Xavier, J.P. and Castro Henriques, G. (Eds.), *Architecture in the Age of the 4th Industrial Revolution – Proceedings of the 37th eCAADe and 23rd SIGraDi Conference - Volume 2*, University of Porto, Portugal, September 2019, pp. 45-54.

Negroponte N. (1970), *The Architecture Machine*, The MIT Press, Cambridge, USA and London, United Kingdom.

Newton, D. (2019), "Generative Deep Learning in Architectural Design", *Technology | Architecture + Design,* Vol. 3(2), pp. 176-189.

O*net Online (2020), *Details Report for: 17-1011.00 - Architects, Except Landscape and Naval*, available at: https://www.onetonline.org/link/details/17-1011.00.

Future memories from the deep. An open artificial system for Kiruna

RESEARCH AND EXPERIMENTATION
Advanced Research (Under 35)

Virginia Sellari, Susanna Vissani,
Department of Architecture, Built environment and Construction engineering, Politecnico di Milano, Italy
susanna.vissani@gmail.com
virginia.sellari@gmail.com

Abstract. Thinking about an increasingly nomadic society that needs to adapt to the economic circumstances and to climate change, the dissertation aims to find a balance between anthropological and environmental needs in the extreme context of Kiruna. This city is an opportunity to imagine a possible spatial translation of a 'liquid' society. Its strong relevance in the contemporary scene is its floating in a perpetual condition of change and movement, until the necessity for its relocation due to the iron mine expansion.
The thesis moves from a deep analysis of Kiruna territory and passes through the research of the main constants that influence the foundation of cities. The project addresses the theme of the limit by creating an unusual relationship between inside and outside, natural and artificial.
Keywords: Urban Relocation; Strategy; Platform; Underground; City in motion.

Introduction

Nowadays, cities increasingly reveal their temporary and provisional nature, guided by rapidly changing forces. The world is not characterised by boundaries and borders anymore, but by networks and flows: flows of people, capitals, goods and information. In this state of affairs, the attempt to fix a stable order through architecture is not feasible anymore due to the unpredictability of the numerous variables, such as climate change, wars, and economic crises, which progressively turn people into global nomads (Aureli, 2013).
This 'forced' attitude to migration deeply affects the sense of inhabiting. It produces new meanings for identity, memory, and spatial belonging that need to be re-established and re-processed through the design process. We can say that cities are defective organisms that can work for a short span of time due to their intrinsic fixed character.
At present, this instability lacks an answer in the physical construction of urban settlements, leaving pieces of architecture built for a specific purpose (economic, energetic or industrial) the most exposed to abandonment and underuse.
The scope of our dissertation is to face this weakness in urban design through a strategic plan capable of recreating a continuous balance in the whole structure, while explaining the possibilities of keeping a city alive.
The city has been chosen as a case study in order to address possible answers to figure out the future spatial layout of this city encountering the identity of the place. The aim is to open new lines of research where «Kiruna will perhaps be a model for other cities in the world. One can for example imagine that climate change and a rising sea level will force cities to move to safer places. In that case our experiences in Kiruna can be of great help to people who work with city planning» (Kiruna, 2007).
Our research has been conducted using multiple methods and a variety of data related to the urban structure. Readings and articles create the theoretical background to build the knowledge of the place. The onsite visit was useful to understand the harsh environmental conditions, always taking into account the different territorial scales, from the very large Arctic landscape to specific site area. Interviews with inhabitants, local indigenous groups, miners and scientific guest workers, municipal officials and economic actors provided information about a territory shaped by continuous struggles.

Kiruna. A city in motion

Located on the northernmost border of Sweden, Kiruna lies 140 km away from the circumpolar line. With its extreme geographical limits, intensely cold climate, and natural landscape, this city emulates visions of towns situated at the edge of the world. Kiruna is part of such an unmitigated nature where clear signs of industrial landscape show pervasive changes brought about by Man.
Born at the beginning of the 20th century as a small mining village, Kiruna is today a city of 20,000 inhabitants where the iron mine represents the most important economy. Its dimension has now reached the same extension of the city itself with a depth of 1,175 m in the Earth.
The iron mine is the predominant feature from every viewpoint: its sight is external for those arriving in Kiruna and internal for those who live there. What its inhabitants are witnessing is a kind of slow-motion earthquake: the soil deformation produced by iron extraction is gradually subsuming a large area of the town endangering the stability of buildings. For this reason in 2004 the municipality, under the influence of the mining company LKAB (Loussavara-Kiirunavaara Arktiebolag), decided to relocate almost the entire town[1].
Kiruna is part of a "mining cities archipelago" including open mines and other drilling sites situated throughout Lapland. We can say that the *genius loci* of this city and this territory is *oeconomicus* and largely derives from a capitalist attitude, namely the exploitation of soil resources and their trade on the global market. LKAB deeply influences the town and its population, in terms of numbers. When the demand for iron is high, the city's population too grows; and when the economy slows down, the population too decreases. This shows how the two entities are interrelated, and how the economy has a real effect on urban structure. The symbiosis between the mine and the inhabitants is obvious even according to the local saying, "Kiruna catches a cold if LKAB sneezes" (Nilsson, 2010).
In Western history, the engine of a city has seldom stopped working, reminding us that cities can die, leaving post-human and de-urbanised territories.
In "Apocalypse Town" (2012), Alessandro Coppola describes the history of the city shaped by capitalism as part of a consolidated script. A violent external shock strikes the city, producing a very sudden conclusion of its existence. The subsequent dispersion of a large part of the population concludes the plot definitively. The end of cities such as Detroit, Cleveland and Flint was not sudden but, on the contrary, a long agony capable of producing a huge amount of ruins, both social and material (Coppola, 2012).
The question is if and how this plot can be turned into something different, making it possible for citizens to live in Kiruna even when the mining era draws to a close.

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01 | Kiruna, panoramic view, image by Virginia Sellari and Susanna Vissani

Kiruna is now witnessing a phase in which the rhythm of the city and the rhythm of the mine are disconnected. They work at different times, and the symbiosis that characterised the first century of its history is currently lost. In a city built in such a harsh environment by a ruthless builder (capitalism), and where the prevalent engine is the mine, what would happen if the engine stopped working? Would the entire city come to a halt?
The project attempts to answer these questions by imagining a different urban structure in which flows, movement and adaptability are the interpretational keys, and in which the traditional 'figures of speech' – the street, the square, the façade – will turn into something different.
The operation of 'moving' Kiruna is not only a pure process of replacement. It also represents the opportunity to think about a new city model: re-shaping its identity, yet maintaining the ability to be the physical support for community life.
The goal of this research is to face the above instability with a strategic plan capable of recreating a balance in the whole structure, even if it is continuously disturbed by external forces. By now, building urban resilient strategies is an unavoidable necessity for our contemporary and future agenda.
«Our time is experiencing a new season in which architecture is no longer the construction of city but, like a new branch of physics, the outcome of the dynamics of force fields in perpetual motion, that precious professional alibi of the architect – the mystical 'spark' of inspiration – is obviously outdated. […] His task is truly impossible: to express increasing turbulence in a stable medium» (Koolhaas, 2016).
Starting from this assumption, the new urban paradigm for Kiruna is a city designed as an "open artificial system". "Open" because it can be freely adapted and is accessible without restrictions. "Artificial" is related to its character of being completely man-made, ruled by a rational logic. The "System" is linked to its individual parts' ability to work together as parts of a mechanism.

The project between nomadic and sedentary attitude

Kiruna is also a place dense with territorial struggles between different forces: underground iron extraction and surface instability, anthropic and natural environments, silence and mine deflagrations, sedentary and nomadic habits. The expansion of the mining industry and the construction of the city itself destabilised free movement of the nomadic Sámi tribes across Lapland.
The Sámi are indigenous groups who have inhabited the northern Arctic and sub-Arctic region for at least 5,000 years. These people, along with other ethnic groups, lived by reindeer herding for several centuries, and they traditionally used to travel across the region following the movement of the herds through the valleys and waterways characterising this landscape by being geographically distributed in parallel strips. They live in a territory that is not related to a specific nation, moving across Norway, Sweden, and Finland, so they do not perceive the stability of State borders (Borchert, 2001).
The habitation of Arctic landscapes seems to blur the notion of city life and boundaries into something that we might call "extended Arctic urbanity" (Hamdouch, 2017).
The inhabitants define their urban lives in a more extensive territory than the physical limitation of the actual city. This concept is also valid in Kiruna. The city itself rests in a vast landscape, with the nearest city situated 120 kilometres away, which means that the inhabitants are continuously interacting with their surroundings - through their cabins, leisure activities, harvesting the land's resources – and thus softening these borders (Johansson, 2010).
Their everyday practices shape this environment, and the life of each inhabitant is mutually influenced by the landscape and its coexistence with the city. Hence, the conflict is not just between local culture and international capitalism but, instead, also involves two types of economies and their very different approaches to land use on which both depend (Forrest, 1996).
Around Kiruna, a particularly important reindeer's route is being

02 | New urban system composition, image by Virginia Sellari and Susanna Vissani

| 02

deviated by the construction of the new railway and, in general, Sámi needs and their idea of space are not taken into account in the general planning of the territory (Borchert, 2001).
This blurred nomadic concept of the territory contrasts with the traditional Western way of approaching space. Setting borders in order to identify man's own space from the uncontrolled outside is something close to Human nature. As explained perfectly by Hannah Arendt in "Vita Activa", the structure of the *polis,* allowed by the physical construction of the walls and structured by its rules, is a sort of "organized remembrance" (Arendt, 1989). In this vision, the walls represented not only a protection from the outside but also from the non-place, from the non-being. So we can say that inhabiting a city also meant an act of identification. In our Western culture, the space is defined by walls, boundaries, and properties, and the city is designed with a specific centre.
This digression about the limit is meant to understand if the concept can have a contemporary meaning, a new relationship with the territory, not immutable anymore but undergoing continuous modification and adaptation. Our research tries to investigate the possibility of inhabiting the threshold by reaching beyond its traditional meaning or, as in the nomadic culture, our space should have a direction and not a centre.
In the modern era, linearity has substituted the punctual aspect. We see flows as the primary element defining our cities' structure. This assumption is particularly evident in the Plan Obus by Le Corbusier for Alger (1933) where the city is an infrastructure in itself, and the urban space is completely translated into a high speed movement facility: an elevated highway containing residences beneath it. In modernity, the infrastructure is not an essential means of transportation anymore but a place to inhabit. The city, finally, acquires its appearance.
The flow is what draws contemporary society closer to a nomadic attitude, where movement on a local and global scale is the motive. In our narration, we took the infrastructures as a fundamental element for the foundation of the contemporary city.
Nomads move through the landscape using the longitudinal valley lines designed by the water system that are now contrasted by industrial infrastructures (railways and highways) connecting the region for mining purposes and cutting those strips in a transversal direction.
These two systems highlighted at the regional scale are maintained in Kiruna: the continuous natural one of the Torne river and the industrial infrastructure of the highway E10 are getting closer to each other, running concurrently from Kiruna to Vittangi and connecting four different mines along their longitudinal journey. We decided to place the new city at a hinge between the river and the highway E10 in the area where their distance is at a minimum in order to exploit their potential on both sides.

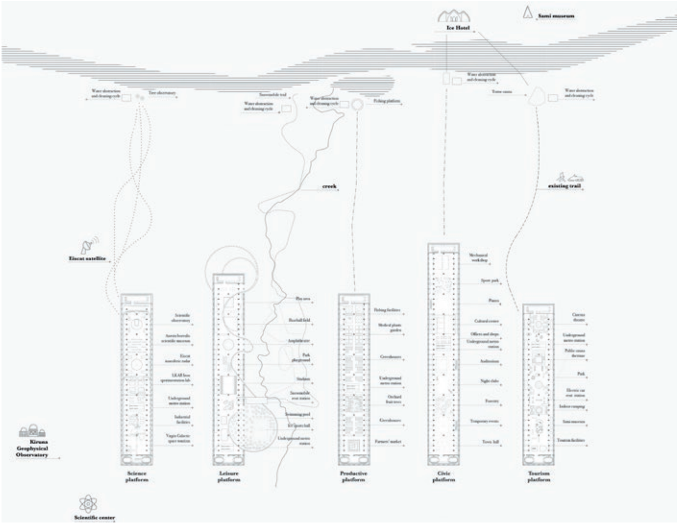
Inhabiting the threshold: a new paradigm for dwelling

Today, the past model of concentric, centralised and dense city typical of the European scene have revealed their fragilities. Moreover, we are facing a territory that has never had real centres but scattered communities organised on the force lines of the landscape. This dispersion can be potentially used as the basis to define a new formula to inhabit the land, working through distributed polarities in strategic nodes capable of dismantling the dichotomy between centre and periphery.
In our idea, the new Kiruna would be a composition of different 'moments', each one with its own identity, capable of fulfilling the needs and desires of a mixed culture and of people with different degrees of nomadism. Those different elements work and communicate together in the same 'tray', generating a complex system but avoiding marginalisation of the parts.
Taking into account these territorial vocations, we organise the entire system following the principle of a "dispersed concentration", where every structure is linked to economies that are already active in the region, and have a main relevant profile:

- scientific;
- leisure;
- productive;
- civic;
- touristic.

These horizontal 'skyscrapers' of mixed functions are capable of blurring the private sphere with the public one.
Projects such as the Non Stop City of Archizoom (1970-71) and the Fun Palace of Cedric Price (1961) provided the background to define the design principles following the idea of a city as a continuous structure, free from architectural types, organised following changing forms of social aggregation: a social interactive machine to accommodate different trends, events, and necessities.
The decision to place the city structure underground was crucial for the design outcome. It was a gesture that solved multiple issues; first of all, the problem of facing the harsh climatic condition, secondly,

03 |



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03 | Plan of the underground city platforms, image by Virginia Sellari and Susanna Vissani

04 | View from the ropeway of the underground city, image by Virginia Sellari and Susanna Vissani

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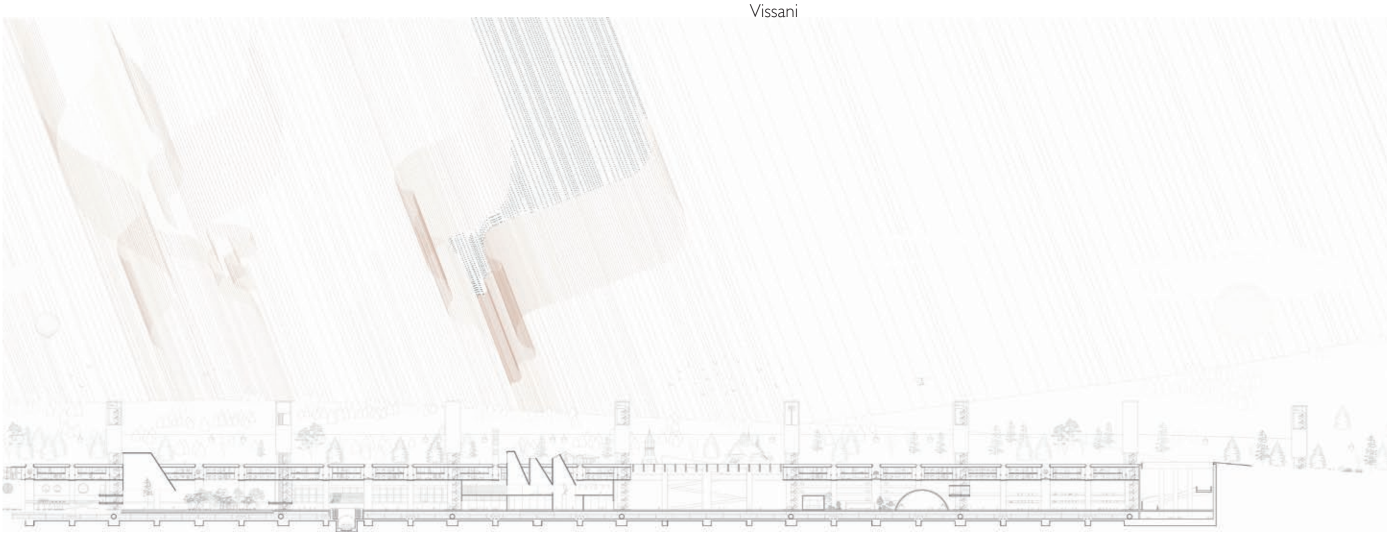


05 | Sample section of the underground city platform, image by Virginia Sellari and Susanna Vissani

to protect the millenary reindeers' migration paths and, above all, to handle the issue of soil consumption hiding architectural skeletons under the soil surface, if and when the city will be abandoned. Building a genealogy of underground facilities already present both in different environments was essential for the work. In the Arctic region, the Svalbard Global Seed Vault is a contemporary valid example of how a scientific facility can be built underground to preserve valuable collections and archives from possible man-made catastrophes. We can also find examples of underground systems of public spaces in Montreal and Toronto where a multi-level network of tunnels connects various activities and functions (shopping malls, underground stations, offices, hotels, schools, concert halls, and restaurants).

Also in the past, underground architectures were either built to assure climatic response and defensibility, or they were linked to symbolic and religious aspects. They act against the harsh climate of the desert in Matmata (North Africa) or the cold winter in the Henan province (China), and respond to the defensive issue in Derinkuyu (Turkey) where the hypogeum city structure was thought to be completely autonomous with all services.

In our vision, the urban life is happening underground, whereas the surface is left permeable and undisturbed to the Arctic extreme wildlife. The two worlds, opposed in terms of image and rhythms of life, work together in building a new model for future urbanity. In the suggested plan, we decided to create a structure where balance is obtained by overlapping different ways of living to allow different economies to operate well independently.

Those massive underground organisms highlight their presence with the element of threshold. Covered by shrubs and tundra, the only evident structures from the upper natural surface would be skylights, gates, towers and landmarks, both new and monuments taken as memories from the previous city.

Towers will not only allow vertical circulation between the inside and the outside, but also the horizontal one extending towards the Torne river using the ropeway[2].

Inhabiting the underground is translated into a matter of layers, overlapping activities, and users. In all the layer plates, a free use of space is permitted through the idea of open permeability.

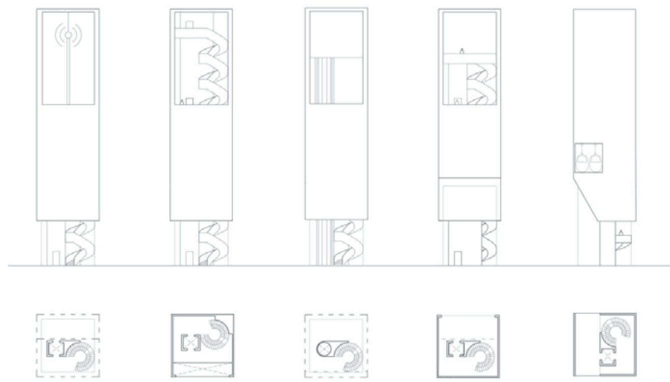
Scattered fixed partitions operate as tools to access basic services, like electricity, water, heating, and sewer systems.

06 | Typological samples of towers, image by Virginia Sellari and Susanna Vissani

07 | Bird eye view, image by Virginia Sellari and Susanna Vissani

08 | Domestic level plan, image by Virginia Sellari and Susanna Vissani

| 06



Results and implications

This research studies the contemporary concept of inhabiting a territory.

Starting from a conceptual point of view, without going into technical-constructive aspects of the city's structure, the project comes to a specific experimental solution by moving towards flexible and adaptive urban design. The limits of this research together with its strengths are related to its utopian and site-specific nature, whereas its strength is to address the theme of the resilient city from an unusual point of view by developing a new consciousness about it.

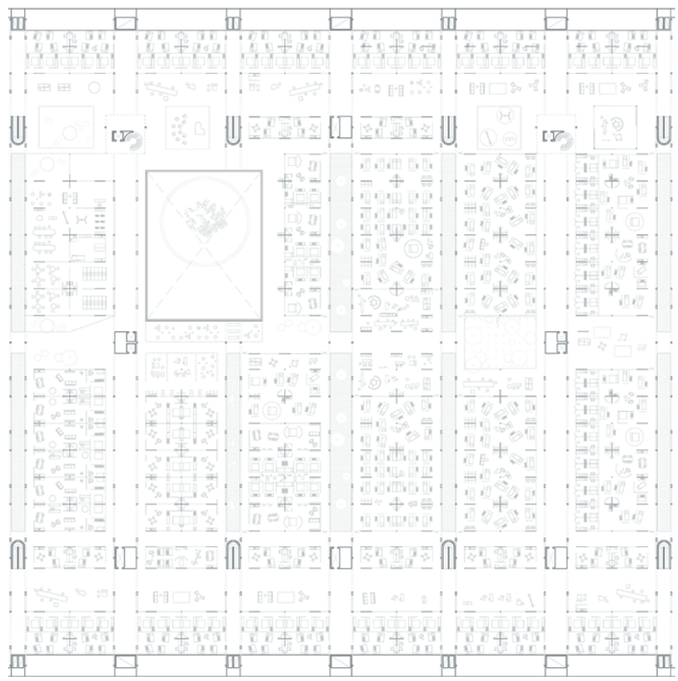
The "European Commission" states: "A resilient city assesses, plans and acts to prepare for and respond to all hazards – sudden and slow onset, expected and unexpected". The design strives to improve the resilient quality of the city of Kiruna by creating a flexible structure that responds to changes, creating a precedent for other similar situations and a response to the future post-industrialisation and post-capitalism transitions.

07 |

The design outcome has its roots in a broader background of underground architectural heritage and in the potentiality of the Arctic to be a new frontier. In the future, climate change will transform millions of people into "climate migrants" escaping water scarcity and sea level rise. In this perspective the Arctic could become a new place to inhabit. The process of relocating Kiruna is an experiment on an unprecedented scale, and it perfectly expresses how economic interests can shape the balance between the city's environment and the memory of a community. The implications of this gentrification tendency have to deal with the mass of the intangible remains of an entire community (Internazionale, 2016).

In such an extreme, problematic, temporary, and changing environment, we approached the project starting from the assumption that we are operating in an emergency situation, faced as such. But at the same time, the idea is to bring this specific situation towards a more general context. The project aims to find a physical answer to the precarious and uprooted condition of our time by establishing a logic and a process more than a fixed shape, avoiding the repetition of the same crystallised typologies of the past.

| 08



NOTES

[1] The new city of Kiruna is currently under construction following the design of the international competition winning proposal of White arkitekter studio. The plan consists in gradually shifting the city two miles eastwards. Their structure for the new city is very close to the modern European concept composed of regular blocks and boulevards where nature's fingers penetrate the city.

Moreover, according to the LKAB and municipality predictions, the mine will be operative until 2030, more or less the same year in which the end of the urban transformation is expected, leaving the open question of future leading economies for this town.

[2] The Torne River is a significant presence both for inhabitants and tourists. During winter it becomes an infrastructure for snowmobiles and dog sleds.

REFERENCES

Arendt, H. (1989), *Vita activa. La condizione umana*, Bompiani, Milan, Italy.

Aureli, P., Mastrigli, G. and Steele, B., (2013), *DOGMA. 11 Projects*, AA Architecture Association, London, United Kingdom.

Borchert, N. (2001), *Land is Life. Traditional Sami Reindeer Grazing Threatened in Northern Sweden,* Arctic Portal Library.

Branzi, A. and Celant, G. (1992), *Andrea Branzi. Luoghi: the complete works*, Idea Books, Milan, Italy.

Coppola, A. (2012), *Apocalypse town. Cronache dalla fine della civiltà urbana*, Laterza, Rome, Italy.

Deleuze, G. and Guattari, F. (1987), *A thousand plateaus. Capitalism and schizophrenia* (tr. it. di Massumi B.), University of Minnesota press, Minneapolis.

Forrest, S. (1996), *Do fences make good neighbors? The influence of territory in State-Sami relations*, B.A., Simon Fraser University, Vancouver.

Hamdouch, A., Nyseth, T., Demazière, C., Forde A., Serrano, J. and Aarsæther, N. (2017), *Creative Approaches to Planning and Local Development,* Routledge, New York, USA.

Johansson, A. and Wingquist E. (2010), *Malmbanan Diaries*, Swedish University of Agricultural Sciences, Lund.

Jull, M. and Cho, L. (2017), *Architecture and Urbanism of Arctic Cities: Case Study of Resolute Bay and Norilsk School of Architecture*, University of Virginia.

Kiruna - en stad i omvandling (2007) *Kiruna: Informationsbroschyr från Kiruna kommun.*

Krier, L. and Economakis, R. (1992), *Leon Krier. Architecture & urban design 1967-1992*, Demetri P. introduction by, Watkin, D. essay by Academy editions, London, United Kingdom.

La Cecla, F. (1988), *Perdersi. L'uomo senza ambiente*, Laterza, Rome, Italy.

Lopez, B. (1987), *Arctic Dreams: imagination and desire in a northern landscape*, Bantam Books, Bantam Books.

Lynch, K. (1960), *The image of the city,* MIT press, Cambridge, USA.

Mumford, L. (1977), *Dalla corte alla città invisibile*, Bompiani, Milan, Italy.

Nilsson, B. (2010), *Ideology, environment and forced relocation: Kiruna. A town on the move*, Umeå University, Sweden.

Robbins, E. and El-Khoury, R. (2004), *Shaping the city : studies in history, theory and urban design*, Routledge, London, United Kingdom.

Stanley, M. and Smith Colleges, W. (2005), "The Fun Palace: Cedric Price's experiment in architecture and technology", *Technoetic Arts, A Journal of Speculative Research*, Vol. 3(2), pp. 73-92.

Ungers, O. M.and Koolhaas, R. (2013), *The city in the city. Berlin: a green archipelago*, Lars Müller Publishers, Zurich.

Wall, A. (2005), *Victor Gruen. From urban shop to new city*, Actar, Barcelona, Spain.

Internazionale (2016), "Viaggio a Kiruna, la città lappone che aspetta di essere spostata", available at: https://www.internazionale.it/reportage/gianluca-didino/2016/10/01/kiruna-lapponia-spostamento-miniere.

Kiruna Kommun, "The city transformation", available at: https://www.kirunalapland.se/en/see-do/the-city-transformation/ (accessed in June 2017)

Hermansen, S. (2013), "Terra Nullius. Kiruna", available at: http://www.sirihermansen.com/terranullius.html.

Learning architecture in the digital age. An advanced training experience for tomorrow's architect

RESEARCH AND EXPERIMENTATION

Roberto Ruggiero,
School of Architecture and Design "Eduardo Vittoria" of Ascoli Piceno, University of Camerino, Italy
roberto.ruggiero@unicam.it

Abstract. What Mario Carpo defines as "the second digital turn" (Carpo 2017) represents for architecture an irreversible process meant to modify many consolidated rules in the professional practice. Without upgrading his methods and points of view, education in architecture turns out to be inappropriate for future scenarios, both in terms of content and methods.
In this regard, in 2018 the School of Architecture and Design "Eduardo Vittoria" (SAAD) of the University of Camerino launched an experimental educational programme focused on: a) "digital fabrication" as a building strategy; b) the SAAD-Lab#Prototype (the SAAD fab-lab) as fulcrum of an innovative workshop in the field of building construction. The paper presents the result of the 2018/19 workshop concerning a temporary settlement for students made with customised building systems.

Keywords: Digital Fabrication; Technology; Education; Architect; Future

Digital in architecture: «nothing is more powerful than an idea whose time has come» [1]

Digitisation of design processes has come a long way since the pioneers of Computer-Aided Design (CAD) «replaced their pencils with mouse and keyboard in the 1980s» (Kuhnhenrich and Rose, 2019). Since then, a new generation of digital tools has become widespread as a natural part of the architect's profession. Particularly in the last decade, the development of ICT technologies has made available new families of interconnected tools. The latter have turned out to be so powerful as to stimulate, in a short time, the emergence of new design cultures and, with them, the rise of new rules and roles in architectural practice. Parametric and Computational Design are just two of the most evident and not fully explored outcomes of the "revolution" underway.

Extending the observation field to the whole building sector, to date, digital innovation has had different types of impact on the three phases of the process (design, production, and construction). In many contexts, construction (in particular) and industrial production for building are, with some exceptions, mainly analogic processes. If digital technologies for manufacturing (from CNC to robotics and other "enabling technologies", according to Industry 4.0 vocabulary) have already largely spread in many branches of industrial production, their application in building construction is still not common. Even if this inhomogeneity constitutes a critical issue, the digital renewal of the building sector is an irreversible process destined to change, in the short and mid-term, many rules, methods, and roles, even in architectural practice.

This is why the architect's role, like that of many construction professionals, is bound to evolve in a time that promises to be short. Without upgrading his expertise, the architect risks marginalisation to the benefit of new figures and new specialised skills brought by digital culture. This does not mean that the architect of the digital age will have to turn into informatics and give up to the humanistic profile (that is a prerogative of his cultural heritage). As Italian writer Alessandro Baricco argues, «the game» - the way Baricco defines our life in the digital age - «more than anything else [...] needs humanism» (Baricco, 2018).

To create the ethical and scientific basis to allow the architect to play a leading role in a future that is announced as increasingly "digital", a radical re-thinking of the educational paths in architecture is necessary, as well as the testing of innovative methods and models based on the prefiguration of future (medium and long-term) scenarios.

A digital training experience

"Digital fabrication" is one of the possible applications of "digital" in the construction sector[2]. Digital fabrication is a process that combines 3D modelling or computer-aided design with additive and subtractive manufacturing for the production of building components. In this context, design and manufacturing constitute a single workflow where digital data directly drive manufacturing equipment[3]. Among the main and crucial consequences of digital fabrication, two, in particular, are strategic for the definition of new design paradigms: a) the opportunity to design and produce "customised" and non-standard elements (structural, façade, internal or otherwise); b) the return to a closer relationship between design and construction.

In 2018, SAAD launched an experimental course focused on digital fabrication as a building strategy for temporary architecture. This work is part of a larger activity promoted by the University of Camerino aimed at developing innovative educational paths[4]. The course is based on the workshop formula and is devoted to the students of the bachelor's degree in Architecture Science[5]. Introducing digital fabrication in the early years of a student's career has been a strategic choice. Indeed, the course aims at introducing digital fabrication not as a specialised topic based on the management of sophisticated tools, but as an innovative approach to architecture potentially destined to change the way we conceive, design and build the space we live in.

The workshop is centred on the SAAD-Lab#Prototype, i.e., the University of Camerino's fabrication laboratory (fab lab). It is equipped with devices for both additive and subtractive digital manufacturing. The basic equipment adopted during the workshop mainly refers to: laser cutting machines with a 600x400 mm working plane, laser cutting machines with a 1500x500 mm working plane, Roland CNC milling machine with a 270x270x145 mm working plane, and a 3-axis CNC milling machine with a 3,000x2,500x 500 mm working plane, Makerboat Replicator 3D printer with a print volume of 280x150x150 mm, and Wasp 3D printer with a print volume of D 600 x H 1000 mm (Fig. 1).

Unlike other educational experiences focused on digital fabrication and carried out in the most advanced fab labs of European universities[6], the SAAD experience is not focused on experimenting with extreme structures and complex geometries as a result of a computational approach. Instead, its main goal is designing and prototyping an innovative artefact based on the hybridisation of conventional components and building systems, coming from the current indus-

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01 | SAAD-Lab#Prototype 3-axis CNC milling machine, Author's pic

02 | The OpenStructure grid adopted as modular basis of the temporary settlement, Author's pic

trial production, with customised components and systems resulting from the application of digital techniques of fabrication. This scenario is not new. There are also not very recent advanced design experiences - that of Renzo Piano, for example – focused on the combination of standard building components and of customised components [7]. If Piano's works were complex hi-tech experiments, the progressive digitisation of industrial production could make these processes less extraordinary, as demonstrated by some experiences of "offsite" construction in northern Europe[8].

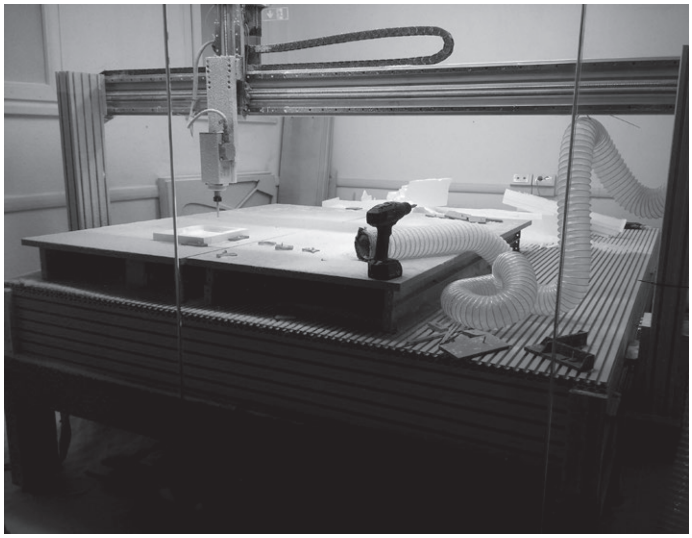
Three workshops have been held since 2018, all focused on temporary and small-scale architecture, according to the research interests and tradition of studies of the SAAD teaching group. In particular, the 2019 edition was centred on the general topic of new urban nomads (refugees, tourists, guest workers, expats, and students, a category of traditionally nomadic city users). The exercise consisted in designing and prototyping a little temporary settlement for students.

One of the peculiar aspects of this experience (in relation to the traditional methods of teaching architectural design and building processes) is the methodology adopted. Each student was given a wooden tablet (Fig. 02) that corresponded, on a scale of 1:10, to a square-shaped lot (with a side equal to 9.6 square metres). A grid was engraved with a laser cutter on each tablet as a shared "guide" for all projects. Students could use just part of this lot, i.e., 40 square metres and a volume of 280 cubic metres to produce their little temporary house. The tablet constituted the basis of the final prototypes (also in a scale of 1:10), but also a tool to check the design phase. The final assembly of the artefacts positioned on the lots - that is the prototypes positioned on the engraved tablet - was the final act of the workshop, the collective product: a modular settlement for temporary users; a theoretically replicable and incremental atypical "village" built with partially customised building systems.

This method represents an innovative application of the "OpenStructure" theory, an open-source modular construction model based on a shared geometrical grid[9]. Conceived by Belgian designer Thomas Lommée, the OpenStructures method explores the possibility of design in a modular environment where "everyone designs for everyone" being able to share with the community the file of their components ready to be fabricated (in the OpenStructure method the file of each component can be made available for public download). In the SAAD experience, students generated their components to share them with their colleagues through an analogue process.

Those "pieces" were designed through the use of cad-cam software technologies (RhinoCAM in particular) and produced with CNC milling and 3D printing techniques[10]. The range of parts manufactured under the digital fabrication regime constitutes a heterogeneous catalogue of construction systems and components: structural joints in thermoplastic material, entire wooden construction sys-

| 01



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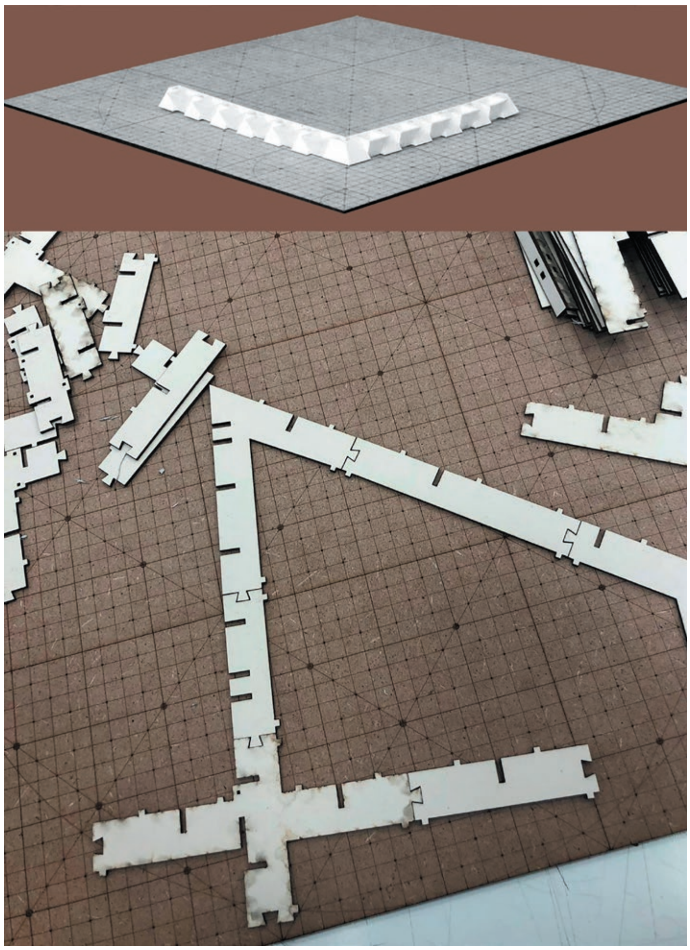
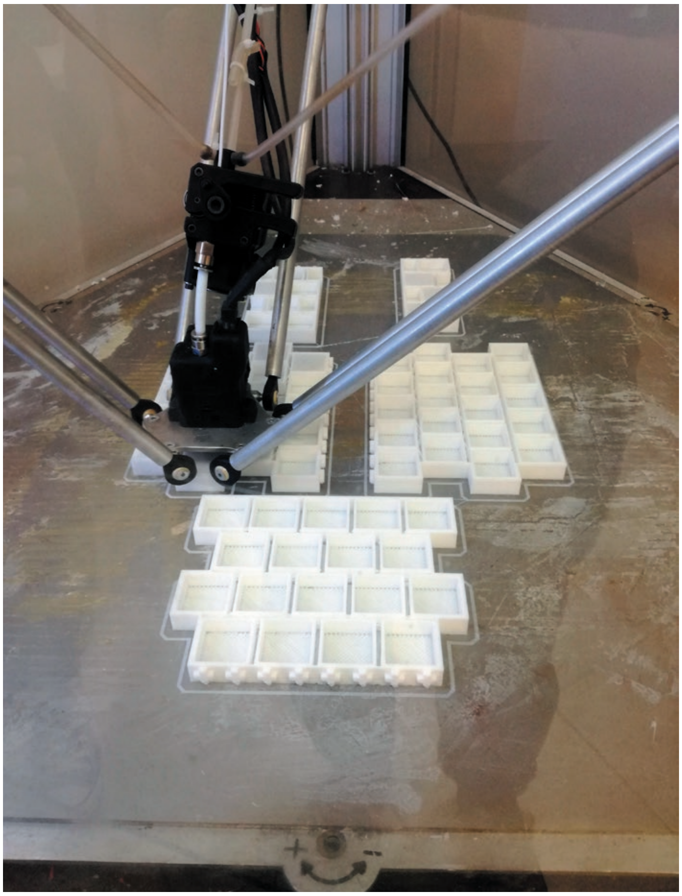




03 | Customised thermoplastic components prototyped with a 3D printing, Author's pic

tems made with an innovative "interlocked" building system (as an innovative interpretation of the traditional Japanese Veneer House system), metal solar shading panels, wooden bricks, and disposable plastic formwork, and even load-bearing walls in concrete are some of the recurring construction elements experimented with in the small temporary village (Figs. 3-4-5).

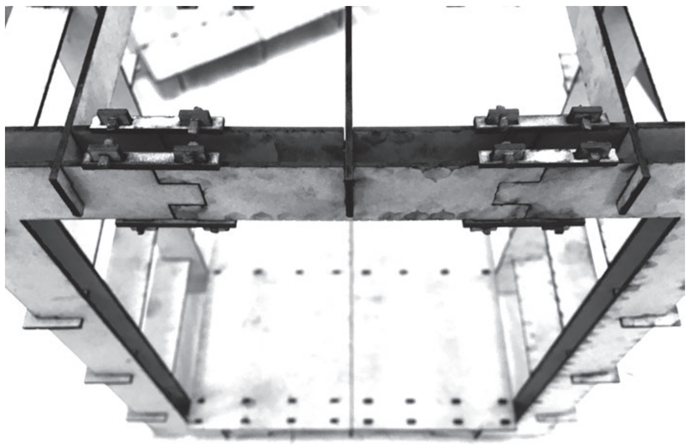
Through tutorials and practical illustrations, students were put in the condition to programme their digital workflow that was based on a reversal of the traditional design phases, where the construction and procedural aspects follow those of architectural concepts and space-functional layout.

In this process, prototyping is the key action of the learning process. If the "model" is the traditional tool for studying and representing architecture, in digital fabrication processes it is replaced by the prototype, which simulates the architectural artefact in all its aspects, including construction and production. This procedure implies an alignment between the creative process and the control of the production phases and requires, in the project construction chain, an anticipation of the concrete aspects of building at the heuristic phases of the project.

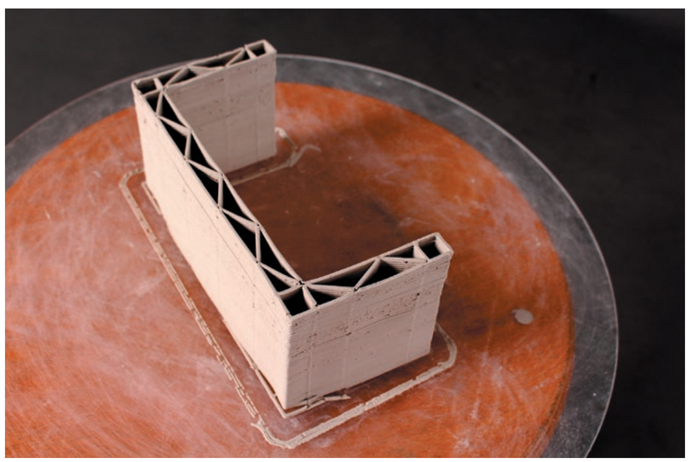
Being able to directly experiment with tools, machines and materials, students were able to take inspiration from "something they find while manufacturing something": doing and thinking become a simultaneous operation again, which has an influence on our thinking as architects. In this design dimension, the laboratory became the place of imagination, training, and production of a "total" experience (Pugh, 1991).

Education in the future tense

Placing the student at the centre of the construction process, where goals and tools of architecture coexist seamlessly, has been a very stimulating experience, even if more powerful instruments would have allowed the design experimentation to go further. For example, it would have also been interesting to prototype some components on a real scale. The SAAD-Lab # Prototype offers a good level of equipment, which can certainly be improved. An upgrade of the devices contained therein is currently planned and, in particular, the addition of a 3D printer



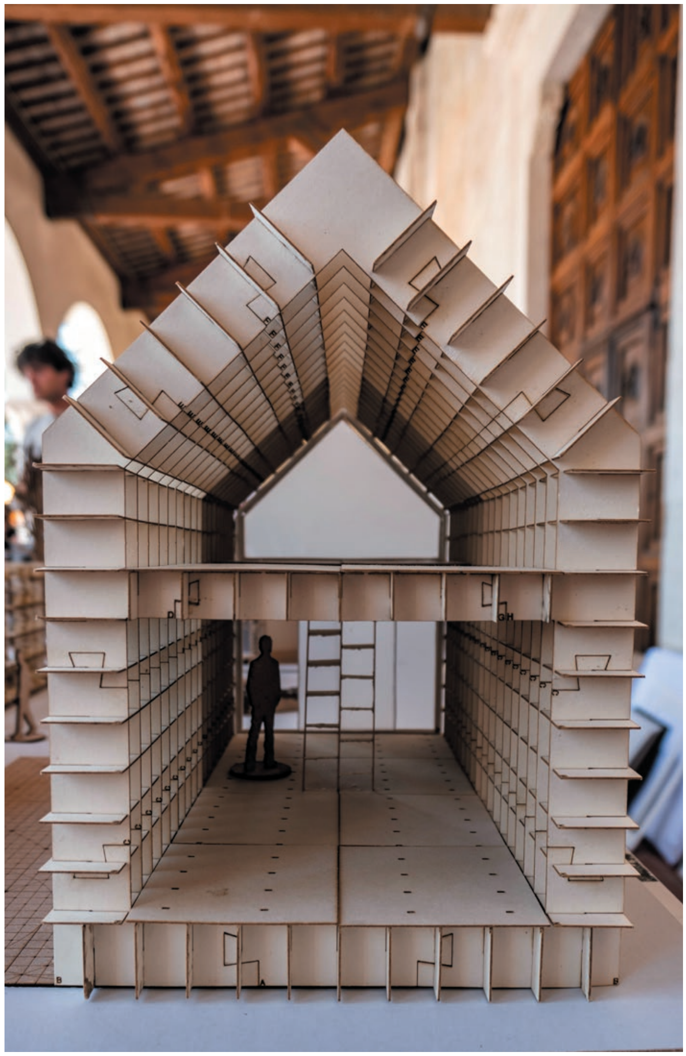
04 | Customised wooden building systems prototyped with a laser cutter, Author's pic



05 | Customised concrete components prototyped with a 3D printing, Author's pic

06 | Temporary house, "mature" approach, Author's pic

08 | Temporary house, "extreme" approach, Author's pic



07 | Temporary house, "positivist" approach, Author's pic

(with a high print volume) and of collaborative robots that today represent significant potential in the field of digital manufacturing.
The quality of this kind of educational experience (in this and other schools) will always be a function of how much the universities want and can invest to integrate digital technologies within educational curricula. Creating fabrication laboratories, making available the use of advanced tools, such as parametric/generative software and prototyping/fabrication machines, would become a priority for Architecture Departments to train the future architect. This is a key challenge for architecture schools to guarantee what Alvin Toffler defined an «*education in the future tense*» (Toffler, 1971). This challenge also requires the organisation of specific courses, both theoretical and practical, focused on digital innovation. Some digital design tools – such as parametric, computational or cad-cam software – bring with them innovative approaches in terms of effectiveness, control, and creativity of the design process.
In this last regard, the models produced in the workshop represent different interpretations of the impact that an educational environment based on the use of advanced technologies can have on student's creativity. At least three creative approaches emerge from the projects of young "architects in training" (as the students are):

a. mature;
b. positivist;
c. extreme.

In the first case, the *Kunstwollen*[11], literally "will of art", prevailed over the technological device. In the project that pursued this path, digital innovation was "incorporated" in the architectural artefact and metabolised by it (Fig. 6). In the second one, the enthusiasm for innovation pushed towards a "constructive sincerity" aimed at making digital construction a term of architectural language (Fig. 7). In the third case, digitisation was not limited to the design and construction process but "entered" the rules of use of the living space, suggesting an interactive architecture in which conception, production and use come from the same culture, which is deeply digital (Fig. 8).
These three positions represent as many ways of interpreting the architectural project starting from full awareness of the tools and techniques necessary for its realisation. That is why the second digital twist represents a great opportunity to propose an educational model, for architecture, based on the reconnection of theory and practice, creativity and ability, humanistic and scientific approach.

NOTES

[1] «Il n'est rien au monde d'aussi puissant qu'une idée dont l'heure est venue». Quote attributed to Victor Hugo. Source: http://webscience.com.

[2] In current architectural practice, digital fabrication found its way in some advanced forms of building processes as "off-site construction" that is, currently, the most advanced prefabrication strategy. But digital fabrication can be also considered a best practice in self-construction and participatory building processes, often aimed at social innovation goals and related to small scale projects.

[3] The techniques of digital fabrication generally fit into four main categories: cutting, subtraction, addition, and formation. Data most often comes from CAD (computer-aided design) and is transferred to CAM (computer-aided manufacturing) software. The output of CAM software is data that directs a specific machine, like a 3D printer or CNC milling machine.

[4] In June 2019, the University of Camerino's Educational Innovation Group was established to share and spread innovative educational approaches. The programme is coordinated by Professor Luciano Barboni, the University of Camerino's Pro-Rector for teaching.

[5] The degree course in Architecture Sciences ends, at SAAD, with four intensive two-week workshops. They are held by different teachers and focused on different disciplines. Students can choose which workshop to participate in. The subject of this paper is the "Architecture Construction Workshop" directed by the author of this paper.

[6] In Europe, the ETH of Zurich, the Institute for Advanced Architecture of Catalonia (IAAC), and the Schools of Architecture of the Royal Danish Academy of Fine Arts of Copenaghen, to mention a few, are among the universities with the most advanced teaching programmes in the field of digital fabrication.

[7] The "leaves" of the skylight of The Menil Collection museum in Houston or the "gerberettes"" of the Center Pompidou in Paris, designed by Renzo Piano with the support of Peter Rice, represent two examples of customisation of construction elements.

[8] The UK, in particular, is an outpost of offsite construction, i.e., a tailor-made prefabrication concept based on the combination of CNC and BIM technologies. See on this point: NLA Research Report, (2018), *Factory-made housing. A solution for London*, National London Architecture, London. [Online] Available at https://www.newlondonarchitecture.org/whats-on/publications/all-nla-publications/factory-made-housing-a-solution-for-london.

[9] See: https://openstructures.net/home-page.

[10] Cad-Cam technology is a computerised technology that allows you to obtain a three-dimensional object starting from a vector drawing performed on the computer.

[11] The term *Kunstwollen* was popularised by the Austrian art historian Alois Riegl, and denotes the characteristics and boundaries of an epoch's aesthetics, as well as the intrinsic creative drive peculiar to it.

REFERENCES

Baricco, A. (2018), *The game*, Einaudi, Turin, Italy.

Barazzetta, G. (2015), *Digital takes command*, Rubettino, Soveria Mannelli (CZ)

Burry, J. and Burry, M. (2016), *Prototyping for architects. real building for the next generation of digital designers*, Thames & Hudson, London, U. K.

Caneparo, L. (2012), *Fabbricazione digitale dell'architettura. Il divenire della cultura tecnologica del progettare e del costruire*, FrancoAngeli, Milan, Italy.

Carpo, M. (2017), *The second digital turn Mit Press*, Cambridge, USA.

Davis, S. D. (1987), *Future perfect*, Addison Wesley, Boston.

Dies, T. (2018), *Fab city: the mass distribution of (almost) everything*, Design market platform, Barcelona, Spain.

Dunn, N. (2012), *Digital fabrication in architecture*, Laurence King Publishing, London.

Gibson, I., Rosen and E.W. Stucker, B. (2015), *Additive manufacturing technologies, 3d printing, rapid prototyping,and direct digital manufacturing*, Springer, Berlin/Heidelberg, Germany.

Goodhouse, A. (2017), *When is the digital in architecture?,* Sternberg Press, Berlin, Germany.

Gramazio, F. Willmann, J. and Kohler, M. (2014), *The Robotic Touch: How Robots Change Architecture*, Park Books, Zurich.

Kieran, S. and Timberlake, J. (2004), *Refabricating architecture*, McGraw-Hill, New York.

Kolarevic, B. and Klinger, K., (2008), *Manufacturing material effects: rethinking design and making in architecture*, Routledge, New York/London.

Kuhnhenrich, H. and Rose, A. (2019), "Digitalisation. A process to be shaped", *in AA.VV. Craftsmanship in the digital age: architecture, values and digital fabrication*, ANCB The Aedes Metropolitan Laboratory, Series: ANCB Edition #4, Berlin, Germany, pp. 16-19.

Maasen, T. (2019), "Forewaord", *in AA.VV. Craftsmanship in the digital age: architecture, values and digital fabrication*, ANCB The Aedes Metropolitan Laboratory, Series: ANCB Edition #4, Berlin, Germany, pp. 10-11.

Madhavan, G. (2015), "Pensare per prototipi", in Madhavan. G., *Come pensano gli ingegneri,* Raffaello Cortina Editore, Milan, Italy.

Naboni, R. and Paoletti, I. (2014), *Advanced customization in architectural design and construction*, Springer, Berlin, Germany.

Ortega, L. (2017), *The total designer*, Actar Publishers, New York/Barcelona.

Papanek, V.J. (1985), *Design for the real world: human ecology and social change*, Academy Chicago; Pantheon Books, New York.

Pugh, S. (1991) *Total design: integrated methods for successful product engineering*, Addison-Wesley, Boston, USA.

Ruggiero, R. (2019), *Progetto esecutivo e processi di costruzione digitale. Una sperimentazione costruttiva tra Italia e Giappone*, *Techne, Journal of Technlogy for Architecture and Environment, Vol. 18, Firenze University Press, Florence.*

Smith, R.E. Quale, J.D. (2017), *Offsite architecture. constructing the future*, Routledge, Oxon (UK) and New York.

Tamke, M. (2019), "Foundamental changes for architecture", *in AA.VV. Craftsmanship in the digital age: architecture, values and digital fabrication,* ANCB The Aedes Metropolitan Laboratory, Series: ANCB Edition #4, Berlin, pp. 36-39.

Toffler, A. (1971), *Future shock*, Bantam Edition, New York.

Novel component for smart sustainable. Building Envelopes

RESEARCH AND EXPERIMENTATION

Gianluca Rodonò, Angelo Monteleone, Vincenzo Sapienza,
Department of Civil Engineering and Architecture, University of Catania, Italy

gianluca.rodono@unict.it
angelo.monte@unict.it
vincenzo.sapienza@unict.it

Abstract. Contemporary approaches to the topic of the responsiveness of architectural components tend to simplify the moving parts as much as possible, avoiding the use of complex mechanisms. KREO is a component for lightweight responsive envelopes made with a composite material with elastic matrix and a textile reinforcement. The composite is pre-folded and it is possible to fold and unfold it without hinges through its elastic mechanism. The component is also capable of producing energy for its handling system through an integrated high efficiency photovoltaic system. Furthermore, its pre-folded geometry ensures its strength. This research involves the construction of a prototype of this energy self-sufficient kinetic component and the definition of its production process.

Keywords: Composite material; Smart envelope; Foldable surface; Kinetic structure; Building integrated photovoltaics.

KREO, the innovative component

In recent times, the increasingly complex and diversified demands of social living require the availability of flexible, lightweight, and reusable service equipment. Think, for example, of the needs arising from climate emergencies, cultural events, first aid for migrants and, above all, the protection of cultural heritage.
The field of study focuses on smart building components, i.e., capable of mitigating the exposure to risks of different kinds by extemporaneously assessing the probability that certain phenomena occur, through their own "sensory system", and in reaction to this they are able to reduce the vulnerability of the areas of action by changing their spatial configurations.
The research referred to in this article focuses on adaptive kinetic building elements, through the use of tessellated geometries originating from the ancient art of origami. The aim is to obtain an architectural component capable of modifying its morphology, adapting to the users' needs (Fig. 1). Hence the choice of the acronym KREO (Kinetic Responsive Envelope by Origami) as the title of the research project and its main output.
The study was directed towards the use of a material similar to a sheet of paper, so that it can be folded according to a pre-established pattern. An additional strength "by shape" is given by folding (Salvadori and Heller, 1963), but the fold lines are also a preferential guide for handling the material through elastic deformation. In particular, tests on the base material were concentrated on composites, which are made with several constituents to guarantee an increase in performance, compared to the individual material, by combining their properties. They generally consist of a matrix, i.e., a homogeneous continuous phase, and a reinforcement, i.e., a phase dispersed in various ways within the matrix.
In testing, the use of a thermoplastic material allows to shape the composite as a result of the type of cross-linking of its structures. In fact, unlike thermosets that, once produced, degrade when heated, the thermoplastic material allows a two-stage process. In the first stage, the composite is produced and in the second one it is hot molded to give a specific folding pattern. The idea of a two-stage production is closely linked to the need not to create a shape defined in advance, but to make it customisable for each individual project, for different components and different kinematics.
The elastomeric properties of the matrix aim, instead, to create a material that, in the wake of the most recent research, can exploit its elastic deformation to ensure the kinematic motion of the component.
Preliminary analyses have made it possible to verify the performance of the material as the matrix and reinforcement layers vary. In those that were found to be more suitable, flexible monocrystalline silicon photovoltaic cells were inserted to guarantee the possibility of using the component, suitably wired with a storage system, in off-grid conditions.

Responsive systems and energy self-sufficiency

Kinematics and Responsiveness
The terminology used to indicate architectures equipped with kinematic components is quite varied and is generally linked to the numerous researches in this field. These have given rise to a proliferation of definitions, whose fields of application often have limits that are not well defined and in any case are made flexible by the continuous evolution of the technique. This is a field that over the last century has experienced the transition from manually controlled mechanical systems to smart materials that interact directly with the environment, so even the terminology tends to follow technological progress to inform about the evolutions taking place.
Among the definitions with a broader meaning there is Kinetic Architecture defined as « the set of those buildings and/or parts of buildings with variable mobility, location, and/or geometry» (Fox, 2002).
The relationship between architecture and kinematics already existed in Roman times in the *velaria*, i.e., solar shading systems for amphitheatres, such as the Colosseum. They were made by reusing naval techniques with a complex system of cables that supported and unfolded the covering fabrics.
In the first decades of the 20th century, the advent of the Modern Movement and technical evolutions allowed designers to experiment with solutions in which buildings could alter their configuration. Just think of Walter Gropius' 1927 project for the Total Theatre by Erwin Piscator or the Villa Girasole designed by Angelo Invernizzi and built in 1929.
In the 1970s, studies on the mathematical relationships at the basis of origami geometries led to important applications in aerospace to obtain Deployable Surfaces to transport and deploy photovoltaic panels in satellites.
Such research had an architectural implication in Frei Otto's studies on Convertible Roofs, i.e., flexible roofing systems that allow buildings to adapt to different functions through mobility (Otto, 1972).
The innovations in the IT field of the early 1970s are also reflected in Nicholas Negroponte's theories on Responsive Architecture. This term refers to a type of architecture or construction that, incor-

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01 | Simulation of an application of the KREO component as a protective shelter for archaeological sites

02 | (a) Flectofold prototype photo by Julian Lienhard; (b) Hylite® panel photo by 3AComposites and Curletto & Gambarotta

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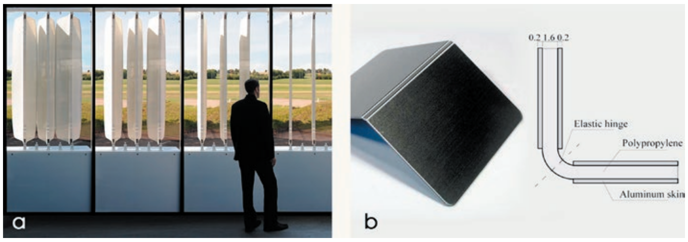

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porating intelligent and responsive technologies, has the ability to modify its shape to continuously reflect the environmental conditions surrounding it (Negroponte, 1975).
Experimentation continued throughout the twentieth century, with high tech solutions, such as those adopted by Santiago Calatrava in the St. Gallen Emergency Services Centre or by Jean Nouvel in the Arab World Institute, in Paris.
In more recent literature, the application of the principles of responsiveness to the architectural envelope is primarily investigated for the optimisation of the energy performance of a building. In this sense, Performative Skin (Turrin *et al.*, 2012), Adaptive Skins (Hasselaar, 2006), or Adaptive Building Shell (Loonen *et al.*, 2013) are mentioned as envelopes capable of adapting to changes in the context by altering the performance of the building.

The Simplification of Movements: Elastic Kinematics
The latest scientific research gives a new and decisive impetus to the subject by tending to limit as much as possible the use of mechanical systems to ensure the possibility of movement. This is essentially due to a need to simplify kinetic components, not so much in the implementation phase as in their management. In fact, even the most sophisticated mechanical systems require maintenance that involves the preparation of regular maintenance plans and activities. Often, due to negligence or financial needs, maintenance is not implemented, causing a premature performance degradation of the items. This has resulted in kinetic component applications remaining limited to projects with large budgets. An alternative solution is given by systems with elastic kinematics (Lienhard, 2014; Barozzi *et al.*, 2016). In these systems, materials capable of deformation, energy storage and return to their initial position when no longer under stress are used. Since there are no hinges, these systems require long-term maintenance cycles compared to previous systems and are, therefore, more economically sustainable. In the first implementations, this result was achieved by using composites formed with glass fibre reinforced polymers (GFRP) to make, for example, the Thematic Pavilion sunshade slats at the World Fair 2012 in Yeosu, or the Flectofin prototype at ITKE (Fig. 2a). Also made of composite material is the Hylite panel (Fig. 2b), consisting of a double layer of aluminium and a layer of polypropylene interposed, used in research on possible applications for Deployable Shelter (Curletto and Gambarotta, 2016).

Energy Self-Sufficiency: Building Integrated Photovoltaic Systems
In cases where the implementation system assumes the use of electricity, it could be produced on site, integrating power production systems into the kinetic component; this would ensure the potential self-sufficiency of the system.
Experiments to offer solutions for the integration of photovoltaic technology into building components were given a major boost with the introduction of flexible amorphous silicon cells in the 1990s. The first photovoltaic textile structure called "Under the sun" was built for the Cooper-Hewitt National Design Museum in New York in 1998 (Fig. 3a), consisting of a 9.7 m high envelope with flexible amorphous silicon solar cells encapsulated and laminated on shaped fabric panels (Orhon, 2016).
Among the solutions for the integration of photovoltaic systems in the building, the so-called BIPV (Building Integrated Photovoltaic) is the "textile solar system" developed for the prototype Soft House in Hamburg (Fig. 3b). Designed by Kennedy & Violich Architecture (Premier and Brustolon, 2014), the house is characterised by a dynamic façade with vertical banded solar shading (Fig. 3b). These are made of a semi-transparent and highly reflective PTFE fabric to which eight thin-film photovoltaic cells are overlapped.
The firm Carl Stahl Architektur GmbH for the central courtyard of the Peace and Security Building of the African Union Addis Ababa (Fig. 3c) (Orhon, 2016) designed a 25x20 metre photovoltaic sail with 445 blue transparent OPV (organic photovoltaics) modules, capable of shading and simultaneously providing sufficient electricity for the interior lighting of the building.

Method

The research aims at systematising the latest findings in the field of kinetic systems and integration of photovoltaics in the building items in order to obtain a component capable of producing the energy needed for movement.
The research method involves the definition of the energy self-sufficient kinetic component in composite material, the optimisation of the stratification of the base material and the production and folding process. The base material produced and the movement system designed were tested through the construction of a prototype, which validated the hypothetical process.
In the specific case of the research, it was decided to use a fibre fabric as reinforcement and a thermoplastic elastomer (TPE) as a matrix,

03 | a) Under the Sun Pavilion - Cooper-Hewitt National Design Museum New York 1998 (Orhon, 2016); b) Kennedy & Violich Architecture - Soft House, 2013 (http://www.kvarch.net.); c) Carl Stahl Architektur - Peace and Security Building of the African Union Addis Abeba, 2015 (Orhon, 2016)

04 | One of the samples and the stratification that passed the first test process

05 | Material sample with insertion of photovoltaic cells and its stratification

06 | Folding process of the composite with metal mould

a technology that is part of textile architecture (Maurin and Motro, 2013). This type of material preserves the characteristics of lightness and versatility typical of fabrics and adds to this impermeable features and resistance to deterioration from atmospheric agents.
The research methodology involved the creation of the first samples of the composite material of small dimensions handcrafted with a hot press, testing different fabric reinforcements (linen, carbon fibres and glass fibres) and two different matrices in thermoplastic elastomer, SEBS (styrene-ethylene-butylene-styrene) and EVA (ethylene vinyl acetate), and testing different possible stratifications.
Production parameters, which have been varied to optimise the material through the vacuum lamination process, are:

1. matrix-reinforcement ratio;
2. process duration;
3. temperature;
4. release agents.

For the first assessment, the samples were visually checked, then touch tested, and samples that passed these checks were further analysed with the cross-section method. Finally, the samples that passed these tests were subjected to a mechanical characterisation process with uniaxial tensile test according to UNI EN ISO 527-4 and UNI EN ISO 527-1 for the determination of the Young E modulus and the shear modulus G (Rodonò et al., 2019).
Once the most suitable parameters and stratigraphies were defined, the production process was industrialised by the company, producing larger samples (about 20x40 cm) (Fig. 4) using the vacuum production process in single Laminator SL-DM 231 made by PANAMAC S.r.l.
Once the laminator production process was validated, new samples of composite material with drowned photovoltaic cells were made in order to make the final component energy self-sufficient (Fig. 5). The choice of photovoltaic technology was oriented towards first generation silicon solar cells. In the component, the photovoltaic cells were positioned in correspondence with the panels and not with the folds; since the composite has a certain flexibility, they are in any case subjected to flexural stress. Therefore, high efficiency monocrystalline silicon solar cells with back-contact technology

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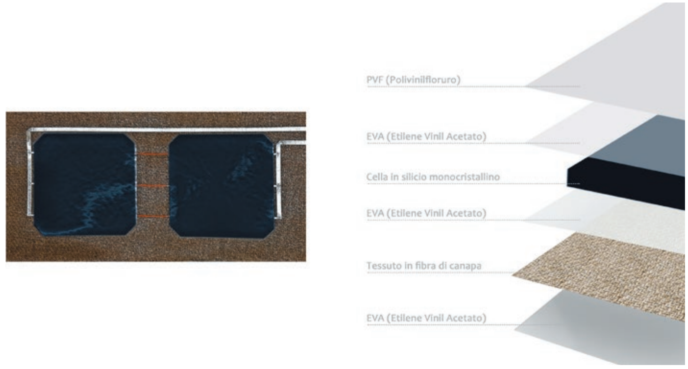

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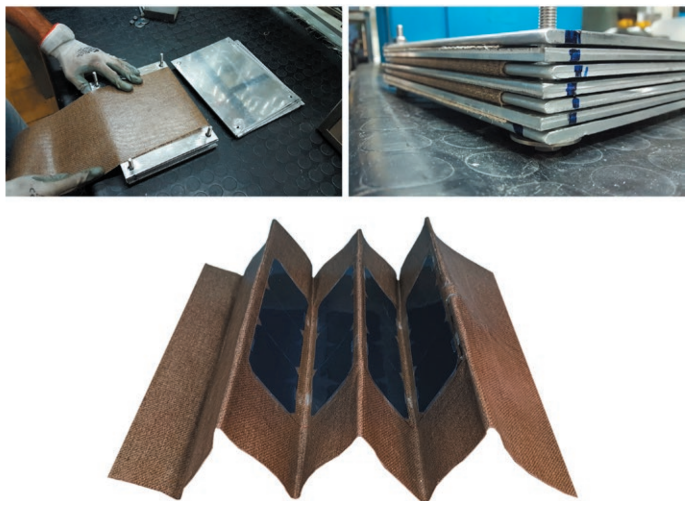

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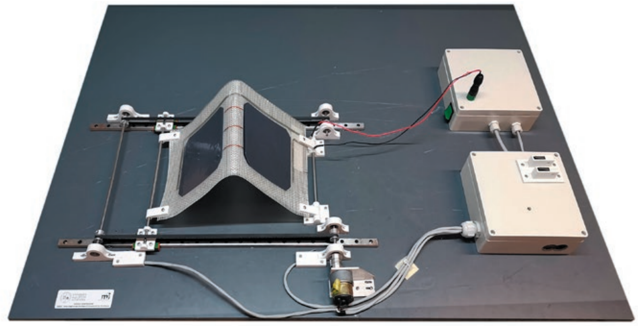
07 | The prototype made with fiberglass fabric reinforcement and monocrystalline silicon solar cells



were adopted and, in particular, SunPower Maxeon® cells measuring 125x125 mm.
In order to optimise the integration of photovoltaic cells into the composite, it was also decided to test the PVF (Polyvinyl fluoride), a thermosetting polymer used (under the name Tedlar) in the production of photovoltaic panels as a coating layer, since it is extremely waterproof and has excellent resistance to weathering and dirt, as well as to numerous chemicals.
For the folding process (Fig. 6) it was necessary to make a metal mould to be used in the press to give the composite the desired geometry, bringing the material to a temperature not exceeding 120°C in order not to recast the polymers contained.
The photovoltaic cells were connected in series using flexible copper braid tracks at the folding points, spaced at least 3 cm apart and connected to the poles through the adoption of rigid plated copper bus bars.

Results

The choice of the material to be used for reinforcement was oriented towards natural fabrics, in particular Biotex Flax fabric made of linen fibres, and glass fibre fabrics, while the other fibre fabrics resulted in poor cohesion between matrix and reinforcement.
The use of EVA as a matrix was defined during the industrialisation process for its easier commercial availability in large format thin sheets and better workability in the vacuum laminator.
The most performing stratigraphy consists of lower EVA layers and Biotex reinforcement fabric, interposition of the photovoltaic cells between two upper EVA layers, and final coverage, limited to the areas of the photovoltaic cells only, with PVF layers.
The results of mechanical characterisation tests show characteristics of the composite material comparable with those of the composite materials commonly used in textile architecture (Rodonò *et al.*, 2019).
In collaboration with Meridionale Impianti S.p.A., research project partner, a 1:1 scale prototype was developed (Fig. 7) aimed at simulating the operating cycles of the component. For the tests concerning charging and handling cycles of the system, the 20x40 cm simple bellows folding sample was equipped with two SunPower Gen I monocrystalline silicon photovoltaic cells and fiberglass reinforcement, and was connected to a Microelectronics ST SPV1040T battery charging circuit and a 3.7 V 2250 mAh 8.33 Wh lithium battery model 18650CA-1S-3J. A shield with Arduino Mega 2660 board was then made with an input reading for control buttons, limit switch and I2C sensing chip for monitoring voltage and charge/discharge current on the battery, load voltage and current (geared motor) and current of the two photovoltaic cells. The component kinematics was made with a mechanical system on 550 mm Mini MGN12H linear guides for 3D Printers, whose carriages are fixed to a pair of 852 mm long, closed-loop Tiptiper 2GT-6 belts for motion synchronisation, operated by four aluminium 20 teeth and 5 mm bore pulleys GT2 SIENOC, one of which is directly fixed to the shaft of a POLOLU-2205 150:1 Micro Metal gear motor LP 6V.
The prototype was tested with the use of a sunlight simulation lamp to check for proper functioning of the electrical connections after the rolling and folding processes. The voltage values were between 1.150 V and 1.155 V. These results are compatible with the sum of the voltage values from the data sheet of the individual cells, allowing the influence of the PVF coating layer adopted to be considered negligible.
Reading the data shows how the electricity produced is largely sufficient to power the handling system and how the need to deploy the layers in the optimal position for recharging can only be limited to a few hours of the day.
In design applications, the geometry of the tessellation, the number of photovoltaic cells, and their positioning on the tiles can be calibrated to the morphological needs of the project and its geographical location. On the other hand, the possibility of having variable inclinations allows to orient the layers in an optimal way at different latitudes.
The program code can also be implemented in order to provide for different settings, aiming at optimising the morphology of the component for battery recharging or orienting it to favour the thermal and/or lighting comfort of the areas concerned in relation to the accumulation state of the battery system.
To do this, the connection of a current sensor to the panel output and a tilt sensor on a single flap will make it possible to record the input values that the processing system will use to manage the correct opening of the component.

Conclusions and impact

The use of folding composite materials makes a significant contribution to the implementation of adaptive architectural systems. Making such systems energy self-sufficient can help to significantly stimulate their use. Their application for roofs or envelopes gives a property of adaptability and versatility to spaces, aiming to improve their comfort and allowing different and customised uses.
KREO is made of a flexible composite with embedded monocrystalline photovoltaic cells. The production process gives it an origami pattern that allows it to be simply folded and unfolded. The matrix is in EVA while the reinforcement (with relative weave, transparency, weight, etc.) can be varied in relation to the performance it will have in the project it will be used for. The tests aimed at guaranteeing a high level of adaptability to KREO, also allowing to vary the

reinforcement and the number of layers in relation to the mechanical stresses to which it will be subjected during operation, since it is the reinforcement that gives the greatest contribution to the stiffness and mechanical resistance of the composites (Phol, 2010). The two-stage production process also allows the geometry to be customised according to the specific application.
For this reason it is expected to maintain these possibilities in large-scale industrial production with the production of the composite fabric in its flat configuration and only in the second phase configure the material with a specific folding pattern. In this way it will be possible to bring industrial production closer to handcrafted production, as increasingly requested by the market in the architectural sector today.

Limitations and future developments

The research presented is based on laboratory and prototype tests. By framing the component in a given application context, it will be necessary to make appropriate corrections to the process outlined, to make it competitive for large-scale production. At the same time, the theme of the relationship between the folding surface and the handling system – until now considered only marginally - will be addressed by identifying systems that provide for non-onerous maintenance cycles.
To this end, a pilot project will be carried out that will allow tests in real climatic conditions and tests with ordinary cycles of use, on the durability of the material, fatigue resistance of the folds, and resistance to exceptional stress (wind, hail, etc.). This experience will be carried out within the 'An Early Warning System for Cultural Heritage' project (http://www.ewas.eu/) in June in an area of the archaeological site of Megara Hyblea (Syracuse - Italy).
In addition to the project, the acquired information will be addressed on further possible future applications of the component for solar shading of existing and new buildings or for temporary roofing for events.

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INDICATION OF THE RESEARCH GROUP

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CONTRIBUTION OF THE AUTHORS

Research programme, Vincenzo Sapienza; method for folding composite, Gianluca Rodonò; method for photovoltaic integration, Angelo Monteleone; analysis, data collection and editing, Gianluca Rodonò and Angelo Monteleone; revision, Gianluca Rodonò; validation and supervision, Vincenzo Sapienza.

REFERENCES

Salvadori, M. and Heller, R.A. (1963), *Structure in architecture*, Maruzen Asian edition Englewood Cliff3, Prentice-Hall.

Pohl, G. (2010), *Textiles, Polymers and Composites for Buildings,* Woodhead Publishing - The Textile Institute.

Maurin, B. and Motro, R. (2013), "Textile Architecture. Flexible Compososite Material", *Archit Constr Inter,* Vol. 232.

Barozzi, M., Lienhard, J. and Zanelli, A., Monticelli, C. (2016), "The Sustainability of Adaptive Envelopes: Developments of Kinetic Architecture", *Procedia Engineering*, Vol. 155, pp. 275-284.

Fox, M. (2002), *Beyond Kinetic*, Spon Press, London, UK.

Otto, F. *et al.* (1972), *Convertible roofs (IL 5), Information of the Institute for Lightweight Structures* (IL), University of Stuttgart, ILEK press.

Negroponte, N. (1975), *Soft Architecture Machines*, The MIT Press, Cambridge, USA.

Turrin, M., Von Buelow, P., Kilian, A. and Stouffs, R. (2012), "Performative skins for passive climatic comfort: A parametric design process", *Autom Constr*, Vol. 22, pp. 36-50.

Hasselaar, B.L.H. (2006), "Climate adaptive skins: Towards the new energy-efficient façade", *WIT Trans Ecol Environ*, Vol. 99, pp. 351-360.

Loonen, R.C.G.M. *et al.* (2013), "Climate adaptive building shells. State-of-the-art and future challenges", *Renewable and Sustainable Energy Reviews,* Vol. 25, pp. 483-493.

Lienhard, J. (2014), *Bending-Active Structures: Form-finding strangeties using elastic deformation in static and kinetic systems and the structural potentials*, Universitat Stuttgart.

Curletto G. and Gambarotta, L. (2016), "Design of a composed origami-inspired deployable shelter: modeling and technological issues", *Proc IASS Annu Symp 2016 "Spatial Struct 21st Century"*.

Orhon, A.V. (2016), "Integration of Photovoltaics into Tensile and Inflatable Structures", *Solar Conference &Exhibition*, Instabul, Turkey, 6-8 December, pp. 454-462.

Premier, A. and Brustolon, V. (2014), Photovoltaic Awnings and Fabrics: Some Case Studies, *Tenda International*, Vol. 1, pp. 62-71.

"Kennedy & Violich Architecture", available at: http://www.kvarch.net (accessed 23 January 2020).

Houtman, R. (2015), "Materials used for architectural fabric structures", in: Llorens JI de (Ed.) *Fabric Structures in Architecture*, Woodhead Publishing - Elsevier, Cambridge, Massachusetts, USA, pp. 101-121.

Rodonò, G., Sapienza, V., Recca, G., Carbone, D.C. (2019), "A Novel Composite Material for Foldable Building Envelopes", *Sustainability*, Vol. 11, p. 4684.

Designing futures of performance and interaction

Ruairi Glynn,
Bartlett School of Architecture, University College London, United Kingdom
r.glynn@ucl.ac.uk

Abstract. This paper shares a novel educational programme that is attempting to detect and nurture emerging transdisciplinary fields of creative production, and stage architectural education as a holistic environment for initiating new forms of practice. Its experimental pedagogy uses physical and virtual prototyping to build and critically examine future applications and socio-spatial implications of emerging technologies. This article contextualises the development of a transdisciplinary programme in relation to the field of media art. It presents our approach to building a transdisciplinary course and the preliminary results of a programme now entering its third year.

Keywords: Transdisciplinary; Pedagogy; Architectural Design; Performance, Interaction

Introduction

The converging fields of digital networked media, smart materials, robotics and artificial intelligence are creating novel forms of synthetic agency that animate our built environment. These advances are precipitating entirely new forms of creative practice that span across architecture, art, design, performance and engineering. They span from the scale of urban sensor networks governing the performance of our city infrastructure, to building systems responding to human occupation and environmental conditions, to context-aware wearable and mobile technologies providing personalised experiences, mediating our engagement with the built environment. The theater of the everyday is now a data rich environment for interaction and today's intuitive communications services are shaping social relations from the interpersonal to the global ones. As a consequence of this dramatic reformulation of social, spatial and technological relations, in 2017 The Bartlett School of Architecture, at University College London (UCL), launched Design for Performance and Interaction (DfPI), a Master's in architecture programme to critically engage these accelerating transformations. The disruption of emerging technologies is explored through the programme's central tenet that the creation of spaces for performance and the creation of performances within them can be symbiotic design activities. The approach is novel and has generated a unique space for examining overlaps between architectural education and other pedagogic practices and discourses engaged in designing near futures. This article contextualises the development of a transdisciplinary programme in relation to the field of media art. It presents our approach to building a transdisciplinary course and the preliminary results of a programme now entering its third year. It is visually illustrated by student work that has emerged in the first two cohorts of graduates.

Pedagogic context: computational entanglements

A classical view of the disciplinary institutions imagines pure and stable branches of knowledge, divided and organised rationally. In practice, disciplines are mutable, historically contingent organisations, growing and shrinking, heterogeneous and fractious at times. In a traditional institutional model, when common challenges are found across departments, a multi-disciplinary approach decomposes problems into sub-parts that are addressed by disciplinary expertise. This compartmentalisation can lead to territorialising research, and often reinforcing disciplinary traditions rather than challenging them. A historical example of where this hampered progress in research can be found in the multi-disciplinary development of early artificial intelligence (AI) and autonomous robotics. Mechanical, electrical, and computational design challenges were decomposed and dealt with as modular problems independently of one another (Brooks, 1999). The incorporation of social sciences, such as psychology, further siloed study with insufficient dialogue between the humanities and sciences. Phil Agre's critique of early AI research illuminates how disciplinary structures with their own self-reinforcing conceptual schemata had limited the scope for self-critical practices within the emerging field. He describes how «disciplinary culture, runs deeper than we are aware» and can make it «actually impossible to achieve a radical break with the existing methods of the field» (1997).

Disciplines are almost conservative by nature. Hence, in recent decades, inter-disciplinary approaches have become popular to create productive spaces of collaboration. Disciplines can overlap to varying degrees, sharing methods and content. By contrast with the decompartmentalising nature of multi-disciplinary approaches, inter-disciplinary research integrates practices often motivated by a shared view that existing modes of working are unable or unwilling to tackle emerging challenges. In its basic form, interdisciplinarity allows for a task to be addressed by a novel arrangement of overlapping expertise. A more reflexive, critical interdisciplinarity can also further epistemological concerns, revealing inherent structures (such as self-reinforcing conceptual schemata) and disciplinary relations that uncover potentially productive new areas of research and practice. An example of productive interdisciplinarity can be found in the development of Science, Technology and Society (STS) research, addressing a gap between social sciences and engineering. STS emerged from a growing recognition that classical disciplinary models of technological study were inadequate in critically examining the complex reformulations in social, spatial and technological relations. This is no small challenge. Technologies such as computing are so ubiquitous, Phil Agre argues, that they are «found contributing to the evolution of the activities and relationships of so many distinct sites of practice – that we have no idea how to begin reckoning their effects upon society» (1997).

Curator Paola Antonelli uses the phrase "Knotty Objects" (2015) to convey the challenging task of disentangling the complex interrelating agencies of art, science, design and technology. When roles and boundaries between disciplinary practices become indistinguishable, some practitioners look beyond disciplines entirely for models that reject discrete historical organisations of knowledge.

«Interdisciplinary work is when people from different disciplines

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work together. But antidisciplinary is something very different; it's about working in spaces that simply do not fit into any existing academic discipline–a specific field of study with its own particular words, frameworks, and methods» (Ito, 2016).
In the inaugural essay for the Journal of Design and Science, architect and researcher, Neri Oxman argues "that knowledge can no longer be ascribed to, or produced within, disciplinary boundaries, but is entirely entangled" (2016). She points to MIT Media Lab's use of the term "antidisciplinary" to demonstrate its disregard for institutional branches of knowledge, engaging vigorously in complex intertwined subject matter. It is notable that the Media Lab emerged out of MIT's architecture school, incubating collaborations that, for the time, stretched far beyond architecture's traditional subject matter. Its founder Nicholas Negroponte set out its agenda in a briefing where he described the Media Lab as "designed to be a place where people of dramatically different backgrounds can simultaneously use and invent new media, and where the computer itself is seen as a medium -- part of a communications network of people and machines -- not just an object in front of which one sits." (Rowan, 2012). This was not a new idea, however. Decade's before the founding of the Media Lab, the notion of the computer as media has been enticing artists seeking novel forms of expression.
Early exhibitions, such as Cybernetic Serendipity held at the Institute of Contemporary Art, London, in 1968, and the presentation of computer generated graphical works by Frieder Nake, Georg Nees, and Herbert Franke at the 1970 Venice Art Biennale, helped to establish a sense of an emerging field. Electronic art, cybernetic art, systems art, computer art, interactive art, new media, multimedia, digital media, digital art, are just some of the terms used in an effort to define a diverse and amorphous field of creative practitioners that emerged. Its slippery resistance to definition is a symptom of its germination in an era of computational entanglements. Today, prefixing media, art or architecture with the word 'digital' seems somewhat quaint. It also fails to reflect recent developments in life sciences that are revealing the computational and creative potential of harnessing biology as media as well. Hybrid Arts is a term employed by an organisation, such as Ars Electronica, to throw a wider net, yet it has failed to achieve popular use. And so, embracing the transmutability of the field as its defining feature, I will refer to it simply as media arts.
The emergence of media arts in the context of a discussion of disciplinarity is important, as it represents the clearest example in the arts, of explicit transdisciplinarity. Widening computational literacy, enabled by networked and open source communities, has driven the development of interoperable tools that blend previously distinct practices of sound and music production, illustration and graphics, movement and performance, biology and robotics, installation and architectural design. This computational fluidity has the effect of dissolving disciplinary boundaries, and developing not only hybrid forms of existing practices, but also the emergence of radically new forms of practice. This is the distinction I make between interdisciplinarity and transdisciplinarity. As someone who has spent the last decade working collaboratively between interaction design, performance, robotics and installation art, while teaching within a school of architecture, I personally characterise my practice as transdisciplinary. Terms like anti-disciplinary and post-disciplinary in my personal view can sound a little hyperbolic when used by Directors of academic institutions, no matter how radically they may view themselves and their colleagues. Those practitioners operating entirely free of academia and institutional frameworks may perhaps be more comfortably able to describe their practices in these ways, but a cursory study of the field of media art and the more experimental domains of architecture will reveal many practitioners balancing artistic and academic practices.

Methodology: foundations of a transdisciplinary programme

The formulation of DfPI began with establishing a working group consisting of key Bartlett staff working in performance, media and spatial practices. In parallel we turned to London's leading studios specialising in performance and interaction who exemplify transdisciplinary practices rooted in architectural methodologies. These included Umbrellium, Bompas and Parr, Scanlab Projects, Stufish, and Jason Bruges Studio. Principle aims and requirements were mapped out including the need for space to fabricate, test and perform interactive installations and performances. The typically compact central London studio environments of UCL's Bloomsbury campus were unsuitable and so the Faculty took the opportunity to add to its estate by becoming a resident of Here East, the former media complex of the 2012 London Olympics that had been regenerated after the games to provide over a million square feet of versatile spaces for creative and technology companies and institutions. Today's tenants include Studio Wayne McGregor, Ford's Smart Mobility Hub, BT Sport, and Plexal, a co-working space for technology start-ups. A stone's throw over the adjacent canal is Hackney Wick, the densest concentration of artist studios in Europe. This diverse ecosystem of creativity and technology offered ideal conditions for The Bartlett to partner with UCL's Faculty of Engineering Science to take up residency at Here East and develop new educational programmes and research to benefit from this context.
In line with the central tenet of DfPI – that the creation of spaces for performance and the creation of performances within them can be symbiotic design activities – we took an active role in not only designing the course but also the facility where it would take place. Core facilities include a large scale 'Black Box' Studio with theatre lighting and a dance floor, a 12-Channel Surround Sound Chamber, 'Artifical Sky' Lighting Studio, a Virtual and Augmented Reality Studio with high performance GPU Computing, and a

| 01

01 | Still shot from film by ScanLab Projects, revealing slices through Lidar scans of The Bartlett's Here East facility. Above you see a large auditorium and beneath it spaces for dedicated research labs

| 02

02 | @heyhexx (2018) by DfPI Students S. Yamaguchi, P. Liewatanakorn and P. Farahzadeh. An interactive social media responsive robot puppet theatre installation. Students developed physical models and scenography alongside integrating a variety of software systems from social media APIs to microcontrollers and robot arm control

330-seat multi-functional auditorium (Fig.01). All researchers and programmes at the facility share access to a state-of-the-art digital fabrication facility including CNC manufacturing equipment and industrial robotics. All of UCL's robotics research, which previously occurred in pockets around campus, were housed at the spacious new site allowing The Bartlett and Faculty of Engineering Science to share its large volume robotics for manufacture, inspection and testing, alongside Computer Sciences current research in autonomous multi-agent mobile robotics and UCL Medicine's surgical robotics. Such a facility is unique in the UK, with few international equivalents making it an exceptionally fertile environment for the establishing of a transdisciplinary programme.

The teaching team was assembled through an exhaustive search for academic and industry practitioners who demonstrated original and sophisticated engagement in at least two of the fields of architecture, design, performance and interaction. Many of those who were selected demonstrated an engagement with all four areas. Half of our teaching staff had architectural backgrounds but were evidently engaged in practices outside the professional architectural domain. These included an architect who was also a neuroscientist. Another had shifted from architectural practice to developing generative graphics for live performance. One more example was an architect working with Artificial Life techniques to design interactive environments. The most difficult challenge was to attract tutors who had no architectural or spatial design background, but who would feel comfortable in the context of the Bartlett. By reaching out to the Media Arts community, we were able to headhunt a mechatronics engineer, game designer, sound designer, film maker, computer scientist, dancer and choreographer who had worked across disciplinary boundaries in performance and interaction.

Teaching structure The programme is structured over 15 months, which allows for an important three-month overlap between incoming and graduating students. This overlap is designed so that the output of the previous cohort can inspire the incoming students who arrive in September and graduate the following year in December. Three integrated modules run in design, theory and skills throughout the first six months (2 terms) of teaching. This preliminary period is focused on introducing a range of technical expertise and theoretical frameworks, through design workshops and critical writing exercises. Theory is drawn from performing arts, digital media, spatial interaction, anthropology, sociology, cybernetics, cognitive neuroscience and aesthetics. Skills training begins with an introduction to coding techniques for beginner students, and advanced classes for those coming from computational backgrounds. Once a baseline of understanding is established, students are exposed to a variety of scripting and visual programming approaches for manipulating a range of media, including computer graphics, sound, physical computing and robotics. Design workshops also introduce a range of techniques in animation, choreography, photography, film-making, 3D modelling, mechanical simulation, and fabrication.

The second phase of the programme shifts from tutor led intensive workshops to students establishing their thesis agendas typically in groups of 2 or 3 though some choose to work independently. The remaining 9 months are led by these agendas in continuous conversation with their design tutors. Individual students also declare a theoretical interest typically aligned with their design work and begin constructing their written dissertation with the support of a network of specialist theory tutors. Terms end with 'Project Fairs' at Here East where student work is presented to the public as a marketplace of prototypes and ideas. Traditional jury based 'Crits' also take place halfway through term so that students develop the ability to present their work to large audiences. Final submission of a portfolio takes place in early December with a graduate show at The Bartlett's Central London campus in Bloomsbury.

Results We were pleased to find that there was a great amount of interest for a transdisciplinary masters. On announcing the new programme we received over 100 applications and accepted 35 students into the inaugural cohort. We have seen a 40% growth each year in applications and an increasingly diverse range of students applying. Our current cohort is a mix of 55% from backgrounds in architecture, interior and urban design balanced by a mix of digital media, fine art, performance and theatre students, with a few coming from computing, 03 | (Un)Balance (2018) by DfPI Student Elyne Legarnisson is an interactive experience in XR (extended reality) inviting participants to play on the edge of stability

04 | CuGo (2019) by DfPI Students Kongpyung Moon and Peng Gao 2019. An CuGo is an interactive board game, where human and robot players collaborate to achieve a shared goal. The students developed the modular robot blocks, the game logic and the robotic interaction software

| 03

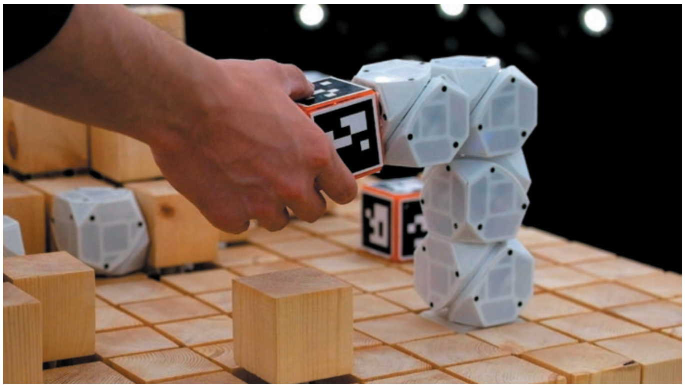
robotics, psychology, literary theory, economics and fashion. The trend seems to show increasing numbers of students coming from outside spatial design disciplines. Our current class of 45 is reaching close to our planned intake limit so as applications increase, we will be able to benefit from being increasingly selective about those we select.

This programme is in its infancy and it is too early to assess its impact, but indicators of certain trajectories are emerging in conversation between staff and students. One emerging area of enquiry is between architecture and dance, centring movement as a way of examining, understanding, and shaping experiences. Some of the experimentation in this area has been through physical kinetic work and some through virtual and extended reality experiences (Fig.03). Another area of rich enquiry is 'crossmodal interactions' and how a range of sensory inputs and outputs in relation to site and context can reveal new forms of situated experience. Site specificity is a particular strength of architectural education that has great value and is perhaps under-appreciated by those who have become so used to discussing it, and they do not realise how alien a conversation it is to large swaths of the creative industry. The productive power of the site to shape a design process is something that we wish to promote. We see it as a feature of the course that distinguishes it from much of media art or interaction design, for example.

A lot has been learnt in the early years of the course. A major challenge when bringing people from diverse disciplinary backgrounds is how to communicate ideas to one another. Different disciplines have their own representational methods, such as drawing, model making, storyboarding and writing. Students coming from further afield, such as robotics or music, can struggle in these situations, so we now teach animation tools to all students as a means to communicate in 4D. A tiered approach to teaching coding has also proven very successful with virtually all students showing confidence in discussing coding principles by the second term. Not only does this literacy give them access to a wider and deeper array of applications, it also gives them confidence to take on other technical challenges, such as learning to weld or producing machining instructions for a CNC Mill.

The design philosophy from the beginning has been to make things quickly, test them with the public and iterate multiple times. Only over the summer should a clear vision for the final 'Production' arrive, so feedback throughout the year is essential for students to shape their own thinking. The one-to-one format of the Project Fairs is far more popular with students than crits, and it appears to generate a lot more positive and useful feedback to build upon rather than what juries can deliver. Though not in our original planning, a key feature of the course to emerge has been a regular invitation to exhibit work at Ars Electronica, the leading annual international festival on media art in Linz, Austria. With thousands of discerning visitors to see the work, the quality of feedback is very valuable to the students and greatly motivating. Other public exhibitions have included a pop-up exhibition at the Barbican Centre in August 2019 for the Life Rewired festival where we shared a variety of artificial life projects including Cugo (Fig.04) pictured below.

In early 2019 we were approached by the Tate, the UK's leading institution for contemporary art. Their Tate Collective Producers team had discovered our work while looking for a partner to put on a special evening event on the theme of the Bauhaus centenary. We were honoured that DfPI had been recognised for sharing some of the radical transdisciplinary spirit we felt the Bauhaus embodied. Ten projects by staff, students and collaborative partners were shown at the Tate Britain Gallery on 1st November 2019 including kinetic sculpture, projection mapping, DJ sets, animation, sound installation, robotic puppetry and dance with a recorded audience of 2835 visitors over the night.



| 04

Conclusion

When the Bauhaus was founded, society was questioning the role of humanity in an age of mechanical automation. The tension between human performance and machine performance inspired the design of kinetic sculptures, android costumes and geometric choreography. At the scale of architecture, entire theatre plays were imagined, composed entirely of autonomous machines, far beyond the technology of the time. Today with rapid advances in robotics and AI, such possibilities are within our grasp, and the tension between human and machine agency continues to provoke us on our Masters in Design for Performance & Interaction where we take advantage of the latest technologies to explore and advance their aesthetic possibilities.

The UK has historically maintained a rigidly vertical model to architectural education defined by professional accreditation. However, we are beginning to see a bifurcation of specialist programmes, particularly at postgraduate level, that one could compare to the carving up of medicine at the turn of the 20th century into distinct areas of expertise. Architecture has historically held a holistic identity between the arts and engineering, but it seems quite certain that as the complexity of designing and constructing the built environment increases, the calls for specialisation will only grow stronger. Our programme does not follow that call but rather resists the strategy of compartmentalisation and, instead, reaches radically further outside the discipline than virtually any other MArch programme in the country.

Literacy in coding, electronic sensing and robotic actuation, animation, digital simulation and fabrication techniques empowers students to realise physical and virtual prototypes that are tested in public settings including the Tate Britain, Barbican Centre and Ars Electronica. These materials and situated engagements with emerging technologies unpack and offer critical reflection on the ideologies, hidden assumptions and values shaping technological design. This practice of material and critical engagement we believe provides a means for navigating today's complex cultural, technological and socio-economic landscape and imagining its possible futures.

REFERENCES

Agre, P. (1997), "Toward a Critical Technical Practice: Lessons Learned in Trying to Reform AI", in Bowker G., Gasser, L., Star L. and Turner, B. (Eds.), *Bridging the Great Divide: Social Science, Technical Systems, and Cooperative Work*, Erlbaum.

Antonelli, P. (2015), *Knotty Objects Summit*. The MIT Media Lab.

Bartlett School of Architecture, UCL (2017), "Design for Performance & Interaction MArch (n.d)", available at: https://www.ucl.ac.uk/bartlett/architecture/programmes/postgraduate/march-design-for-performance-and-interaction (accessed 2 January 2020).

Brooks, R.A. (1999), *Cambrian intelligence: The early history of the new AI*, MIT press.

Ito, J. (2016)."Design and science", *Journal of Design and Science*, MIT Press.

Oxman, N. (2016), "Age of entanglement", *Journal of Design and Science*, MIT Press.

Payne, Andrew O. and Jason K.J. (2013), "Firefly: Interactive prototypes for architectural design", *Architectural Design*, Vol. 83(2), pp. 144-147.

Ratto, M. (2011), "Critical making: Conceptual and material studies in technology and social life", *The Information Society*, Vol. 27(4), pp. 252-260.

Rowan, D. (2012), "Open university: Joi Ito plans a radical reinvention of MIT's Media Lab", available at: https://www.wired.co.uk/article/open-university (accessed 2 January 2020).

A teaching strategies model experiment for computational design thinking[1]

Selin Oktan, Serbülent Vural,
Department of Architecture, Karadeniz Technical University, Turkey
selinoktan@ktu.edu.tr
svural@ktu.edu.tr

Abstract. This study aims to share an educational model experiment for teaching computational thinking with hands-on activities. There is a gap between today's architectural education system and computational thinking. The exercises aim to fill this gap. In this study, conventional and computational design processes are not considered as two opposing poles, but as integrated processes and as a bridge between these processes.
Starting from Gagné's model, the learning process classification is reinterpreted, and the exercise processes are discussed in the titles of reception, expectancy, computation and semantic encoding, responding and creating alternatives. The outcome of this study will be a discussion on the first results, observations, and feedback from the students about the educational model attempted to be created.

Keywords: Computational design; Computational thinking;Conventional design; Parametric model; Material studies

Introduction

The idea of modernism plays an important part in today's architectural education system. However, modernist doctrines fail to discuss and explain computational design processes. Rivka Oxman (2008) says that developing technology is changing architecture evidently, and that the architectural education system must be updated to answer this transformation. The progressive architectural schools are aware that students are becoming more familiar with technology. The discourse, knowledge, practice and research must be redefined by architectural schools within the context of developing technology (Sheil, 2012), which brings computational fabrication techniques, thus increasing the importance of computational thinking. This study focuses on creating an educational model to fill the gap between today's architectural education system and computational thinking processes. The methodology is based on Bauhaus teaching methods and attempts to reconsider them within today's computational design methods. It uses various techniques, such as hands-on activities, learning by doing, and flipped classroom to teach computational thinking to undergraduate students.

Within the scope of the study, conventional and computational methods are not considered as two separate poles, but as integrated processes that support each other. For this reason, each exercise carried out as part of this study starts with a conventional method and is finalised with a computational method. The exercises are based on "hands-on activities". During the semester, four exercises and one final exercise based on various techniques and materials were performed, but only two of them are presented in this paper. One of these exercises focuses on knitting technique and fibre material, while the other concerns the form-finding technique and fabric material. The exercises were carried out with fifth year architectural students. It is important to carry out the computational thinking exercises with undergraduate students in order to make future architects familiar with the developing technology and computational thinking.

The conventional method is the first process a student of architecture learns. Within this study conventional methods, which students are accustomed to, are used as a first step for teaching computational thinking. This is important to underscore the common points between computational methods and conventional methods. A pre-test – post-test design method is conducted to measure the students' change after the exercise series. A questionnaire is administered at the beginning and at the end of the semester. The questionnaire is drawn up within the frame of the Lawshe method. As a part of the Lawshe method, questions are evaluated by six experts and the final form of the questionnaire is produced (Lawshe, 1975). The outcome of this study will be a discussion on the first results, observations, and feedback from the students about the education model attempted to be created.

Constructivist approaches for computational thinking

The transition period in architecture, which starts with computer aided design (CAD) methods, continues today with digital architectural design (Oxman, 2008). The digital tool was previously used instead of paper, and only for presentations. However, today it has been transformed into a co-designer and a tool for defining the design process. Clark says that «Conventional CAD is just an electric pencil» (Whitney, 1990). But computational tools have more potential than an electric pencil. Hence the need to improve computational thinking. The concept of computational thinking, which is discussed as a part of this study, describes the design process step by step and with computational relations as in the algorithm.

Developments in the field of technology lead to new research areas in architecture. Similar associations between architectural education and technology occurred in the past. For example, the establishment of the Bauhaus School is directly related to the 2nd Industrial Revolution. It is a foregone result that today's technological transformation will affect architectural education. Within this context hands-on activities, a core method of this study, were used by the Bauhaus School too. In this sense, Bauhaus methods guide towards the model the research is attempting to create to teach computational thinking. Constructivist approaches in education are the common points for both Bauhaus and the exercises carried out within this study. The constructivist approach first focuses on 'knowing how' and then on 'knowing that' (Schoenfeld, 1987). In this aspect it is believed that the constructivist education process is related to computational thinking. The progressive architectural schools in the field of computational design, such as MIT, IAAC, etc., which also adopt constructivist approaches, prefer to carry out their studies with graduate level students. For example, Neil Gershenfeld's famous class called 'How to Make Almost Anything' is only open for graduate level students (Gershenfeld, 2008). This study tries to teach computational thinking at undergraduate level, and aims to do so by learning by doing exercises, which are closely related to hands-on activities. 'Hands-on activities in the learning process make the students focus even more. In this process students face problems about details and try to find a solution. As a result, the students learn how to do it. For this reason, hands-on activities lead to constructivist learning.

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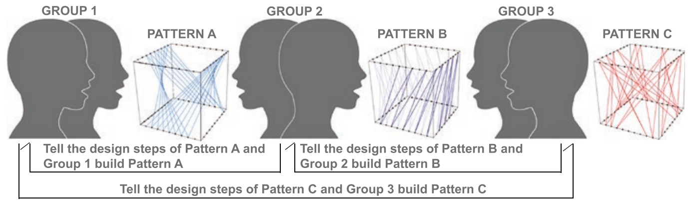
01 | The conventional process of knitting exercise



Hands-on activities

Learning by doing (Dewey, 1938; Özkar 2007), bringing theory and practice together (Tzonis,2014), are the concepts reconsidered in today's architectural education system after Bauhaus. John Dewey (1938) emphasises that learning by doing in the conventional design process is insufficient, and doing and experiencing must be at the core to personalise the learning process. Dewey's claim gains importance today to bring theory and practice together. It is also important to direct the student's attention to the course content. This study aims at developing new teaching methods. Within this context, Dewey's (1938) determination is taken into consideration and the exercise processes are integrated with hands-on activities.

The hands-on activities were also a part of Bauhaus' education system, and learning by doing was at the core. Bauhaus was aimed at graduate students who are familiar with the new technology. Within this perspective, both this study's aim and Bauhaus School's aim coincide. Both Dewey's (1938) vision about learning by doing and the hands-on activities of the Bauhaus School are considered as previous experiences for this study. The study attempts to integrate such experiences with computational design thinking. The study develops an educational model to improve computational thinking.

A model experiment for teaching computational design thinking

The model to be created for teaching computational thinking consists of two main phases. In the first phase, a design problem is assigned to the students and they are expected to apply the solutions to this problem. This stage is usually implemented on a model scale. The first stage is carried out with conventional methods and the computational relations of the design process are questioned in this stage. In the second stage, a similar process to the first stage is carried out in the digital environment by means of the parametric model. At this stage, students discover that the digital and the conventional design processes are complementary processes.

Gagné (1985) classifies learning conditions of cognitive processes as reception, expectancy, retrieval, selective perception, semantic encoding, responding, reinforcement, retrieval and generalisation. Within this context, starting from Gagné's model, the learning process classification is reinterpreted at the intersection of conventional design approaches and computational thinking:

- reception: defining the design problem;
- expectancy: detailing the design problem;
- computation: defining the computational relations about the design problem; design phases are defined step by step as in the algorithm; the black box of the conventional process thus becomes explicit;-
- semantic encoding: students are told how to create a parametric model for a similar process; the flipped classroom model is applied in this process; within this context, homework is done at school and a lecture is given as homework;
- responding: students recreate the parametric model within the context of computational relations defined by themselves;
- creating alternatives: the parameters of the parametric model are redefined, and the alternative models are created. If the student can create meaningful alternatives that answer the design problem, this shows that the student has successfully learnt the computational modelling process.

Reception, expectancy and computation phases are carried out in the conventional design process; semantic encoding, responding and creating alternatives phases are developed in the computational design process.

Conventional process of the exercises

The design process is shaped by the designer's subjective approach to the problem. In the conventional design process, the designer is not obliged to explain his/her decisions with the related reasons, which is called the black box of design process. On the other hand, in the computational design process the design process itself is designed. For this reason, every step of the design process should be explained. For computational thinking to become part of the design process, the designer must be able to explain even its intuitive steps. Within this context, the computation phase, which is performed in the conventional stage, is the base for the model to be created.

As a part of this study, the exercise processes which focus on various making techniques and materials are discussed in point of learning process classification. Within this context, the first exercise was carried out with fibre material and knitting technique. The first phase of this exercise is reception. In this phase the students were asked to design a pattern in the given 30 cm3 cube volume. The fourteen students worked in pairs. The second phase of the learning process is expectancy. In this phase the details about the design problem were given to the students. At first, the students drew their pattern designs as a perspective view and wrote down their design process step by step, including the computational relations.

The third step of the learning process is computation. As a part of this study, the computation process is performed as writing a kind of G-code manually. G-code, in the digital fabrication process, is a language that provides human – machine collaboration. Every machine has its own coordinate system and travels according to it. In the study, the students were asked to describe every step of the design process of creating their patterns in a way that everyone could understand. The logic of G-code was thus taught. Each group tried to apply the pattern of another group (Fig. 1). Thus, the success of step-by-step description could be measured.

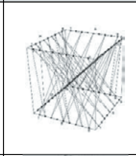
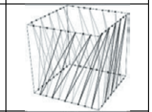
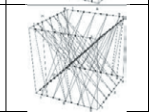
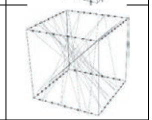
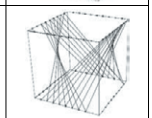
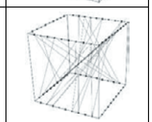
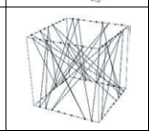
In the computation process, the general approach followed by the students was to tag the points with numbers or letters. A coordinate system was thus created, as in G-code logic. Then, every move made when designing the pattern was explained with this system (Tab. 1)

02 | The final products of conventional design process

Tab. 01 | The rules and images of the patterns

Tab. 02 | The rules and images of tensile structure exercise

Tab. 01

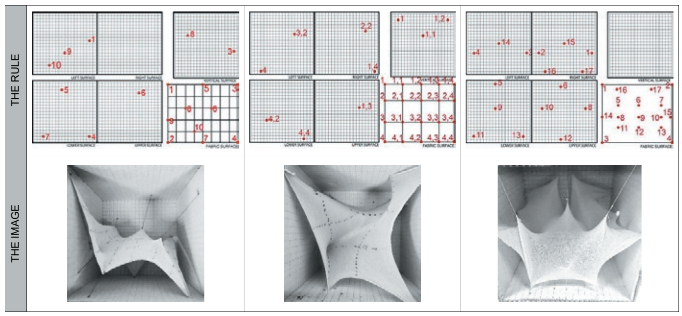
THE RULE	THE IMAGE
On the first edge of A plane, begin with an odd number and in every step add 3 to it, On the fourth edge of B plane, begin with an even number and in every step add 3 to it. A=[1,2,3,4] 1 2 3 4 ⇕ ⇕ ⇕ ⇕ B=[5,6,7,8] 8 7 6 5	
From left to right (for the beginning point); the number of bottom plane + 4 = the number of top plane From right to left; the number of top plane + 4 = the number of bottom plane	
Skip one point in every step. From A9 to B9 odd numbers are paired: (1-1) (1-3) (3-3) (3-5) (5-5) (5-7) (7-7) (7-9) (9-9) From B2 to H1 the empty points are paired.	
In the first round; From A plane to B plane → x + 4 From B plane to A plane → x – 1 In the second round; From B plane to A plane → (x+1), (x+2),…, (x+n) From A plane to B plane → (x+(n-1)) n= the first point of the new round	
Starting from the first point of A edge, in clockwise direction pass from one edge to another and add 1: A - 1 → F - 2 → C - 3 A1 – F2; F2 – C3; C3 – H4; H4 – A2; A2 – F3; …	
If you are on A go to G; If you are on G go to C; If you are on C go to E; If you are on E go to B; If you are on B go to H; If the point is an odd number then; point number + 3 (mode9) If the point is an even number then; point number + 5 (mode9)	
 A1→G9→A6→E3→B2→F5→B7 H3→C7→G1→C2→G8→D6→E4 D1→F6→A5→H2→B1→H9→B6 H7→C8→E5→C4→F7→D8→H1 D3→H8→A3→G6	

A Model Experiment for Teaching Computational Design Thinking

In the process of computing the conventional design process, it can be said that the students used repetitive movements, mathematical expressions or the computational equivalent of design steps. The design rules defined by one group were applied by another group. The final products are the same as the perspective drawings. This shows that the exercise process was successfully accomplished (Fig. 2).

The second exercise carried out as a part of this study was performed using the form finding technique and fabric material. In the reception phase, which is the first phase of the learning process, the design problem was described as designing a tensile structure in the 20 cm^3 cube volume. In the second phase, expectancy, the design problem was detailed. Within the context of the design problem, a five-face closed volume was prepared by dividing the surface into 1 cm grids. The grids were used in the computational phase of the conventional design process. In this phase the tension points were defined on the fabric material and tagged by numbers. The tension points on the fabric and the anchor points on the surfaces were matched. The parameters of the form finding process were thus defined (Tab. 2).

The final conventional phase of the exercise was completed by creating the first answer for the design problem and by applying the answer integrated with the hands-on activities. As a result of the conventional process, the design product which would be modelled parametrically was created. The first stage of the exercises, which are carried out with conventional methods, also involves a preparation for the computational design process. The link between the conventional process, which students are familiar with, and the computational design process is established at this first stage.



| Tab. 02

Computational process of the exercises

Computation means to formulate problems to represent them as steps or algorithms (Aho, 2012). The computational design process focuses on computational thinking. It is almost completely explicit, unlike the conventional design process. It also can be defined as designing the design process. The second stage of the exercise processes are carried out with the computational design process. In this stage a parametric model is achieved which, based on the information collected, forms the computed conventional design process.

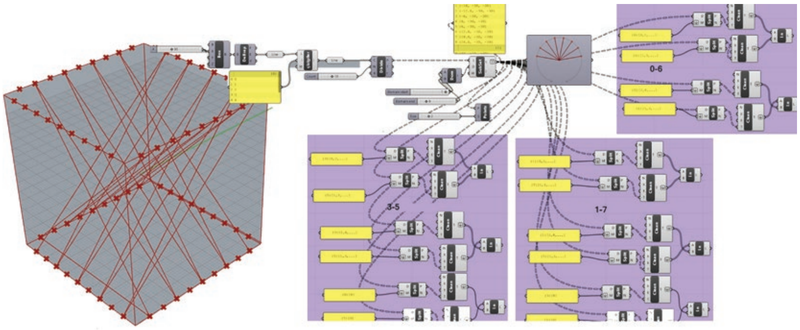
Grasshopper, which is a plug-in for Rhinoceros, was used as the parametric model tool. Semantic encoding, responding and creating alternative phases are performed in computational design stage as a continuation of the learning process.

The computational design process of knitting exercise, which is the first exercise of this study, begins with semantic encoding. In this phase students are taught how to create a parametric model of a similar design product. The modelling process is carried out in a similar way to the conventional design process. The model is

02 |

03 | The Grasshopper definition of knitting exercise

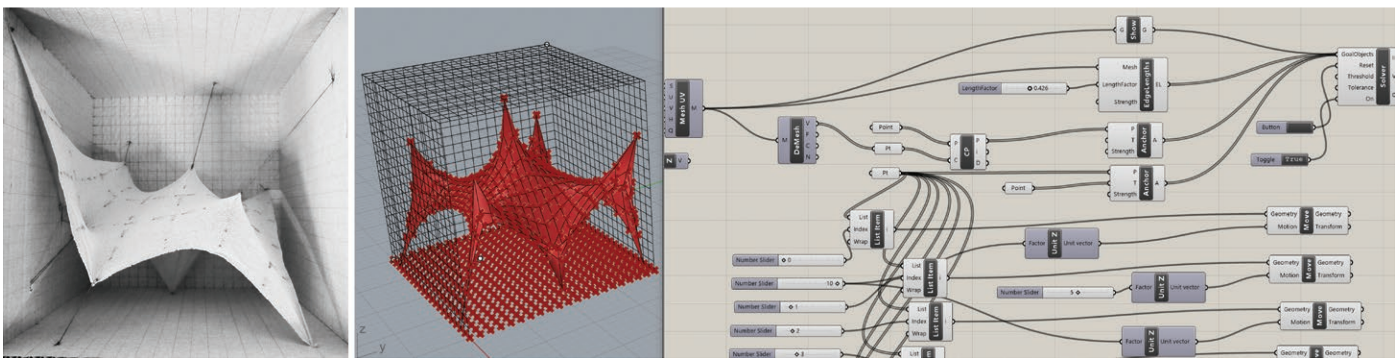
04 | The final products of conventional and computational processes



created by matching the set of points placed on the cube's edges against each other (Fig. 3).
In the responding phase, students try to redo the parametric model by themselves. In this phase the data collected from the conventional design process is used as the parameters of the parametric model. Thus, the bridge between conventional and computational design processes begins to be established.
The responding phase is followed by the creating alternatives phase, which is the last phase of the exercise process. One of the most important goals of computational design is to be able to create a design space, which includes lots of design alternatives. If the parametric model is structured in a proper way, creating alternatives for the design problem will take a very short time. At the end of the creating alternatives phase, the design products' success and its suitability with the design problem show that the parametric model was able to be created in a proper way. The students, who created proper models, also achieved the computational design process.
The second exercise process depends on form finding study. In the semantic encoding phase, students are shown how to model the material behaviour parametrically. In the modelling process, the anchor points on the cube's faces and the tension points on the fabric are matched; these points were computed in the computational design process. This exercise process teaches students a multi-directional approach about computational design, such as how to manage the data, to compute material behaviour, to model the external forces affecting the design system.
In the responding phase, the students try to precisely redo the parametric model phase conducted by the lecturer. In the creating alternatives phase, they try to model the design products, which were created as a result of the conventional design process. Within this process the parameters are redefined as they are computed in the conventional process. In this model redefining the parameters of tension points, anchor points and the data about material behaviour enables alternative models to be created (Fig. 4).
Making the computational data a part of the design process is an output for the performed exercises. As a result of the exercise processes the students were able to experience designing the design process as integrated with hands-on activities. Thus, the initial data about the educational model to be created were collected.

Results

It is widely believed that conventional and computational design processes are in conflict and differ from each other. This study focuses on making computational thinking a part of architectural education. A section of the performed exercises was shared to discuss this. The study attempts to create a unique educational model, which brings the conventional design process, hands-on activities and the computational design process together. These exercises are defined with a spirit recalling the Bauhaus-Industrial Revolution relation. Constructivist approaches have a place in the exercise processes.
The exercise processes start with conventional design methods and are finalised with computational design methods. The hands-on activities and learning by doing are at the core of both methods. This makes the learning process more understandable for the students. Instead of computational design education that only depends on teaching a software, this educational model focuses on turning design process into data and on using the data collected in the computational design process. It was observed that with these exercises, a bridge between conventional and computational design processes can be established.
As a result of the exercise processes, it can be said that the students easily understood the logic of computational thinking because the exercise process was integrated with the conventional methods, which the students are familiar with. Hands-on activities made the students concentrate on the design problem, and their atten-



tion on the course content increased. In addition to this, the flipped classroom model has a positive effect on learning Grasshopper/ Rhinoceros modelling because the students had a chance to watch the tutorials prepared by the lecturer repeatedly and to practice by themselves.

As a part of the pre-test – post-test design evaluation method, a questionnaire, which is drawn up within the frame of the Lawshe method, was conducted with the 14 students taking the course. The results of the questionnaire revealed that the students were already aware of the meaning of computational thinking and of the methods of parametric design even before the course. This shows that students, who are familiar with technology since their childhood, can easily adapt the computational design and fabrication processes. The number of students who thought that computational design ability and digital fabrication process are mutually relevant increased from 28% to 72%. This shows the students could identify the relationship between computational thinking and digital fabrication process. In the conventional design stage of the exercises the problem was deeply analysed, and the computational relations were defined. This process shows that conventional design processes can be performed in a completely explicit way. Carrying out the computational design process after that stage minimises the randomness of the design process because, to define the parameters of the design process, the students start thinking deeply about the design product and try to explain the design steps by themselves.

The computational design process has not emerged suddenly with no reason. It has emerged as a reflection of developing technology and to meet the needs of new fabrication techniques. It is crucial to catch up with developing technology by improving computational thinking skills. The design and fabrication processes are needed to be computed to provide human–machine cooperation. Both the logic of a machine language like G-code and creating an algorithmic definition of a design process are experienced within this exercise series. As a result, making computational thinking a part of the conventional processes of architectural education deserves deeper consideration, and hands-on activities must be at the core of the education system.

NOTES

[1] This paper has been converted from the ongoing PhD thesis.

REFERENCES

Aho, A.V. (2012), "Computation and Computational Thinking", *The Computer Journal*, Vol. 55, n. 7, pp. 832-835.

Dewey, J. (1938), *Experience and Education*, Kappa Delta Pi, Indianapolis.

Gagne, R. (1985), *The Conditions of Learning*, 4th ed., Holt, Rinehart & Winston, New York, USA.

Gershenfeld, N. (2008), *Fab: The coming revolution on your desktop--from personal computers to personal fabrication*, Basic Books, New York, USA.

Lawshe, C.H. (1975), "A quantitative approach to content validity", *Personnel Psychology*, Vol. 28, pp. 563-575.

Oxman, R. (2008), "Digital Architecture as a Challenge for Design Pedagogy: Theory, Knowledge, Models and Medium", *Design Studies*, Vol. 29, pp. 99–120.

Özkar, M. (2007), "Learning by doing in the age of design computation", *Proceedings of the Computer-Aided Architectural Design Futures (CAADFutures)*, 2007, pp. 99-112.

Schoenfeld, A.H. (1987), *Cognitive science and mathematics education*, Routledge, Abingdon, United Kingdom.

Sheil, B. (2012), "The digital generation", in Spiller, N. & Clear, N. (Ed.), *Educating Architects: How Tomorrow's Practitioners will Learn Today, Thames & Hudson*, London, pp. 138-144.

Tzonis, A. (2014), "A framework for architectural education", *Frontiers of Architectural Research*, Vol. 3, pp. 477-479.

Whitney, D.E. (1990), "Designing the design process", *Research in Engineering Design*, Vol. 2, pp. 3-13.

Climate-resilient urban transformation pathways as a multi-disciplinary challenge: the case of Naples

Mattia Federico Leone[a], Giulio Zuccaro[b],
[a] Department of Architecture, PLINIVS-LUPT Study Centre, University of Naples Federico II, Italy
[b] Department of Structures for Engineering and Architecture, PLINIVS-LUPT Study Centre, University of Naples Federico II, Italy

mattia.leone@unina.it
zuccaro@unina.it

Abstract. The effects of climate change in cities are already visible with extreme events globally increasing in both frequency and intensity. It is essential to consider the impact of urban regeneration strategies on local microclimatic conditions in order to guide urban planning and design in a resilient key. The complex management of information required to define adequate intervention strategies at a local level is a growing challenge for public administrations. The paper presents the first results of the ongoing H2020 project CLARITY (2017-2020) aimed at developing climate services for the integration of adaptation measures in urban redevelopment actions focused on activities performed in partnership by the UNINA team and the City of Naples, one of the project's case studies.

Keywords: Urban microclimate; Multi-scale design; Multi-level governance; Urban adaptation co-benefits; Naples case study

Introduction

The climate-resilient transformation of cities is a multidisciplinary challenge and a unique opportunity to bridge the "forecasting" approach typical of climate science and risk studies with the holistic "backcasting" perspective of urban, environmental and technological design. In this context, the project is the materialisation of a future urban vision, where mid- to long-term mitigation/adaptation strategies need to be synergised with short-term social, economic and environmental co-benefits aimed at tackling specific urban regeneration needs by assessing and prioritising the design alternatives, thus shaping and phasing the preferable and feasible scenarios.

The methodology adopted by CLARITY aims at identifying climate change scenarios at city level that take into account the variability of urban microclimate and the contribution of districts' morphology, building and construction typologies, surface materials and characteristics of open spaces in either amplifying or reducing the impact of extreme heat and flood events in order to identify and prioritise suitable adaptation measures.

To this end, dedicated GIS-based and parametric design tools have been developed to refine the information derived from climate models, with a typical resolution of 10 km and a detail of up to 250 m (city plan) and 5 m (district development)[1]. Satellite data at pan-European (Copernicus) and local (national to regional database) levels have been processed to extract detailed information on key parameters to model the response of urban environment to climate stresses (albedo, emissivity and run-off, buildings and green fraction features, etc.).

The City of Naples is currently integrating such information in a multi-scale planning perspective, from strategic vision to district level design by updating the local Sustainable Energy and Climate Action Plan (SECAP), the new City Plan (PUC), and the Urban Regeneration Project in the eastern suburbs (PRU Ponticelli). The scope is to drive the urban policy towards climate-resilient transformation pathways. In particular, simulations and reports produced within project CLARITY have been publicly discussed by the Municipality of Naples and integrated into the Preliminary City Plan and Environmental Report[2].

Climate change scenarios for the city of Naples

Naples, like many cities in the Mediterranean area, is already facing a significant climatic variation, compared to the 1971-2001 "historical" reference period. The last few years have shown a constant increase in minimum and maximum temperatures (to which more frequent episodes of heat waves are associated), while seasonal precipitation patterns present an increasingly evident alternation between periods of drought and extreme events characterised by high rainfall concentrated in a few hours (often resulting in surface flooding episodes).

Climate projections confirm these trends, with uncertainties related to the entity of the expected variation, depending on the different GHG emission scenarios (RCPs). Recent studies (WHO-UNFCCC, 2018; Ministero della Salute, 2019) estimate an increase in the number of heat waves and extreme precipitation, and in the duration of drought periods in Italy.

However, annual average values processed with statistical methods from observations on single weather stations (Fig. 1, top) do not allow to represent the critical issues that cities face in relation to climate change. More precise information about the frequency of extreme temperature and precipitation events (often concentrated in limited periods of the year and, therefore, not "caught" by annual average values) is required, taking into account the effect of urban environment features, such as urban heat island and surface run-off, in aggravating the expected impact.

CLARITY project has, therefore, focused on defining these aspects, identifying in detail the increase in frequency of heat waves and heavy rainfall until 2100, and processing accurate modelling of urban morphology and land use to capture the effect of built environment features on the urban microclimate.

Detailed analysis of extreme events related to climate change

Heat waves

Heat waves occur when high temperatures are recorded for several consecutive days, often associated with high levels of humidity, strong solar radiation and absence of ventilation (Pyrgou et al., 2017). These weather-climate conditions can represent a health risk for urban communities (Italian Ministry of Health, 2019; Ng and Ren, 2015).

EURO-CORDEX data processing allowed to estimate the number of events expected in the period 2020-2100, starting from the 1971-2011 historical series. The projections refer to the IPCC emission scenarios RCP8.5 and RCP4.5. Figure 1 shows the summary of some significant extreme events for the Naples area. The data analysis shows that events similar to those recorded in recent years (36°C for periods even longer than 6 consecutive days) will increase significantly in terms of frequency and intensity in the next thirty years, reaching intensity levels never recorded before (over 9 consecutive days with temperatures above 38 °C).

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Surface flooding

Surface flooding events usually occur when high amounts of rain are concentrated in a limited period of time. The scientific complexity linked to the projection of precipitation scenarios with sub-daily detail led to the decision to observe daily trends and assimilate them to concentrations of less than 6 hours, which is a recurring characteristic in the case of Naples. Figure 1 shows the number of expected events in which the amount of rain exceeds the minimum threshold observed in recent storms in Naples. The data analysis shows that events similar to those recorded in recent years will increase significantly in terms of frequency and intensity over the next thirty years, reaching levels never recorded before (100 mm/day) in the second half of the century.the second half of the century.

Analysis of the "local effect" and supporting data for urban planning

As mentioned, the sole analysis of data derived from the observation of past events recorded by local weather stations and projected in the future through statistical "downscaling" of Regional Climate Models (RCM) cannot capture the microclimatic variability linked to the settlement characteristics of the urban environment. The urban morphology and the land cover greatly influence the thermal stress conditions and the ability to absorb rainwater, resulting in significant diversification of the main hazard parameters.

In order to support urban planning, CLARITY has developed specific simulation models running in a GIS environment and able to capture the urban "local effect" of heat waves and floods, thus providing more precise information on the climate adaptation strategies to be implemented in different parts of the city. The first essential element of information is the creation of a GIS database of land use that contains all the parameters necessary for "local effect" simulations. The datasets shared by the City of Naples (currently used for planning purposes at various levels) have been verified and corrected (in terms of geometries and intended uses) through comparisons with recent high resolution satellite images (Pleiades 2018 data), and integrated with the input parameters required by the models.

The resulting land use map is extremely detailed, and includes essential elements not present in ordinary cartographies, such as the presence of trees and the characteristics of albedo, emissivity and run-off of the different urban surfaces.

The processing of the different datasets through the simulation models developed by PLINIVS-LUPT Study Centre for CLARITY has allowed to identify the expected levels of hazard related to heat waves and surface flooding phenomena. This information is the hazard component at the basis of the corresponding impact models, currently being calibrated, which will allow to identify the effects of heat waves on the population (in terms of impact on human health, including the increase in mortality), and the effects of flooding on buildings (in terms of interruption of road networks and economic damage to property or production activities).

Heat waves - local effect

The thermal stress variation in the different city areas is simulated through the Mean Radiant Temperature (Tmrt) indicator, which is widely validated in the literature as representative of perceived outdoor comfort (Chen et al., 2016). This is essentially derived from air temperature, surface temperature, urban morphology and surface characteristics of buildings and open spaces[3].

It is noteworthy that, although Tmrt does not consider wind as a parameter, extremely low wind speeds are recorded during heat waves and, therefore, the simplification adopted, which has been widely recognised in the scientific literature (e.g., Gulyás et al., 2006; Oke et al., 2017), is suitable in relation to the objectives of the simulation.

Heat wave simulations can be carried out according to different temperature thresholds. The simulation shown in figure 2, as an example, has been included by the Municipality of Naples in the PUC as a useful element to support urban planning, since it allows to highlight areas characterised by critical conditions depending on land use and urban morphology (like medium-low density areas with prevalence of dark horizontal waterproof surfaces, lack of green areas and trees).

Each cell of the grid can be analysed more in detail to determine to what extent the specific land use and building-open space configurations influence Tmrt values and, therefore, the heat outdoor discomfort and associated health risks (Fig. 3). Such detailed analyses allow to appreciate some aspects that link urban morphology and land use to microclimatic conditions.

In the ancient centre area, building density determines shading conditions that reduce thermal stress. Differences between cooler green areas and overheated asphalt roads can be noticed in bigger squares. In the courtyards of historic buildings, differences can be observed between the larger and smaller ones, where the latter are cooler due to greater shading. The presence of green areas and trees represents a thermal stress reduction factor in the larger courtyards. In Rione Traiano and Ponticelli areas, the greater distance between the buildings and the limited presence of trees cause considerable overheating, which is reduced, especially in the case of Ponticelli, by the large green areas present in some urban blocks.

The model also allowed to develop further simulations related to the perceived discomfort conditions detected by the UTCI indicator (Fig. 4). The damage classes are calibrated with reference to weak population groups (children under 15 and elders over 65) for the Naples climate zone (D'Ippoliti *et al.*, 2010).

Surface flooding - local effect

Flooding simulations are extremely complex due to the large number of parameters involved and the level of detail needed to repre-

01 | Top, annual rainfall and temperature averages in the period 1971-2100 for the city of Naples for concentration scenarios RCP4.5 (green) and RCP8.5 (red). Source: CMCC – Centro Euromediterraneo sui Cambiamenti Climatici (D'Ambrosio e Leone, 2018); middle, historical and projected heat waves in the period 1971-2100; bottom, historical and projected extreme precipitation events (Source: ZAMG / PLINIVS-LUPT, CLARITY project)

02 | Mean Radiant Temperature map in Naples for a typical day of heat wave with air temperature 36-37°C (250x250m grid) (Source: PLINIVS-LUPT, CLARITY project)

03 | Detailed analysis of the Mean Radiant Temperature in some areas of Naples, for a typical heat wave day with air temperature 36-37°C (Source: PLINIVS-LUPT, CLARITY project)

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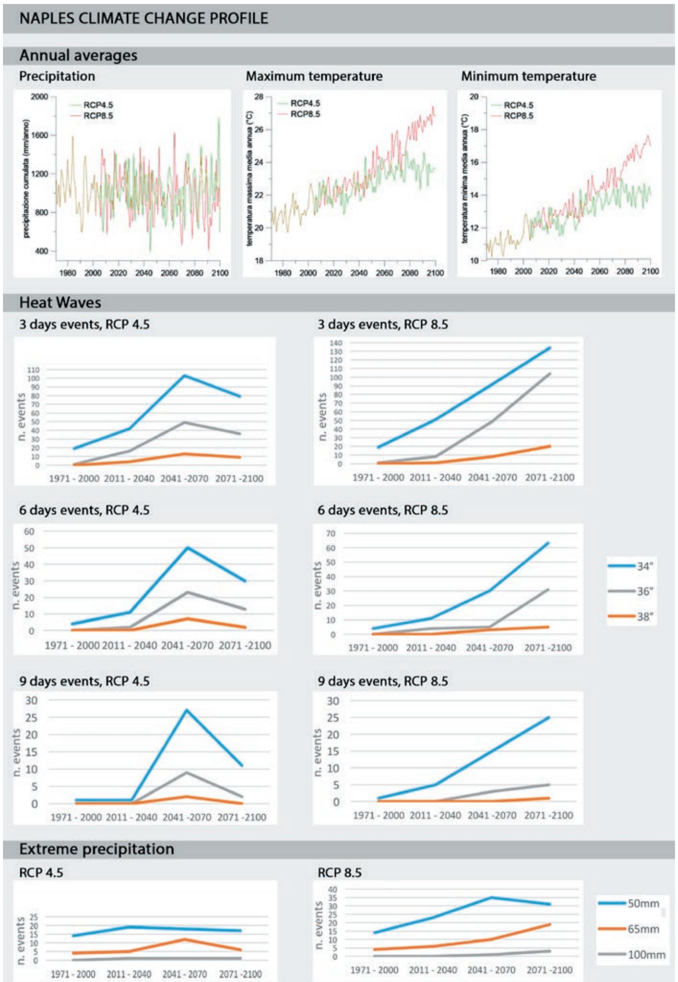

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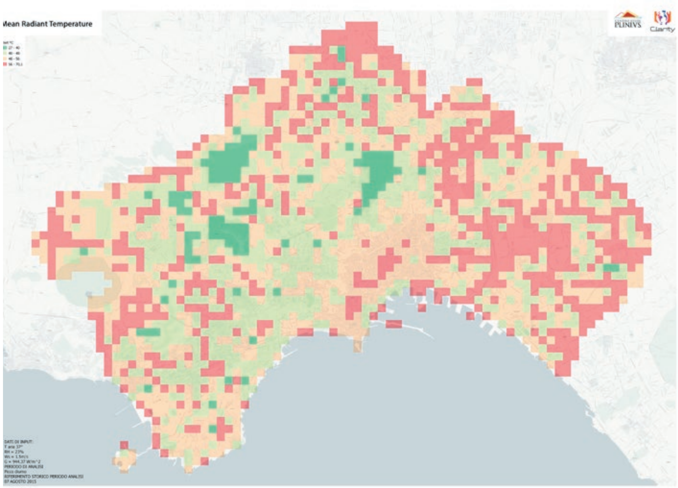

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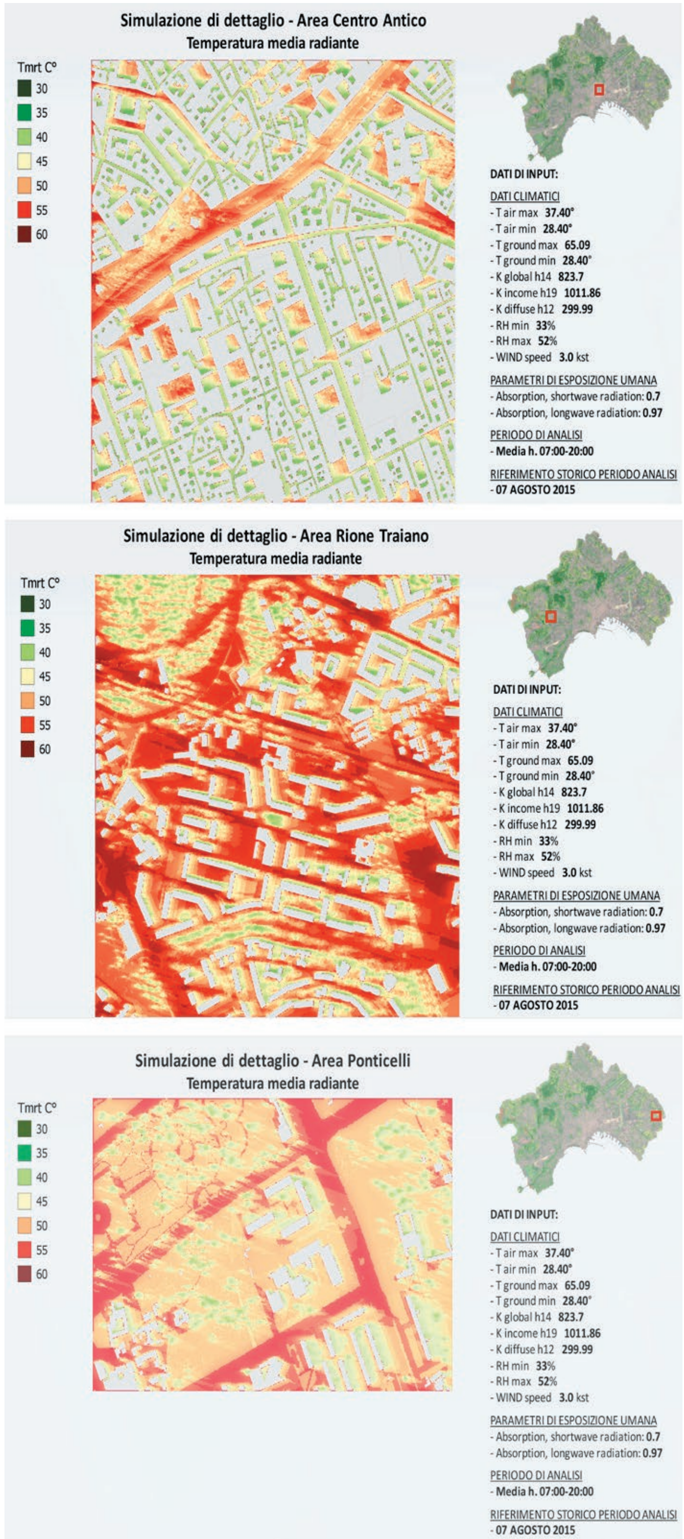

04 | Universal Thermal Climate Index (UTCI) map for a typical day of heat wave with air temperature 36-37°C (250x250 m grid) (Source: PLINIVS-LUPT, CLARITY project)

05 | Flood risk probability of urban areas in Naples (Source: PLINIVS-LUPT, CLARITY project)

Tab. 01 | Performance indicators to quantify climate benefits associated with the various adaptation measures (Source: PLINIVS-LUPT, CLARITY project)

sent the dynamics of the phenomenon, which depends on the duration and intensity of the event. The main variables are linked to the absorption capacity of urban surfaces, calculated on the basis of the run-off index, as well as the morphology of the water catchment areas in the city determined by natural orography, which include the run-off streams. In the Naples case, most of the city's sewer follows the natural orography, and almost all natural streams are today converted into roads in which most of the rainwater is channelled.
In relation to the urban planning objectives, the drainage capacity of urban surfaces is particularly important, along with the maintenance and adaptation of sewage systems. It must be balanced taking into account the specific features of each river basin and other hydraulic characteristics (including the height of aquifers, which are very near to the surface in some areas of the city).
A simplified approach[4] was adopted to determine the surface flooding probability of urban areas in case of extreme rain events by assigning a "risk coefficient" to each of the parameters (orography of drainage basins; concentration of run-off streams; run-off coefficient for each land use; emergency calls related to flooding events, intended as a proxy of sewage system capacity). The overall picture produced at city level (Fig. 5) highlights priority areas for deeper analyses to be conducted using continuous simulation modelling tools that usually require a very high computational capacity, if applied to large urban areas.

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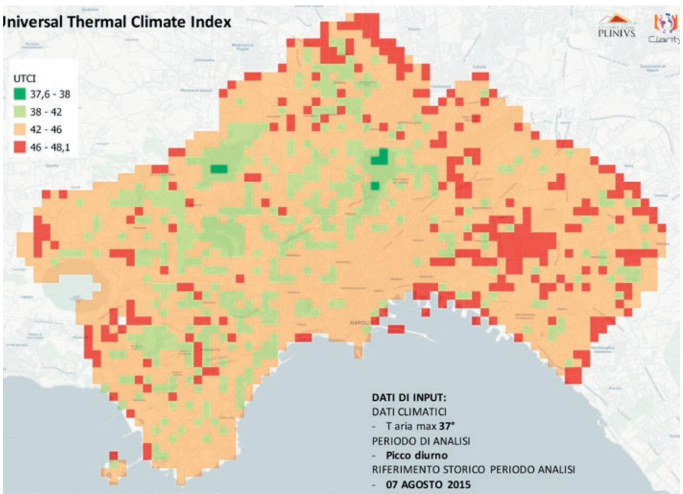

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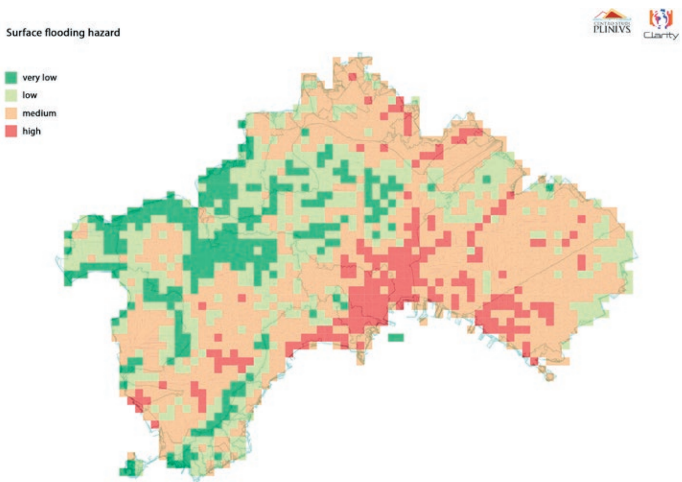

Climate adaptation strategies for the city of Naples

The goal of integrating climate adaptation measures into urban planning is a strategic priority at international level. The available literature allows to identify a series of adaptation measures in response to the impact of extreme temperature and precipitation events, whose effectiveness can be linked to a series of indicators defining each measure's contribution to controlling the urban microclimate.
The systematisation process of relevant literature performed within CLARITY has allowed to identify a catalogue of the most recurring adaptation measures, classified according to their ability to provide climate benefits in terms of:

1. reduced impact from heat waves, acting on the surface temperatures of buildings and open spaces, improving the conditions of perceived thermal stress and reducing the Urban Heat Island (UHI);
2. reduced impact of flood events, acting on the capacity of urban surfaces to guarantee adequate rainwater drainage and storage.

To assess the climate benefits linked to each adaptation measure and, therefore, the positive effect on urban microclimate, performance indicators have been defined (Tab. 1), based on the parameters affecting the results of "local effect" simplified models. The way such parameters affect the urban microclimate is complex to

| Tab. 01

Performance parameter	Description	Range
Albedo	Fraction of incident solar radiation that is reflected. It therefore indicates the reflective power of a surface. Higher factor corresponds to higher reflectivity.	0-1
Emissivity	Effectiveness of a material in emitting thermal radiation. Surfaces with high emissivity factors remain cooler thanks to their rapid heat release capacity.	0,8-0,99
Run-off	Correlates the amount of rain with the amount of surface run-off. This value is higher for areas with low infiltration and lower for permeable and well-vegetated areas.	0-1
Transmissivity	Portion of transmitted solar radiation (measured e.g. under the canopy of trees) with respect to the actual values of the global radiation measured at the nearby open site. The value varies from 0 to 1, where the lower the value the higher the shading effect.	0-1
Sky View Factor	Represents the ratio at a point in space between the visible sky and a hemisphere centered over the analyzed location. The value varies from 0 to 1, where the lower value corresponds to higher density.	0-1

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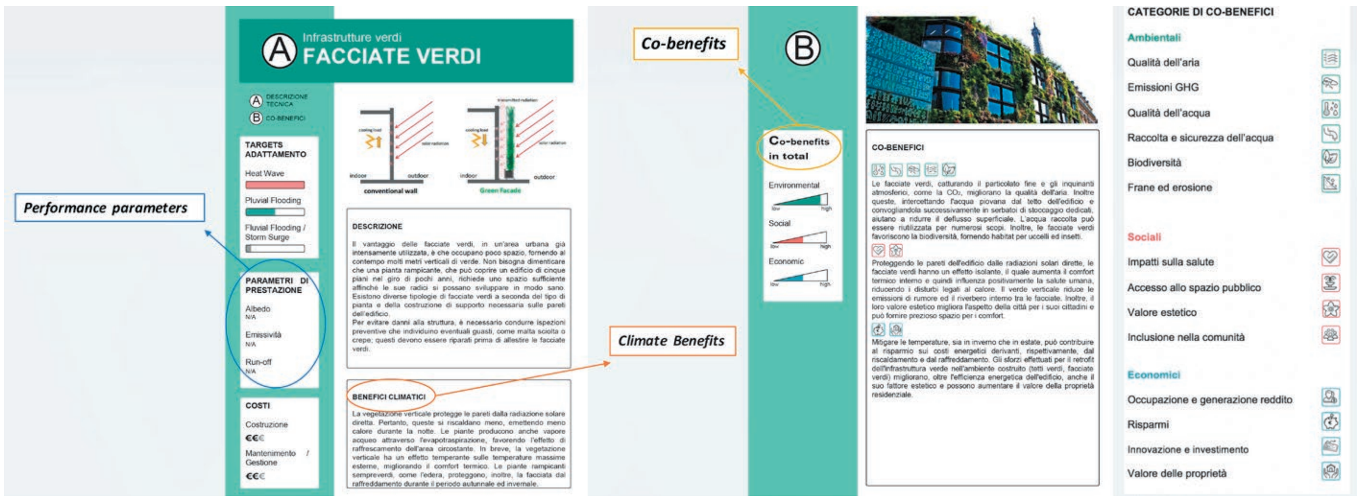

06 | Example descriptive sheet from the catalogue of adaptation measures (Source: PLINIVS-LUPT, CLARITY project)

summarise, and effective design approaches should address the potential synergies among different adaptation measures, besides managing possible trade-offs induced by their application in urban environments. As an example, while reducing the absorption and consequent storage of heat on urban surfaces, high albedo pavements can cause thermal discomfort due to the reflection of solar radiation at human height. Their use should be considered mainly in dense building fabrics or coupled with the integration of appropriate shading elements. A low Sky View Factor results in increased net heat storage within buildings and in an increase in UHI, but it also characterises dense urban areas where relative shadow between buildings contributes to reducing direct solar radiation, thus limiting thermal stress.

The application of CLARITY models allows to take into account those variables simultaneously, supporting the identification of the most suitable adaptation measures, depending on the specific urban morphology and land use.

However, the choice of climate adaptation measures to be integrated into urban transformation actions is linked not only to the expected climate benefits, but also to the possibility of conveying a series of social, economic and environmental co-benefits. Identifying and communicating the co-benefits of climate adaptation is a priority for urban decision-makers. It allows to broaden the consensus regarding resilient urban transformation strategies by local communities (Leone and Raven, 2018; Floater et al., 2016), which are often bearers of urban redevelopment needs indirectly related to the improvement of microclimatic conditions (e.g., better housing quality, greater provision of equipped public spaces and green areas, better accessibility to transport systems, etc.), thus triggering a virtuous loop supporting public initiative in the implementation of interventions.

Independently from the assessment of the effect of adaptation measures through modelling and simulations, this information has been provided to the Municipality of Naples in a descriptive form (Fig. 6) and included in the Preliminary City Plan (PUC), reflecting the climate benefits and the co-benefits of 18 common adaptation measures.

In order to maximise the impact of adaptation measures in terms of climatic benefits and associated co-benefits, such measures should

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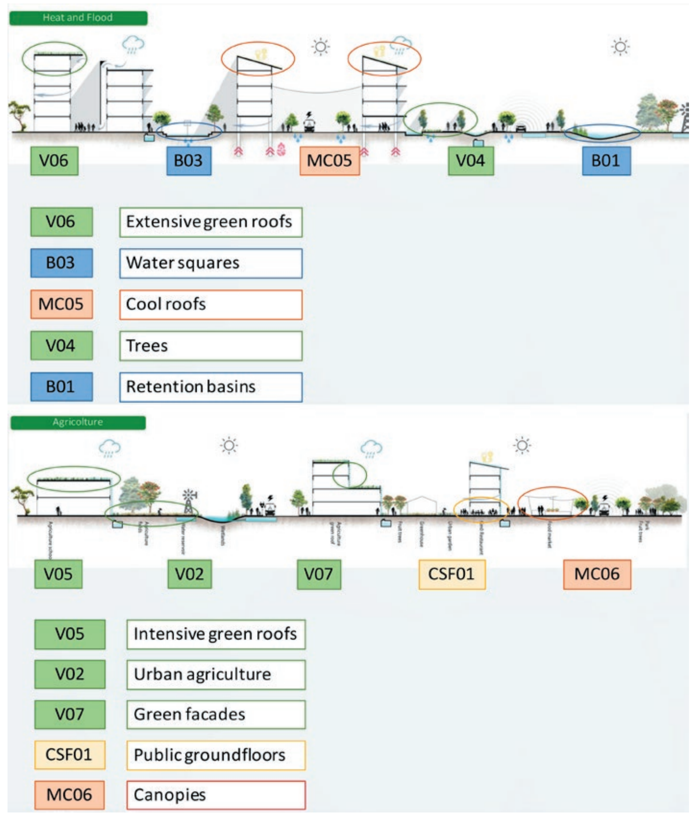

07 | Example of adaptation strategies in the Ponticelli area, aimed at maximising an integrated adaptation action to the risk of heat wave and flooding (top) and urban agricultural improvement (bottom) (Source: PLINIVS-LUPT, CLARITY project, processed by Leone and Tersigni, 2018)

be integrated into more complex "adaptation strategies" relative to the identified urban transformation/regeneration objectives (Fig. 7), considering how only widespread application of the measures in the urban area can guarantee the effectiveness of the adaptation action, and only their diversification according to other priorities for urban transformation can deliver the expected co-benefits.

Conclusions

The application of CLARITY tools by local authorities can support the development of coherent multiscale urban planning and design strategies. The different degree of detail achievable with the analysis output allows to use the tool from the strategic planning level up to urban district design, ensuring the consistency of the measures adopted by plans and projects across multiple scales and urban governance bodies.

The main feedback from the Naples case is that, despite the growing interest in climate change, other urban regeneration priorities (housing needs, public space quality, social cohesion, scarce budget for design and maintenance, etc.) are often overarching issues for public officials and communities. In addition to user-friendly analysis tools, such as the thematic maps provided by CLARITY project for the Naples City Plan, a cultural challenge that research in this domain has to tackle is how to effectively communicate the multiple societal co-benefits of climate-resilient pathways.

The objective of overcoming the globally observed "adaptation gap" (Neufeldt et al., 2018) can only be achieved through cooperation among multidisciplinary research teams. Local authorities can effectively support the translation of scientific advancements into actionable results for urban decision-makers, thus improving the quality of urban governance actions tackling the key priorities and innovative perspectives emerging as global societal challenges.

ACKNOWLEDGMENTS

CLARITY project (clarity-h2020.eu) has received funding from the EU H2020 R&I programme (GA no. 730355). The Consortium, coordinated by AIT, includes 17 partners with multidisciplinary expertise, and several national/local authorities from 4 case study areas (Italy, Austria, Sweden, Spain).

The outcomes of the Naples case presented herein were jointly developed by UNINA-PLINIVS, ZAMG and the City of Naples.

NOTES

[1] The paper presents the results of the "Expert Study" conducted as part of CLARITY Demonstration Case (DC1) in Naples. Reference to other case studies can be found in Havlik *et al.*, 2020, while the online "Screening services", on a 500x500 m grid, can be accessed at https://csis.myclimateservice.eu/ (accessed 7 May 2020).

[2] Available at: http://www.comune.napoli.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/37912 (accessed 7 May 2020).

[3] The "PLINIVS Simplified Heat Wave Model" is based on the transposition in a GIS environment of the SOLWEIG model, developed by Lindberg et al. (2011, 2016). Due to limitations in length and the journal's scope, the details of the model cannot be presented here, and can be found in the deliverable CLARITY project "D3.3. Science support report v2", available at http://www.clarity-h2020.eu/deliverables (accessed 7 May 2020).

[4] Due to the length limitations and scope of the journal, the details of The "PLINIVS Simplified Surface Flood Model" cannot be presented here, and can be found in the deliverable CLARITY project "D3.3. Science support report v2", available at http://www.clarity-h2020.eu/deliverables (accessed 7 May 2020).

REFERENCES

Chen, L., Yu, B., Yang, F. and Mayer, H. (2016), "Intra-urban differences of mean radiant temperature in different urban settings in Shanghai and implications for heat stress under heat waves: a GIS-based approach", *Energy and Buildings*, Vol. 130, pp. 829-842.

D'Ippoliti, D., Michelozzi, P., Marino, C., de'Donato, F., Menne, B., Katsouyanni, K. and Perucci, C. (2010), "The impact of heat waves on mortality in 9 European cities: results from the EuroHEAT project", *Environmental Health: A Global Access Science Source*, Vol. 9, n. 37.

Floater, G., Heeckt, C., Ulterino, M., Mackie, L., Rode, P., Bhardwaj, A. and Huxley, R. (2016), "Co-benefits of urban climate action: A framework for cities", available at: https://www.c40.org/researches/c40-lse-cobenefits.

Havlik, D., Schimak, G., Kaleta, P., Dihé, P. and Leone, M.F. (2020), "CLARITY Screening Service for Climate Hazards, Impacts and Effects of the Adaptation Options", in Ioannis, N., *et al.* (Eds.) *Environmental Software Systems Data Science in Action*, International Symposium, The Netherlands, February 5-7.

Gulyás, Á., Unger, J. and Matzarakis, A. (2006), "Assessment of the microclimatic and human comfort conditions in a complex urban environment: modelling and measurements", *Building and Environment*, Vol. 41(12), pp. 1713-1722.

Leone, M.F. and Raven, J. (2018), "Multi-Scale and Adaptive-Mitigation Design Methods for Climate Resilient Cities", *Journal of Technology for Architecture and Environment*, Vol. 15, pp. 299-310.

Leone, M.F. and Tersigni, E. (2019), *Progetto resiliente e adattamento climatico*, Clean, Naples, Italy.

Lindberg, F., Onomura, S. and Grimmond, C.S.B. (2016), "Influence of ground surface characteristics on the mean radiant temperature in urban areas", *International journal of biometeorology*, Vol. 60(9), pp. 1439-1452.

Lindberg, F. and Grimmond, C.S.B. (2011), "The influence of vegetation and building morphology on shadow patterns and mean radiant temperatures in urban areas: model development and evaluation", *Theoretical and applied climatology*, Vol. 105, pp. 311-323.

Ministero della Salute (2019), "Piano Nazionale di Prevenzione degli effetti del caldo sulla salute. Linee di indirizzo per la prevenzione. Ondate di calore e inquinamento atmosferico", available at: http://www.salute.gov.it/imgs/C_17_pubblicazioni_2867_allegato.pdf.

Neufeldt, H., Sanchez Martinez, G., Olhoff, A., Knudsen, C.M.S. and Dorkenoo, K.E.J. (2018), *The Adaptation Gap Report 2018. United Nations Environment Programme (UNEP)*, United Nations Environment Programme, Nairobi, Kenya.

Ng, E. and Ren, C. (2015), *The urban climatic map: A methodology for sustainable urban planning*. Routledge.

Oke, T.R., Mills, G., Christen, A. and Voogt, J.A. (2017), *Urban climates*, Cambridge University Press, New York/London.

Pyrgou, A., Castaldo, V.L., Pisello, A.L., Cotana, F. and Santamouris, M. (2017), "On the effect of summer heatwaves and urban overheating on building thermal-energy performance in central Italy", *Sustainable cities and society*, Vol. 28, pp. 187-200.

WHO-UNFCCC (2018), "Climate and Health Country Profile - Italy", available at: https://apps.who.int/iris/bitstream/handle/10665/260380/WHO-FWC-PHE-EPE-15.52-eng.pdf;jsessionid=072ADE142E2C3E45B4DE5582CFE7E28A?sequence=1.

Enhancing the integration of Nature-Based Solutions in cities through digital technologies

Chiara Farinea,
Advanced Architecture Group, Institute for Advanced Architecture of Catalonia, Spain
chiara.farinea@iaac.net

Abstract. During the last decades a growing awareness about the effects of pollution on our planet and its inhabitants has led to a demand for a new environmental sensitivity in urban planning. Nature-Based Solutions have the potential to enhance the liveability and prosperity of cities, providing ecosystems services (Millennium Ecosystems Assessment, 2005).
The paper explores pathways towards a progressive knowledge construction to shape a future in which NBS are largely integrated in our buildings and public space thanks to the use of digital technologies and design, transforming our cities into healthy, productive and collaborative environments.

Keywords: Nature-based solutions; Digital technologies; Advanced manufacturing; Food; Mushrooms.

Building with nature

Over the past decades, European cities have strengthened their economy, efficiency and liveability through the implementation of new and innovative planning paradigms, such as the "Urban Regeneration" and the "Smart City" models. However, they still face major problems, such as pollution, rising inequities and unemployment. Innovative models to overcome these problems, therefore, need to be developed, adopting a new transdisciplinary approach, which takes into consideration new ecological and social approaches, innovative business models, latest scientific and technological findings.

Nature-Based Solutions (NBS) represent a way to address urban issues with a holistic approach. They are defined by the European Commission as «living solutions inspired by, continuously supported by and using nature, which are designed to address various societal challenges in a resource efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits» (European Commission, 2015). NBS are addressing societal challenges by providing multiple ecosystem services. These services, according to the Millennium Ecosystems Assessment (2005), can be divided into four main categories: life support, such as soil formation and oxygen production; procurement, such as the production of food, drinking water, row materials or fuel; regulation, such as climate control and tidal waves, water purification, pollination; and cultural values, including aesthetic, educational and recreational values.

Building with nature, taking advantage of the services that living systems can provide, is a planning model that has been developed over the last fifty years and is gaining increasing importance today. The idea of environmental interdependency started to be defined in the modern scientific literature during the 1970s. However, in the 19th century, some scientists already mentioned it: at the beginning of the 19th century, the Prussian naturalist Alexander von Humboldt described the earth as a living organism where everything is connected (Wulf, 2017), and the Russian botanist Kliment Timiryazev wrote in the late 19th century that plants are the link between the Sun's energy and that of Earth (Mancuso *et al.*, 2018). The Gaia hypothesis, developed in 1979 by James Lovelock, is heir to the visionary spirit of Humboldt (Sampedro, 2016). It states that the earth, and more in detail its biosphere, is a living organism where the oceans, the seas, the atmosphere, the earth's crust and all the other geophysical components remain in conditions suitable for the presence of life thanks to the behaviour and action of living organisms, plants and animals (Lovelock, 1979). By the 1990s it was generally understood that a more systematic approach would have promoted the conservation, restoration and sustainable management of ecosystems (Millennium Ecosystem Assessment, 2005). During the late 2000s, the term 'Nature-Based Solutions' emerged, marking a shift in the planning perspective: human kind is not only the passive beneficiary of the benefits that nature can bring, but can also proactively protect, manage and restore natural ecosystems contributing to address major societal challenges (IUCN, 2016). Currently one of the main sources of knowledge on NBS are the international research projects supported by the European Commission under the programme Horizon2020[1]. They are targeted at developing strategies to implement NBS in cities, assessing the ecosystem services; guidelines and platforms gathering the knowledge acquired are under development (or in some cases already available) to allow their replicability, assessing climatic, technical, financial and urban planning aspects among others.

Advanced Nature-Based Solutions design

At the turn of the century, the irruption of the digital age and of a new interactive logic contributed to strengthen an environmentally conscious perspective through optimisation of the processes (Gausa, 2019).

In the field of Nature-Based Solutions advances in digital technologies open new chances to facilitate the integration of NBS in the urban environment increasing the number and the quality of the ecosystem services provided. Digital technologies, such as simulation tools and parametric design software, open to the possibility to develop passive environments optimised to support living organisms, simulating the system performances during the design phase, while digital fabrication allows for the production of non-standardised design systems specifically tailored for local needs.

We are now experiencing a big shift, starting to understand architecture as an integrated system of inert and biological matter, a scaffold for inhabitation, not only for humans, but also for an entire surrounding biota. In this framework advanced software is helping us to predict very complex growing and emerging systems, and it is starting to open the doors to a type of design sophistication that we did not deal with before (Cruz, 2019).

We are starting to work on cities with a new multidisciplinary approach, at the intersection of design, technology and biology. Since this type of research is at an early stage of development, currently most of the projects working with this approach are developed in the form of prototypes in academic or research institutes, and presented in exhibitions or expos.

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01 | Production of the project prototype, IAAC, photo by Federica Ciccone

The Advanced Architecture Group (AAG), part of the Institute for Advanced Architecture of Catalonia (IAAC), is developing, within its educational programmes and in the framework of several European Projects, a research on Advanced Nature-Based Solutions aimed at hybridising technologies, urban and natural environment and innovating the solution design and implementation process.

Creative food cycles project

The AAG is developing part of this research within the framework of the Creative Food Cycles (CFC) project, co-funded by the Creative Europe Programme of the European Union. CFC involves 3 partners, the Leibniz University of Hannover, the IAAC, and the University of Genova, and is aimed at capacity building through training and education in the field of architecture, focusing on food sustainability in urban environment. Several activities have been performed within the project, such as workshops, development of project mock-ups, exhibitions and conferences.

The project lays its foundations on the awareness that today we have accessibility to products coming from anywhere in the world, all year round; however, it is questionable whether the quality of these products is healthy, and whether the food chain is sustainable. For instance, food production, distribution and disposal involve a complex set of economic activities, exchanges (digital and physical) and human behaviours that all sharply affect the living conditions of the planet and its inhabitants. It is, therefore, necessary to rethink food systems, focusing, at local level, on their potential to strengthen and eventually restore the environment, the communities and the economy. The project takes into consideration the whole Food Cycle chain: production, distribution, consumption and disposal.

The AAG addresses the first part of the chain, working on digital technologies and NBS for food production.

Educating to develop advanced design projects integrating Nature-Based Solutions

In order to create new knowledge regarding the development of architectural projects designed as passive environments to integrate in the urban environment living systems producing food, the "Creative Urban Farming" workshop was held in May 2019 and the best project was further developed and scaled up in a mock-up that was tested and exhibited at several events.

The projects of the students participating in the workshop had to meet the following questions: how can we integrate food production and distribution in the urban environment, enhancing participatory processes and circular use of available resources? How can new and innovative technologies help to design, develop and implement healthy food production systems for the urban environment? As vegetables are Living / Nature-Based Solutions, can they provide also further ecosystem services while they are growing?

During the workshop the students were working following the "learning by doing" methodology, designing their projects and developing a working prototype (Fig. 1) of their solutions using digital fabrication tools, such as laser cutters and CNC machines. Within the "learning by doing" methodology the production of prototypes is an integral part of the design process, as it allows designers to explore alternatives, test theories and concepts and confirm the performance of a new design system (de Kastelier and Rabagliati, 2012).

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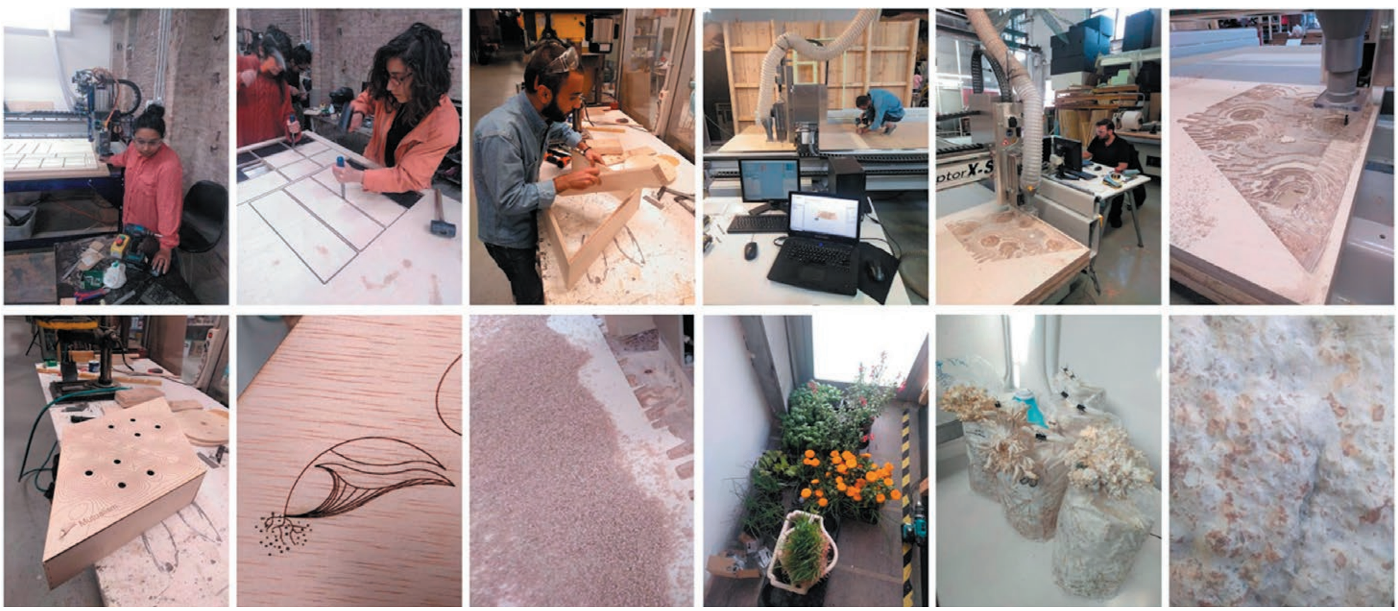

02 | Mutualism external surface, IAAC, photo by Federica Ciccone

03 | Mutualism internal surface, IAAC, photo by Federica Ciccone

04 | Mycoscape project, IAAC, photo by Federica Ciccone

Mutualism project

The students' work that was chosen as the most outstanding in responding to the initial questions is project Mutualism.

The word 'Mutualism' refers to the ecological interaction between two or more species where they both benefit from each other. The collaborative living systems integrated in the project are herbs and Oyster mushrooms: mushrooms need moderate temperatures to grow, and herbs have the potential to mitigate the urban heat island effect. The project consists in a modular pavilion with two sides: the external side, which is exposed to sunlight, is targeted at the growth of edible plants, which narrow down the temperature during the hot season, while the internal side, which is shadowed, is targeted at mushroom growth. The pavilion is an urban infrastructure managed by neighbours: they provide maintenance for the plants and, in exchange, receive the pavilion's products. Neighbourhood coffee grounds are recycled and implied as nutrients to be added to the straw substrate used to grow Oysters mushrooms. The pavilion produces one further output, acoustic panels for the construction industry: while Oysters mushrooms are grown, the straw substrate is converted by the mushrooms' roots into a phono-absorbent resistant material. This can be sold by the neighbours to produce extra income. The herb and mushroom substrate is separated by a shaped surface, which serves to isolate the roots of the plants, that could transfer bacteria affecting the mycelium growth, and to shape the form of the acoustic panels.

The surfaces of both sides are parametrically designed to optimise both mushroom and herb growth conditions: the external surface (Fig. 2) is designed to collect rainwater and to direct it towards the holes in which the plants are placed; the internal surface (Fig. 3) is defined to maximise lighting and reflection to help mushrooms to fruit.

During the workshop, students learned that digital design programs make it possible to develop building systems integrating plants

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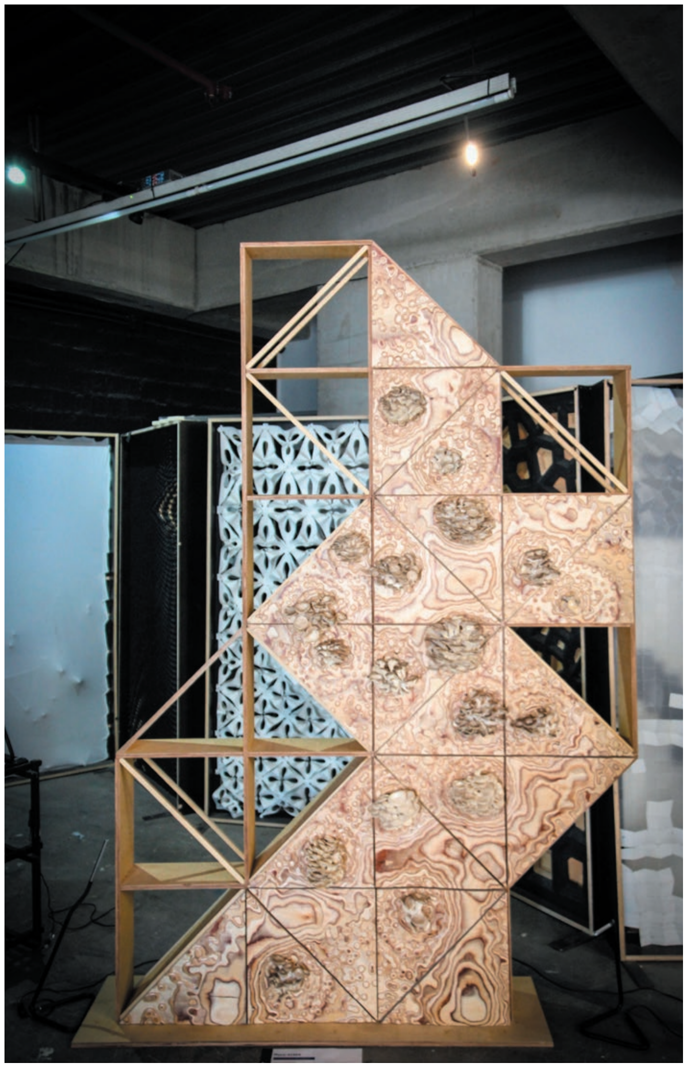

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05 | Mycoscape external surface, IAAC, photo by Federica Ciccone

06 | Mycoscape drawings, IAAC, drawings by Mohamad Atab

07 | Mycoscape external surface detail, IAAC, photo by Federica Ciccone

08 | Vision of the application of Mycoscape to a building facade, IAAC

growth in the urban environment, running simulations to correct and optimise the surface morphology. Moreover, they learned that the shift from analogue towards digital does not only happen in the design stage, but also in the manufacturing and fabrication stages. Milling, cutting, bending and drilling are now processes that are directly driven by a computer code.

Demonstrating advanced design projects implementing Nature-Based Solutions

The Mutualism prototype has been further developed and scaled up into the Mycoscape project (Fig. 4), which consists in a façade modular system integrating the growth of edible mushrooms in the urban environment, producing food and construction materials.
Mycoscape aims at defining innovative design protocols, demonstrating the potential of parametric design and digital fabrication supporting the development and implementation of systems for urban food production, responding to local environmental conditions and making sustainable use of local resources.
The mushroom growth takes place thanks to two systems: the first one consists in triangular modules where the straw substrate and the Oyster mushroom spores are located, and the second one consists in the external surface (Fig. 5) aimed to passively control the parameters that affect mushroom growth, namely temperature, humidity and shade. In order to control these conditions a tree trunk and bark, which are the mushroom's natural habitat, have been studied and mimicked. With the aim of reproducing the microclimate that the tree trunk and bark create, protrusions increasing the thickness of the external surface were distributed along the external surface (1), thus favouring the temperature control of the area where the substrate is placed, and creating shadows on the holes where

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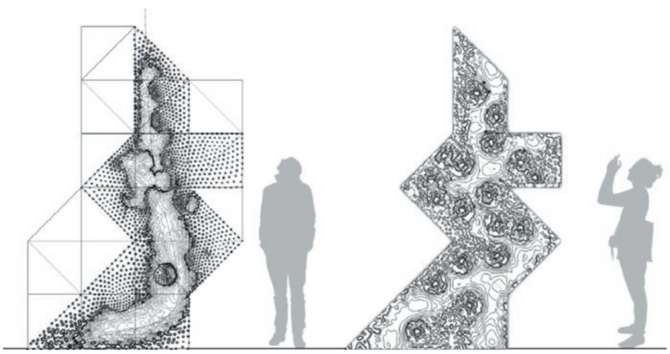

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mushrooms fruit and (2) circular elements collecting air humidity during the night and releasing it during the day (Fig. 6 and 7).
The project brings significant improvements to the state of the art in the field of mushroom application in the urban environment. Currently there are two types of applications. The first one is the urban mushroom farm. An outstanding example, focusing on circular economy, is the Mushroom Forest developed in Amsterdam by Jacques Abelman. It consists in vertical tubes in which various types of waste can be inserted to be used as mushroom growing substrate. Existing urban mushroom farms do not make any use of the material produced by the mushrooms and the substrate during the growth process. The second application consists in the development of building materials and home design products with mycelium, the vegetative part of the mushroom. One of the first producers has been the company Ecovative Design, which since 2007 started to commercialise mycelium lamps. Since than several new companies have been established and products developed with mycelium are gaining importance and visibility: the tower 'Hy-Fi', designed by David Benjamin, was exhibited at MoMA in New York, demonstrating the use of mycelium bricks for hi-rise buildings, while the 'Growing Pavilion' presented at the Dutch Design Week 2019 by the Krown Design studio demonstrated the use of mushroom panels for façades. However, producers of mycelium products do not use the mushroom fruits for food proposals. Mutualism brings several improvements to the state of the art: it brings together the production of food and building materials in a unique system, providing two different ecosystem services within one NBS, thus avoiding waste and making the most out of available resources. Moreover, it makes use of design to control environmental parameters connected to mushroom growth, allowing to use urban surfaces as agricultural fields. This new approach has several implications at social and economic level. It allows to envision new forms of hybrid and collaborative economies: for example, municipalities could make available public building façades, citizens could organise themselves in associations to cultivate, as low skills are required, start-ups could create product branding and take care of their commercialisation.
Mycoscape is a proto-environment (Gausa, 2019), which simulates a new collaboration between nature and humans, technology and design, and new relations between city inhabitants (Fig. 8).

Conclusion

Creative Food Cycles project has created capacity and demonstrated the potential of the use of computer aided technology towards the integration of living systems in the urban environment. Bullivant (2006) states that if architects aim to create a responsive environment, they are required to think like designers of operating systems, arguing also that the development of complex, comprehensive and informed design process are fundamental procedures that generate new relations, narratives, potentialities and hybrid forms of [co]existence.

NOTES

[1] The European Commission under the programme Horizon2020 has supported the following projects: EdiCitNet, CLEVER Cities, proGIreg, URBiNAT, CONNECTING Nature, GrowGreen, UrbanGREENUP, UNALAB, CLEARING HOUSE, REGREEN, RECONECT, Operandum, MyBuildingIsGreen, OPPLA, THINK NATURE.

REFERENCES

Bullivant, L. (2006), *Responsive Environments: Architecture*, Art and Design, V. & A. Publications, London.

Cruz, M. (2019), "Bio-integrated design in Black Ecologies", *Iaac Bits Magazine*, Vol. 9, pp. 76-88.

de Kastelier, X. and Rabagliati, J. (2012), "Smart Geometry. Working Prototypes", in Ipser, C. (Ed.), *Fabvolution, Ajuntament de Barcelona*, Barcelona, Spain.

European Commission (2015), *Towards an EU Research and Innovation Policy Agenda for Nature-based Solutions & Re-naturing Cities: Final Report of the Horizon 2020 Expert Group on 'Nature-based Solutions and Re-naturing Cities*, Publications Office of the European Union, Brussels.

Gausa, M. (2018), "The agricultural landscapeas in-between, and eco-info-infra territorial structure", in: Gausa, M. and Canessa, N. (Eds.), *AC+ Agri-Cultures Agro-Cities Eco-Productive Landscapes*, Actar Publishers, New York/Barcelona.

Gausa, M. (2019), "From dirty realism to dirty ecology", *Iaac Bits Magazine*, Vol. 9, pp. 6-11.

IUCN (2016), *Nature-based Solutions to address global societal challenges*, IUCN, Gland.

Lovelock, J. (1979), *Gaia. A New Look at Life on Earth*, Oxford Landmark Science, Oxford.

Mancuso, S. *et al.* (2018), "The plant world plays and active part in monitoring and controlling the environment of smart cities", *Domus*, pp.36.

Millennium Ecosystems Assessment (2003), *Ecosystems and Human Well-being*, Island Press, Washington.

Sampedro, J. (2016), "Alexander von Humboldt, la ciencia al completo", available at https://elpais.com/cultura/2016/09/09/babelia/1473420066_993651.html (accessed 5 April 2020).

Wulf, A. (2017), in *The Anthropocene: the age of mankind, documentary* available at: https://www.youtube.com/watch?v=AW138ZTKioM (accessed 2 April 2020).

Upcycling plastic waste for the development of construction materials

RESEARCH AND EXPERIMENTATION

Alexandre Carbonnel[a], Hugo Pérez[a], María Ignacia Lucares[a], Daniel Escobar[a], María Paz Jiménez[a], Dayana Gavilanes[b],
[a] Environmental Architectural Materials Laboratory (LEMAA), School of Architecture, University of Santiago, Chile
[b] Polymers Laboratory, Faculty of Chemistry and Biology, University of Santiago, Chile

alexandre.carbonnel@usach.cl
hugo.perez.h@usach.cl
maria.lucares@usach.cl
daniel.escobarc@usach.cl
pazjimenezvilla@gmail.com
dgavilanes.ruiz@gmail.com

Abstract. Consideration of plastic waste as a secondary raw material obtainable by means of upcycling presents fresh possibilities in the search for new construction and architectural materials. This paper demonstrates the possibility of recycling thermoplastic polyethylene terephthalate (PET) and the potential for enhancement of its properties through the incorporation of nanoparticles. The design of materials by means of managed complexity involving processes of *materialisation* and *configuration* is explored by processing film from recycled plastic and their subsequent assessment as a possible semi-finished product with photocatalytic potential.

Keywords: Upcycling; Photocatalysis; Materials design; Plastic recycling; Nanotechnology.

Introduction

Some directives (CE, 2015) propose that waste should be considered as a secondary raw material with potential for reintroduction into productive cycles. Considering the risks posed by plastic to health and ecosystems (CE, 2013), there is an urgent need to boost recycling.

In 2016, 242 Mt of plastic waste were produced worldwide, accounting for 12% of municipal solid waste (WBG, 2018). In 2015, the European Union recycled 25% of its plastic waste (CE, 2015), a figure far greater than that achieved by Chile, which only reached 8.5% (ASIPLA, 2019).

In light of this, the present study adopts an exploratory approach to the problem of plastic waste, and views the latter, following a process of upcycling, as a secondary raw material for the design of construction materials.

Some studies refer to upcycling in the development of components for construction or architecture (Rose and Stegemann, 2018; Baiani and Altamura, 2018). Baiani & Altamura (2018) focus on upcycling in the experimental design and development of technical solutions for concrete elements, such as paving blocks and stones, incorporating recycled additives in a process referred to as "superuse". This approach considers upcycling to be an evolution of recycling that yields an improvement in the value or functionality of the original material (Rose and Stegemann, 2018).

The study, therefore, views upcycling as *managed complexity,* and adopts the materials design objectives posed by Ezio Manzini (1992), defining this complexity by exploring the mechanical recycling process of polyethylene terephthalate (PET), as well as the potential environmental function of degrading atmospheric contaminant gases through the addition of a titanium dioxide (TiO_2) semiconductor that would generate a photocatalytic reaction (Fig. 1).

Design hypothesis: a new and improved material based on recycled PET and TiO_2

The design hypothesis rests on two questions. What is the potential of PET waste recycling for the development of materials? Can PET waste be repurposed to develop a new material with photocatalytic potential through the incorporation of nanoparticles?

In order to answer these questions, the present study employs a process of three *materialisations* to produce a set of materials: (1) titanium dioxide (TiO_2) nanoparticles, (2) recycled PET, and (3) recycled PET mixed with TiO_2. This is followed by the configuration of three series of plastic film, each providing seven samples for study and testing.

Materialisations and *configurations* are each conditional on two developmental frameworks (DF). The former, DF1, encompasses technology in the form of machines and instruments (see Figure 2), while the latter, DF2, covers the regulatory provisions applicable to polymer-based construction materials.

DF1 included the Labtech LP20-B press, which enabled us to create films with maximum size 150x150 mm between its stainless-steel plates. This was the first step in the *configuration* process. DF2 covered national and international standards and, beginning with the validation of variables, sample dimensions and testing methods, allowed us to speculate as to the use of the *semi-finished product* as a building material, adjusting the thickness of the film as a second step in the *configuration* process.

The "Chilean standard – construction – plastic tiles – testing methods (Nch 873:1999)" establishes two thickness test ranges from 2.4 to 3.2 mm and from 1.4 to 1.6 mm. The standard for "Determination of the behaviour of self-supporting plastics in response to a flame (NCh 2121/1)" specifies a test thickness of 3-12 mm.

In accordance with these standards and considering the film as a possible semi-finished product – tiles or cladding – we decided upon a minimum thickness of 3 mm for their *configuration.*

The film *configuration* adjustments were as follows: Series A, based on pressed PET flakes (PETr-t); Series B based on extruded and pressed PET flakes (PETr-e); and Series C (the new material) consisting of PET flakes extruded with TiO_2 nanoparticles and pressed (PETr-e-TiO_2).

Finally, in order to answer the questions posed by the design hypothesis, four sets of measurements and observations (MO) were made of the resulting film. MO1 was a qualitative evaluation of the three series, which resulted in the selection – based on their physical characteristics – of the best Series B and C films with which we would then move on to the subsequent MOs. MO2 consisted of a Differential Scanning Calorimetry (DSC) conducted on a sample of the films selected at MO1 in order to observe the thermal properties of the polymer and any possible variations following the heat treatments involved by extrusion

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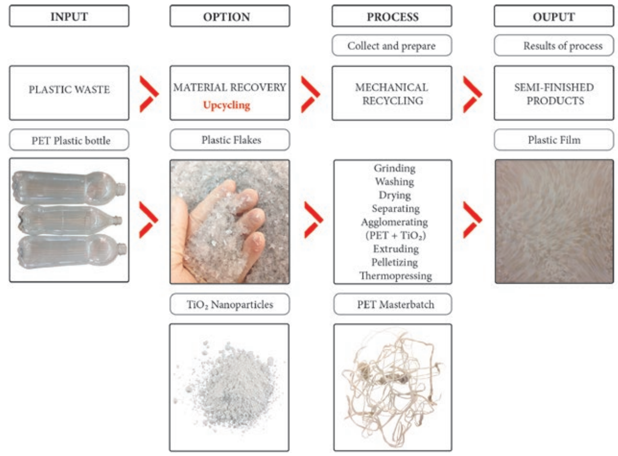


and pressing. MO3 consisted of Transmission Electron Microscopy (TEM) that allowed us to establish the presence of nanoparticles in the polymer. Finally, MO4 was Scanning Electron Microscopy (SEM), which allowed us to visualise and quantify the presence of TiO_2 nanoparticles on the surface and within the microstructural morphology of the new material, PETr-e-TiO_2.

Materialisations and configurations: exploration methods

The procedure began with the collection of plastic bottles (input) and their classification (plastic waste), and culminated in the development of a semi-finished product with improved properties as a result of upcycling.

Materialisation (1): TiO_2 nanoparticles synthesis

Synthesis of spherical TiO_2 was achieved by means of the sol-gel method, using titanium isopropoxide (Ti $[OCH(CH_3)_2]$) as a precursor (Aldrich, 97%). Two solutions were prepared at room temperature. To prepare the first solution, 5 mL of titanium isopropoxide (IV), measured in a nitrogen atmosphere, were added to 15 mL of isopropanol (Equilab, 99%). To prepare the second solution, 3M nitric acid (HNO_3) (Aldrich, 90%) was added to 250 mL of distilled water, bringing the solution to a pH level of 2. Once the two solutions had been prepared, the second was placed in a silicon bath above a heating plate set to 60°C and stirred while the first solution was added dropwise. The resulting mixture was stirred at 60°C for 20 hours, then placed on a heating plate set to 80°C. The solvent evaporated to leave yellow crystals, which were then washed with ethanol and vacuum filtered. Finally, the n TiO_2 were calcinated in a muffle furnace at 200°C for 4 hours, after which they were ready for incorporation into the PET.

Materialisation (2) and (3): production of recycled PET mixed with TiO_2 nanoparticles

The molecular structure of PET may be amorphous or semi-crystalline, with maximum 45% crystallinity. The amorphous portion gives the material its elastic properties, while the crystallinity – the result of a specific molecular order – provides resistance to mechanical force. The glass transition temperature (Tg) is reached when the polymer chains acquire a degree of molecular movement, giving the material elasticity and causing it to pass from a glassy state to a rubbery one (transition). The melting temperature (Tm) is the temperature at which crystals form (transformation) and the polymer passes from a solid to a viscous liquid state, acquiring fluidity and losing its mechanical properties.

The mixing of recycled PET (PETr) with TiO_2 involved a six-step process (Fig. 2). Used transparent PET bottles were collected (1), manually washed (2) and ground into flakes (3). Several loads of 1000 g of PET were processed in the grinder (equipped with a 4 mm screen) for 10 minutes each. This produced a secondary raw material in the form of flakes (ISO 15270; 2018).

The mixture of PETr and TiO_2 was created by extrusion. The process uses a *configuration* of heat, pressure and rotation to combine the PETr with TiO_2, extruding a new polymeric material in a filament known as Masterbatch. This is finally cooled in water and pelletised to form the new secondary raw material PETr-e-TiO_2.

Three sequential extrusions were made. Firstly, 400 g of PETr were extruded as a cleaning routine in order to avoid contamination of the sample. Secondly, 900 g of PETr were extruded to produce a pelletised Masterbatch as a secondary raw material for the creation of film for comparison. Finally, 690 g of PETr were combined with 60 g of TiO_2 nanoparticles (8% of the sample) in the extruder's hopper.

Configuration: pressing and production of the three series of film

The configuration process, based on DF1 and DF2, determined the testing of film with dimensions of 150x150x3 mm. Series A: flakes (PETr-t); Series B: extrusion (PETr-e); Series C: extrusion of mixture with TiO_2 nanoparticles (PETr-e-TiO_2). Configurations were achieved by adjusting the pressing variables (Fig.3).

Measurements and Observations of the film: development of the 4 MOs.

MO1: Qualitative analysis was conducted of five physical characteristics. These were visually assessed and entered into a matrix using a scale of 0 to 5, where a lower score corresponded to better film performance. The aim was to identify the best film samples to take forward for testing, based on the criteria of fragility, presence of bubbles, calcination, presence of fissures, and heterogeneity.

MO2: the glass transition temperature (Tg), melting temperature (Tm) and enthalpy of fusion (ΔH) of the second and third series as

TYPE OF MATERIALISATION	STAGES OF CONFIGURATION PROCESS					
SYNTHESIS OF TITANIUM DIOXIDE TiO_2 NANOPARTICLES (No. 1)	**A**	**B**	**C**	**D**	**E**	**F**
	Preparation of solution 1 (titanium isopropoxide added to isopropanol)	Preparation of solution 2 (nitric acid added to distilled water)	Solution 1 added dropwise to solution 2	Evaporation of solvent	Vacuum Filtration	Calcination
PROCESS ASSISTED BY MACHINE					Boeco R-430 Vacuum/ Pressure Pump	Thermo Scientific Lindberg Blue Muffle Furnace
PROCESS ASSISTED BY INSTRUMENTS	Round-bottom flask 100 mL	Erlenmeyer flask 500 mL	Heating Plate Thermometer	Heating Plate Beaker Thermometer		Mortar
MATERIALS	**MEASUREMENT**					
ISOPROPANOL (mL)	15					
TITANIUM ISOPROPOXIDE (mL)	5					
ETHANOL (mL)					50	
NITRIC ACID [M]		3				
pH OF THE SOLUTION		2				
DISTILLED WATER (L)		0,25				
TEMPERATURE (°C)			60	80		200
TIME (min)			20	24		4

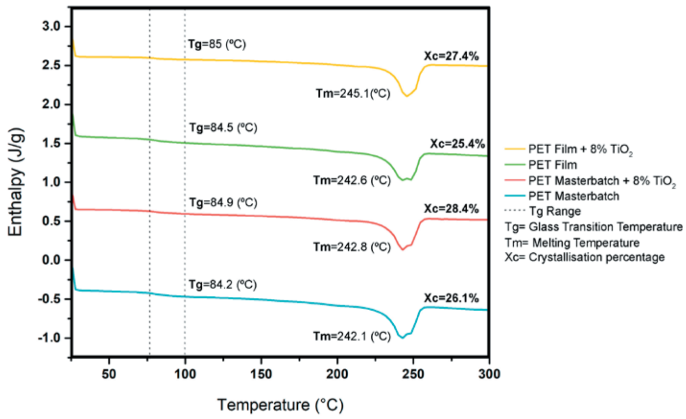
RECYCLING PROCESS OF POLYETHYLENE TEREPHTHALATE (PET) MIXED WITH TITANIUM DIOXIDE NANOPARTICLES TiO_2 (No. 2 & 3)	**1**	**2**	**3**	**4**	**5**	**6**	**6F**	**7**	**8**	**8F**
	STORAGE OF BOTTLES	WASHING OF BOTTLES	GRINDING /GENERATION OF PET FLAKES	WASHING OF PET FLAKES	DRYING OF PET FLAKES	EXTRUSION OF PET FLAKES	EXTRUSION OF PET FLAKES WITH NANO-PARTICLES	**PETr-t FLAKE PRESSING: SERIES A (7 films)**	**PETr-e MASTER-BATCH PRESSING: SERIES B (7 films)**	**PETr-e-TiO_2 MASTER-BATCH PRESSING: SERIES C (7 films)**
MANUAL PROCESS	35 bottles (size 3 L)	35 bottles (size 3 L)					Mixing PETr-e + TiO_2			
PROCESS ASSISTED BY MACHINE			Thera A200-E Grinder/ 4 mm strainer		Elos "Heat" HO55F Heating Oven	Labtech 20-40 Twin Screw Extruder	Labtech 20-40 Twin Screw Extruder	Labtech LP20-B Press	Labtech LP20-B Press	Labtech LP20-B Press
PROCESS ASSISTED BY INSTRUMENTS	Storage tray 120 L			Sifter 250 microns Steel spatula Brush No. 8-14	Drying tray Aluminium foil	Beaker Steel spatula Brush No. 8-14	Beaker Steel spatula Brush No. 8-14	Kern PFB 200-3 Balance Steel matrix Teflon (3 mm) Beaker Brush No. 8-14	Kern PFB 200-3 Balance Steel matrix Teflon (3 mm) Beaker Brush No. 8-14	Kern PFB 200-3 Balance Steel matrix Teflon (3 mm) Beaker Brush No. 8-14
MATERIALS	**MEASUREMENT**									
WATER / DISTILLED WATER (L)		105		3						
PET MATERIAL WEIGHT (g)			2040	2040		900	690	568	621	630
TiO_2 MATERIAL WEIGHT (g)							60			60
PRESSURE (bar)						45	47,5	70 - 90	80 - 90	55 - 80
TEMPERATURE (°C)					60 - 80	255	255	255 - 260	260	260
TIME (min)		105	34			40	72	10 - 24	17 - 24	17

02 I Materialisation process

03 I Configuration of the three PETr-based film series

04 I Physical characteristics – evaluation matrix
The combined scores for each characteristic provided the final value for each film. The best performance was achieved by films SSA2 and SSA6 (Series A), SSB2 and SSB3 (Series B), andSSC2, SSC3 and SSC6 (Series C)

05 I DSC of PETr-e and PETr-e-TiO2 samples



both Masterbatch and film were measured using DSC (Mettler-Toledo DSC 1 STARe). The samples were heated from 25°C to 300°C at a rate of 10°C/min and then cooled to 25°C at the same rate. The readings were taken from the second heating curve in order to eliminate any thermal history. The percentage of crystallinity was calculated using the enthalpy of fusion of an ideal PET sample with 100% crystallinity (Blaine, 2002).

MO3: the morphology of the TiO_2 nanoparticles and their dispersion in film was analysed using TEM (Philips Tecnai 12) operating at 20 kV. Samples were prepared for TEM by placing a drop of TiO2 on a carbon-coated standard copper grid (400 mesh) and evaporating the solvent. Figure 6A shows the TEM images of nanoparticles obtained using the sol-gel process, with spherical morphology and a diameter of ~10 [nm]. Figure 6E shows the TEM images of the TiO_2 structure.

MO4: on a nanometre scale, SEM images 7A and 7D show that the nanoparticles are not visually detectable in the polymer. Images 7B and 7E, generated using X rays (Energy-Dispersive Spectroscopy, EDS) show the presence of three principal chemical elements: oxygen (yellow), carbon (blue), and titanium (green). Finally, images 7C and 7F show the presence of titanium only, with the other elements omitted.

Reflection and conclusions based on the MOs.

MO1 provided evidence of the importance of adjustments made to film *configuration*. Series A highlighted the relationship between pre-contact time (3.5-8 min), contact time (3-6 min), and pressure (70-90 bar). These variable adjustments from SSA1 to SSA5 yielded improvements in terms

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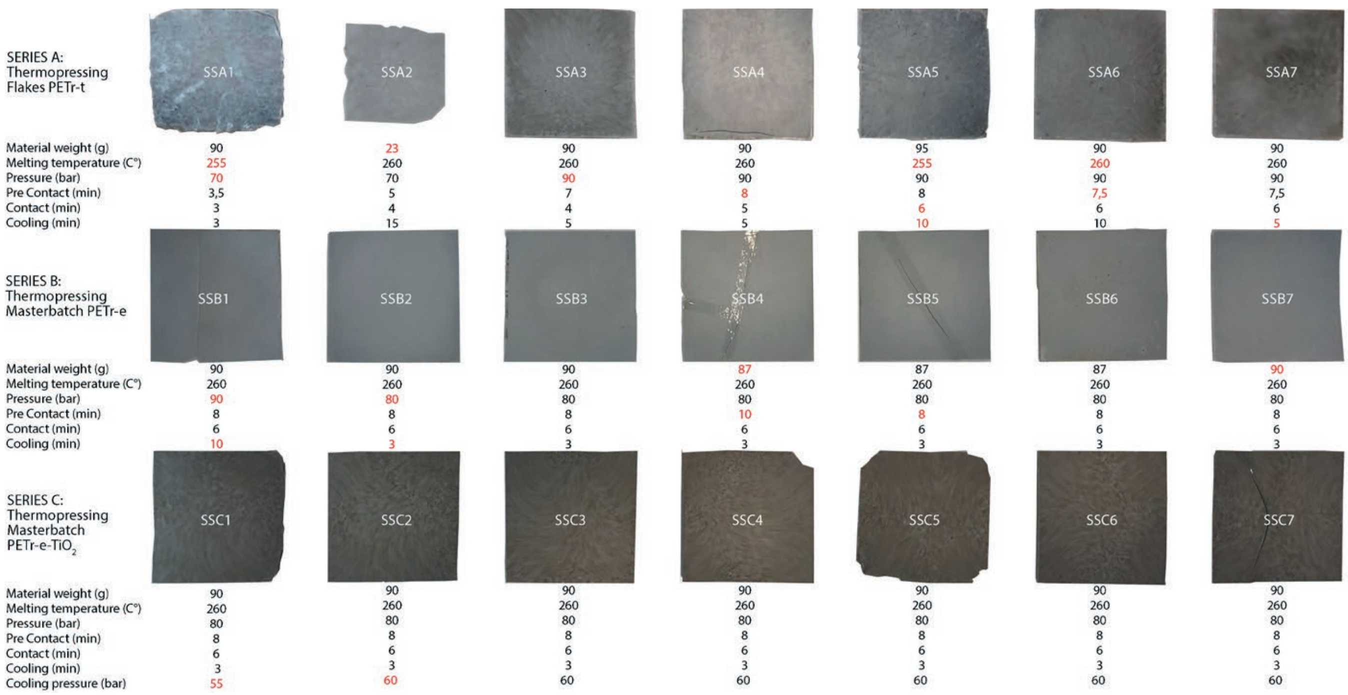

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PROCESS	PHYSICAL CHARACTERISTICS	SERIES A							SERIES B							SERIES C						
		SSA1	SSA2	SSA3	SSA4	SSA5	SSA6	SSA7	SSB1	SSB2	SSB3	SSB4	SSB5	SSB6	SSB7	SSC1	SSC2	SSC3	SSC4	SSC5	SSC6	SSC7
Pressing	Fragility	3.7	2.5	2.5	2.7	3.5	2.3	2.7	4.5	3.2	2.8	4.5	4.3	3.3	4.2	3.2	2.8	2.8	3.0	3.7	2.8	4.5
	Bubles	4.7	1.2	1.0	1.7	2.5	1.7	1.5	1.0	1.2	1.7	1.2	1.3	5.0	12,0	2.0	1.8	1.7	1.8	2.3	1.8	3.0
	Calcination	3.3	2.7	3.5	2.5	2.8	3.3	4.5	2.2	1.8	2.7	2.5	2.2	2.7	1.7	2.0	1.3	1.5	1.2	1.3	1.7	1.3
	Fissures	2.0	2.3	1.2	1.8	1.3	1.2	1.3	5.0	1.2	1.2	5.0	5.0	1.2	5.0	2.0	1.0	1.0	1.7	2.2	1.0	5.0
	Heterogeneity	5.0	1.8	1.8	1.8	4.3	1.8	2.5	3.2	2.7	2.8	2.7	2.2	4.2	2.8	1.8	1.5	1.7	1.7	3.0	1.3	3.5
Sample Total		18.7	10.5	10.0	10.5	14.5	10.3	12.5	15.8	10.0	11.2	15.8	15.0	16.3	14.8	11.0	8.5	8.7	9.3	12.5	8.7	17.3
Sample Average		12.43							14.14							10.86						

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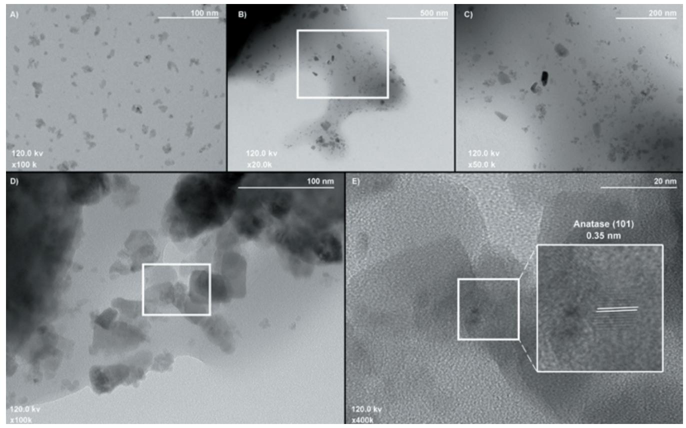
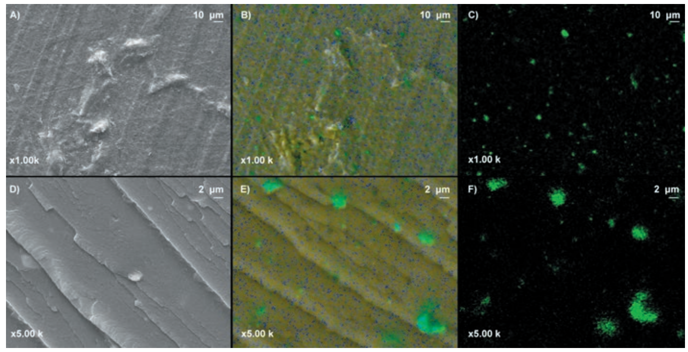


06 I TEM: visualisation of the presence of TiO2
A) TiO2 nanoparticles. B), C) and D) Film made from PETr + TiO2 nanoparticles, different scales. E) Film PETr + TiO2, showing their anatase structure



07 I SEM: identification of TiO2 nanoparticles
A) and D) Film surface and cross-section. B) and E) film surface and cross-section Oxygen (yellow), titanium (green) and carbon (blue). C) and F) titanium isolated on film surface and in cross-section

of reduced heterogeneity, fissures and bubbles (Fig. 3). From SSA3 onward, temperature was fixed at 260°C. This provided optimum melting, avoiding calcination.

Series B film presented greater fragility, possibly due to the heat treatment involved in extrusion. To correct this, pressure was adjusted to 80 bar and cooling time was reduced to 3 min from SSB2 onward in order to avoid excess fissures and crystallisation. From sample SSB3 onward, a number of problems became apparent, possibly attributable to the weight reduction to 87 g. At SSB7, therefore, weight was restored to 90 g.

Finally, the previous parameters were maintained for the entire Series C, with the only change being to 60 bar of pressure during the cooling phase. This adjustment reduced fragility and fissures in the samples.

This iterative process across the three series of *materialisation* produced improvements in film *configuration* thanks to the use of machines (DF1). Adjustments to pressure, pre-contact time and contact time had the most meaningful effects.

MO2 consisted of a DSC test of Masterbatch and film (Fig. 5). The incorporation of the nanoparticles (ca. 10 [nm] in diameter) into the film does not modify either the transition (Tg) or transformation (Tm) of the polymer. The percentage crystallinity of composites did not show a significant change with nanoparticle incorporation, either during the first heat treatment by extrusion (Masterbatch), or in the second by pressing (film). However, a small increase in crystallinity was observed, which may be explained by a nucleant effect of the nanoparticles (Fonseca et al, 2015).

These observations confirm, in line with the design hypothesis, the potential for mechanical recycling of material using heat, extrusion and pressing treatments, and incorporation of TiO_2 nanoparticles into the process, without significantly altering their thermal properties. This validates the potential use of PETr in the development of new PETr-e-TiO_2 material.

MO3 used TEM analysis to explore the photocatalytic potential of a new material through the incorporation of TiO_2. The nanoparticles were uniformly dispersed throughout the PETr film, with only some agglomerations, proving that homogeneous PETr-e-TiO_2 film can be effectively produced by means of the melting process.

Figure 6 shows TEM images of PETr-e-TiO_2 film prepared by melting. The nanoparticles (8 wt%) were generally well distributed throughout the film (Fig. 6), as shown in images 6B and 6C, although small aggregations can be seen. One limitation revealed by the analysis, visible in images 06B and 06D, is the presence of dark zones. These were due to the fact that the sample was thicker in places than intended, meaning that the beam of electrons was unable to penetrate some zones of the sample. In any case, the outer zones (Fig. 6) show a possible presence of TiO_2 nanoparticles.

In summary, although TEM did not confirm the distribution of the TiO_2 throughout the polymer, our interpretation of the images is that they are present, along with an anatase structure of TiO_2 nanoparticles (Fig. 6E)

Finally, SEM analysis in MO4 allowed to study the presence and quantity of TiO2 using a sample taken from the surface, and another within the cross-section of the PETr-e-TiO_2 film. The images exhibit homogeneous surface morphology. The surface image of the composites (Fig. 8B) shows 0.1% titanium dioxide, and the cross-section image (Fig. 7E) shows 0.4% titanium dioxide. This leads to a positive conclusion as to photocatalytic potential resulting from incorporation of TiO_2 nanoparticles.

According to the literature (Loddo *et al.*, 2012) a basic requirement for the removal of contaminating atmospheric gases, such as nitrogen oxides (NO and NO_2), is to ensure the presence of a semiconductor catalyst, such as titanium dioxide (TiO_2), on the capture surface. This promotes oxidation/reduction by ultraviolet light through photocatalysis. If we observe spectra 1, 2 and 3 of the surface sample, we obtain values for the presence of titanium of 4.4%, 11.2% and 17.6%, respectively (Fig. 8). These results are a clear indication of the photocatalytic potential of the new PETr-e-TiO_2 material. Finally, finding TiO_2 nanoparticles on the surface of a 3 mm thick film validates the possibility of developing a semi-finished product.

Conclusions

The use of photocatalysts has been developed primarily based on studies of cement and paint coatings for use in urban infrastructures, such as roadways and footpaths (Liu *et al.*, 2015), and of paints for interior and exterior wall coatings (Maggos *et al.*, 2007). Hence, it possible to identify an emerging market for products used as photocatalytic cladding, such as paints, ceramics and mortars. It is also possible to find some building cladding products made from recycled plastic. However, configuration of new materials based on recy-

08 I SEM: Map Sum Spectrum for surface sample

cled PET with photocatalytic potential has not been widely considered as part of the development of construction and architectural materials.

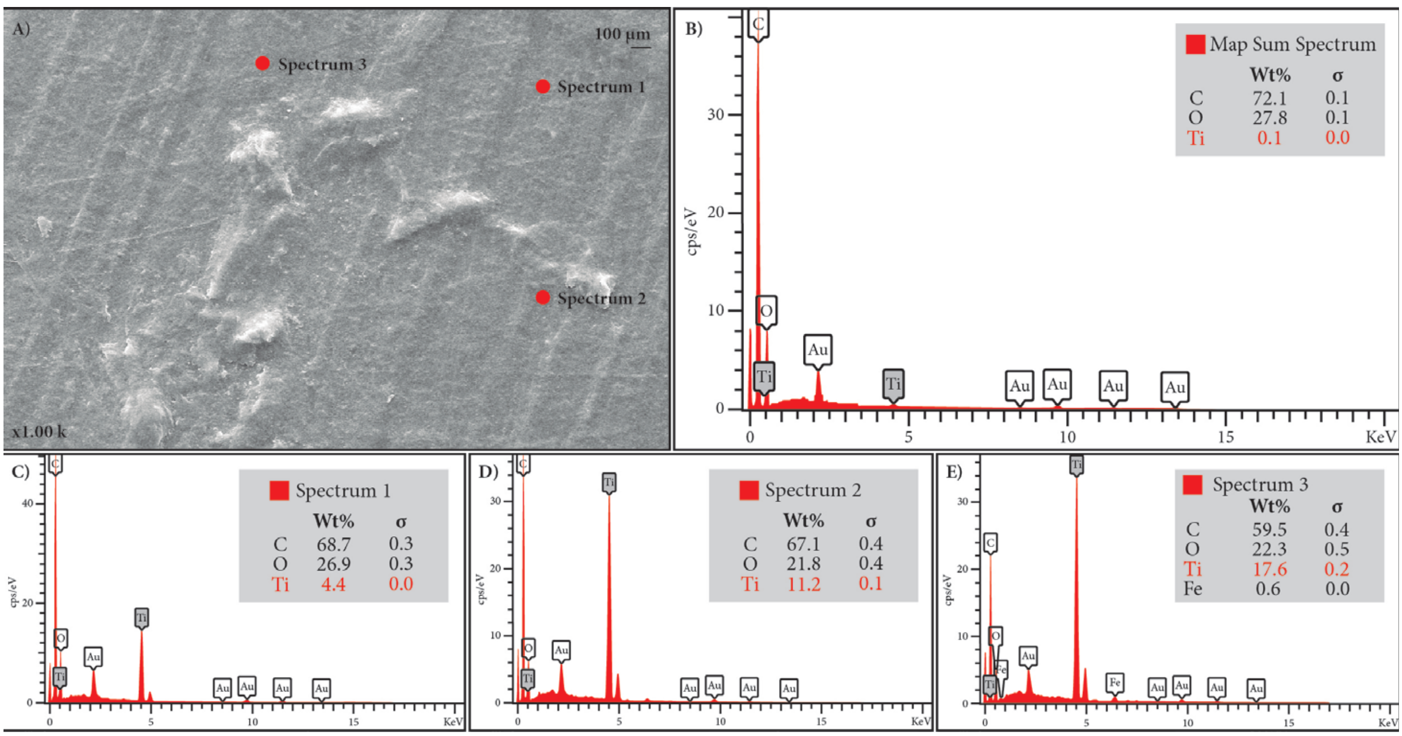
In order to be able to validate this new material as a potential product for the construction market, additional tests must be done, i.e., mechanical, fire and estimation of the energy footprint. As a reference, for the PETr-e-TiO_2 film developed according to the process described in Figure 2, the energy footprint was estimated on 6.67 KWh for each film. Further research should validate this new material as a low energy footprint product.

Concluding, the contribution of the research can be summarised in two important findings. The first is the identification of the presence of TiO_2 nanoparticles (TEM and SEM analysis), particularly on the surface of the films, as this validates the photocatalytic potential. The second finding is the confirmation using DSC analysis of the feasibility of recycling PET waste without altering the thermal properties (Tg and Tm) of the material. An additional outcome of this study is the iterative learning process of *configurations*, involving pressing the three series of film (MO1), which constitutes practical technological laboratory-level knowledge of relevance for future upscaling.

The main concern regarding this progress is the real world effectiveness of the material's photocatalytic potential. However, confirmation of the presence of TiO_2 on the surface of a film that is even 3 mm thick is a positive sign. Future research should seek to assess the material's effectiveness in terms of degradation of different gases, primarily NOX and SO_2.

Another concern is the tolerance of the film to mechanical forces. This should be validated using tensile, impact and other tests to evaluate the behaviour of the film and, therefore, their potential as a material for tile-type coatings.

Finally, the design of materials with new environmental functions prompts reflection of an iterative relational process of variable adjustment that offers new possible *configurations* for materials design. An acceptance of the challenge to recycle and, as such, to rethink plastic in terms of materials design and new environmental functions – such as the breakdown of contaminating gases – fosters a utopian work structure for design practice. In this framework, managed complexity becomes a platform on which the designer adopts a process of iterative knowledge accumulation while performing an exercise of *configuration* and *materialisation*, both of which are inherent to the exploration of environmental architectural materials.



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REFERENCES

ASIPLA (2019), *Asipla y la economía circular en Chile*, Asipla.

Baiani, S. and Altamura, P. (2018), *Waste materials superuse and upcycling in architecture: design and experimentation*, Techne, Journal of Technlogy for Architecture and Environment, Vol. 16, Firenze University Press, Firenze, pp. 142-151.

Blaine, R.L. (2002), *Method and apparatus of modulated-temperature thermogravimetry,* US Patent US6336741B1.

Comisión Europea (2013), *Libro Verde sobre una estrategia europea frente a los residuos de plásticos en el medio ambiente*, Comisión Europea, Bruselas.

Comisión Europea (2015), *Cerrar el círculo: un plan de acción de la UE para la economía circular*, Comisión Europea, Bruselas.

Fonseca, C., Ochoa, A., Ulloa, M.T., Alvarez, E., Canales, D., and Zapata, P.A. (2015), *Poly (lactic acid)/TiO_2 nanocomposites as alternative biocidal and antifungal materials. Materials Science and Engineering*, Vol. 57, pp. 314-320.

Instituto Nacional de Normalización. INN Chile (1999), *Prevención De incendios en edificios - Parte 1: Determinación del comportamiento de plásticos autosoportantes a la acción de una llama*, Norma Chilena Oficial NCh 2121/1.Of91

International standard, (2008) *Plastics - Guidelines for the recovery and recycling of plastics waste*, ISO 15270:2008.

Loddo, V., Marci, G., Palmisano, G., Yurdakal, S., Brazzoli, M., Garavaglia, L. and Palmisano, L. (2012), "Extruded expanded polystyrene sheets coated by TiO_2 as new photocatalytic materials for foodstuffs packaging", *Applied Surface Science.* Vol. 261, pp. 783-788.

Liu, W., Wang, S.Y., Zhang, J. and Fan, J. (2015), "Photocatalytic degradation of vehicle exhausts on asphalt pavement by TiO_2/rubber composite structure", *Construction and Building Material*s, Vol. 81, pp. 224-232.

Maggos Th., Bartzis J.G., Liakou M. and Gobin C. (2007), "Photocatalytic degradation of NOx gases using TiO_2-containing paint: A real scale study", *Journal of Hazardous, Material*s, Vol. 146, pp. 668-673.

Manzini, E., (1992), *Artefactos. Hacia una nueva ecología del ambiente artificial*, Celeste Ediciones.

Instituto Nacional de Normalización INN Chile (1999), *Construcción - Baldosas Plásticas - Métodos de Ensayo*, Norma Chilena Oficial NCh 873.Of1999.

Rose, C. and Stegemann, J. (2018), *From Waste Management to Component Management in the* Construction Industry, *Sustainability*, Vol.10 (1), pp. 2-21.

Digital anonymity
Human-machine interaction in architectural design

RESEARCH AND EXPERIMENTATION
Advanced Research (Under 35)

Giuseppe Bono[a], Pilar Maria Guerrieri[b],
[a] The Bartlett School of Architecture, University College London, United Kingdom
[b] Dipartimento di Architettura e Studi Urbani, Politecnico di Milano, Italy

ucbqono@ucl.ac.uk
pilar.guerrieri@gmail.com

Abstract. The paper seeks to define the concept of *digital anonymity*. *Digital anonymity* is defined as the autopoietic condition of architectural design in the digital era, a state in which the combination of decontextualisation and depersonalisation of the design process leads towards emergent and anonymous design results.
Starting from the analysis of principles coming from the architectural world and then extending their definitions to considerations relative to other disciplines, the paper tries to delineate a new ethic of human-machine interaction and integration in the current architectural discipline.
The evidence suggests that *digital anonymity* is the touchstone of an ongoing evolutionary process, which is translating architectural design into its new digital realm.

Keywords: Algorithmic Design; Architecture; Authorship; Creativity; Digital Architecture.

Introduction

The modernity of our era is characterised by the dichotomy between what is real and what is virtual. The traditional design approach based on acquisition and sedimentation of knowledge is now more frequently substituted by algorithms, which can autonomously produce endless variations starting from a given set of data. The debate on mathematical computation and its relationship with human creativity offers the opportunity to reflect deeper on the new autopoietic status of architecture in which design can potentially be reproduced in an independent way compared to human creativity.
There are significant cultural implications related to the fact that, nowadays, new software and plug-ins are able to partially substitute human creativity. This shift is changing the profession consistently, the overall built environment, design and production processes as well. The topic is of interest not just for architects, but also for specialists in other disciplines in which ongoing digital progress plays an important role in the production of final results.
This paper seeks to define the concept of *digital anonymity* as the autopoietic condition of contemporary architectural design, a state in which the combination of decontextualisation and depersonalisation of the design process leads towards emergent and anonymous design results. In order to define the concept of *digital anonymity*, the paper critically analyses specific cases, which provide evidence of the ongoing shift from human creativity towards artificial creativity. The examples are taken from three specific areas related to architectural design and the built environment, such as structural design, environmental design and morphogenetic design, i.e., the use of algorithms for structural optimisation and form-finding techniques, environmental building design, and morphogenetic design strategies for material synthesis.

Methodology

The methodology adopted is based, on the one hand, on the selection of the most recent case studies from the most advanced international research centres and, on the other hand, on a critical reinterpretation of historical references, which clarify the transition towards anonymity within the architectural field.
Concerning references, in terms of research centres, the work developed by institutes and laboratories referring to leading universities, such as MIT (Massachusetts Institute of Technology), ETH Zurich (Eidgenössische Technische Hochschule Zürich), UCL (University College London) and University of Stuttgart, is particularly important. In this regard, research groups, such as the Design Computational Lab at The Bartlett School of Architecture (UCL) or the Institute for Computational Design and Construction (ICD) at University of Stuttgart, are research clusters in which the most advanced studies in architecture are conceived and developed. Furthermore, journals such as AD (Architectural Design) and the work done by specialist groups in renowned architectural firms – i.e., ZHACode (Zaha Hadid Architects Code) at Zaha Hadid Architects, and ARD Group (Applied Research + Development Group) at Foster+Partners – are other pivotal references used for the development of this paper.

The digital measure of anonymity

The rise of artificial creativity over human creativity is the first step to take into consideration to understand the digital measure of anonymity. Talking about the primacy of artificiality over humanity means believing in the fact that computers are creative in themselves, and that their creativity is in some way independent from any human input. Although the genesis of artificial creativity lies in the similitude between the human brain and the computational machine (Von Neumann, 1958), the current evolution of computational design is giving life to artificial processes, which have their starting point in human inputs, while at the same time assuming their independence through a level of complexity that only computational calculation can reach. The evolution of Big Data analysis is a clear example of this. Furthermore, the level of novelty created through this computational complexity is unique and independent from the human input. For instance, the work of the British artist Harold Cohen and his pioneering AI system AARON is quite significant in this regard, since the entire concept of computer-generated art gives evidence to the fact that computers can produce unique and unexpected design results from a set of rules created by human beings.
Having specified that the primacy of artificial creativity over human creativity is legitimated by the new level of complexity and novelty, which exclusively belongs to the artificial world, it is more appropriate to say that such primacy is complementary rather than opposite to the human one. In fact, as Margaret Boden clearly explains in her book *The Creative Mind. Myths and Mechanisms* (Boden, 1990), computational processes – including scripts, frames, and semantic nets – are helpful to understand how the brain works and how some aspects of human creativity are possible. The reason is «because symbolic and representational structures and transformations are the focus of computer programming, the essence of creativity may not be so far removed from computational processes as is usually as-

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01 | Truss design explorations with StructureFIT, MIT (Massachusetts Institute of Technology), © Caitlin Mueller and Digital Structures

02 | Roof structure design exploration, MIT (Massachusetts Institute of Technology), © Renaud Danhaive, Caitlin Mueller and Digital Structures

sumed» (Boden, 1983). Margaret Boden herself – commenting the work of Harold Cohen and his AI system AARON – provides the interpretative key to read the complementary relations between human and artificial creativity:

A functioning program has its own inbuilt dynamism. Its activities can be both flexible and constrained, and a proper amalgam of flexibility and constraint is central to creative intelligence (Boden, 1983).

Hence, flexibility and constraint are the two main qualities to understand the real measure of complementarity between human and artificial creativity, a balance that can only be fully appreciated through the awareness of an «inbuilt dynamism». Such inbuilt dynamism represents the appropriate measure through which anonymity should be viewed in the current digital era, intending anonymity not merely as a lack of human authorship, but rather as its transformation due to the complexity and novelty promoted by the current process of mathematisation and, more in general, by the influence of artificial intelligence over human intelligence. For this reason, human creativity interacts with the artificial one through a model based on inbuilt dynamism. This factor can be considered as the most appropriate measure for digital actualisation of the concept of anonymity.

Three examples of digital anonymity

In addition to the relationship between artificial and human creativity, reading the main literature and looking into design processes referring to the last twenty years of architectural history is another important step towards understanding digital anonymity. After all, architecture has played a central role in the construction of the new digital society since its very beginning, designing spaces not only for the consolidation of static identities, but rather for the rise of new dynamic ones. The invention of digital mass customisation is particularly significant in this regard: «Digital mass customization is one of the most important ideas ever invented by the design professions […]. It was developed, hosted, tested, and conceptualized in a handful of schools of architecture in Europe and the United States in the 1990s. To this day, designers and architects are the best specialists in it» (Carpo, 2017). Apart from being at the forefront of the digital revolution, architects and designers are constantly extending the boundaries of architectural design through the introjection of external references into the architectural discipline. Such an endless extension is a distinctive feature in the current digital era, and some of the results obtained with such an attitude represent pertinent examples of *digital anonymity*.

Three design areas can be considered of particular importance to better understand the existence of *digital anonymity* in contemporary design practice. Such design areas are structural design, environmental design and morphogenetic design.

The first design field in which traces of *digital anonymity* can be found is structural design. In this case, the use of custom algorithms and software applications plays a fundamental role in the creation of the final design results, in particular through the use and development of optimisation and form-finding techniques. As explained by Mark Burry in his description of the works of Antoni Gaudí and Frei Otto as main precursors of computational design in terms of form-finding and structural optimisation (Burry, 2016), nowadays such techniques are widely used in contemporary design conception, and they are based on several software applications. For instance, Kangaroo is one of the most popular plug-ins in the Grasshopper platform; it allows to modify design in response to engineering analyses simulating aspects of the behaviour of real-world materials and objects.

Always regarding structural design, the work of the Digital Structures research group at the MIT is an important example in terms of structural optimisation and the different design configurations generated from it. Group leader Caitlin Mueller pays particular attention to the relationship between structural optimisation and design conception in her article Distributed Structures: *Digital Tools for Collective Design* (Mueller, 2017). Highlighting the fact that the creation of new computational tools is shifting the role of computation itself from representation and analysis to creativity and the gen-

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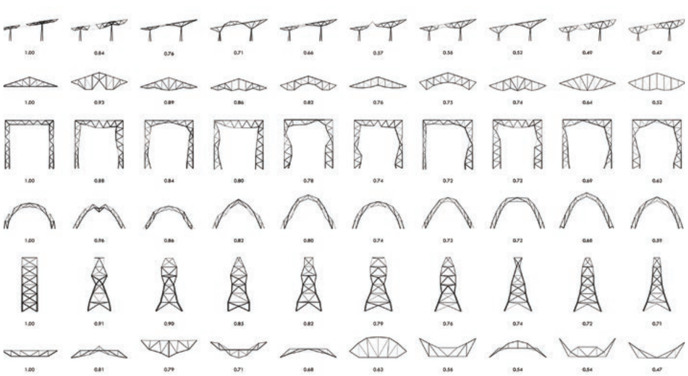

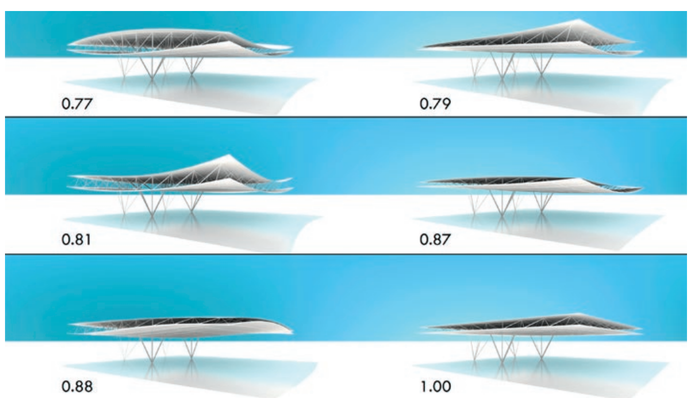

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03 | Museum of the Human Body: simulation of the annual solar radiation used for design and orientation of the louvres system, Montpellier (France), © BIG (Bjarke Ingels Group)

04 | Stettin 7 Residences: studies of solar radiation on each building façade, Stockholm (Sweden), © BIG (Bjarke Ingels Group)

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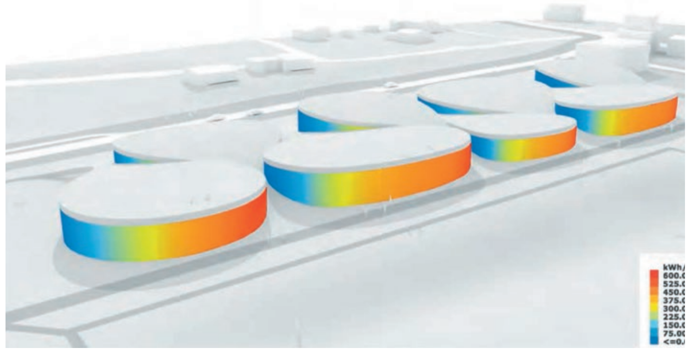

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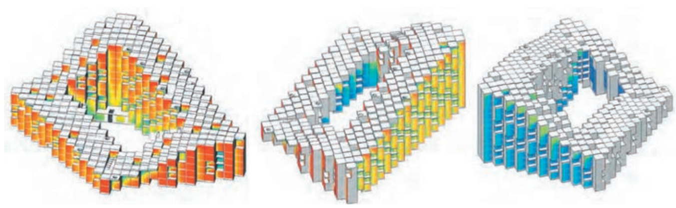

eration of ideas, Mueller provides a series of examples in which the use of multi-objective optimisation techniques offers the opportunity for the designer to choose between different options generated during the optimisation process. For instance, the Web-based design application StructureFIT allows designers to explore new design typologies and forms with a high level of structural feasibility. It is interesting to note the significant difference between the initial condition set by the human author and the final results generated by the computational machine. Between the two there is a design process in which human creativity is substituted by computation, and the end results and configurations are led by the artificial intelligence, rather than by the human one. Such a complementary primacy of artificial intelligence in relation to the human one leads towards new forms of artificial creativity, new forms of *digital anonymity* (Figs. 1-2).

Another important design area in terms of *digital anonymity* is environmental design. Nowadays, the increasing global awareness over climate changes is promoting the use of new computational tools capable of optimising design solutions according to several aspects, such as internal comfort, energy efficiency, CO2 emissions and so on. Such optimisation refers to several parameters, such as daylight, thermal exposure, airflow, turbulence, wind, space syntax and traffic flow. Although the consideration of these parameters and the use of complex computational techniques might suggest a more technical engineering approach to architectural design, an optimistic point of view to sustainable design is able to produce an independent architectural language in which buildings are shaped by environmental forces combined together with parametric and generative design procedures. The level of complexity and novelty generated by the use of such procedures produces design options and configurations, which are independent of the human author who initially set up the input parameters. Environmental building design can, therefore, also be considered an appropriate example of *digital anonymity*.

In terms of environmental design, the work conducted at BIG Ideas is particularly significant. BIG Ideas is the specialist group of environmental consultants at the architectural firm BIG (Bjarke Ingels Group), currently one of the most successful offices in the world with ongoing projects across five continents. As explained by Brady Peters in his essay *BIG Ideas: Information Driven Design* (Peters, 2018), by combining expertise in design, computation and performance simulation, the team develops its own computational tools to generate design solutions in relation to social and environmental conditions. For instance, the façade system designed for the Museum of the Human Body (Montpellier, France) is based on a Louvres system with geometry varying from horizontal to vertical orientation according to the side of the location and the direction of sunlight. In other projects, such as Stettin 7 Residences (Stockholm, Sweden), King Street West (Toronto, Canada) and VTC Tower (Copenhagen, Denmark), the entire building geometry is designed according to neighbouring building parameters (height, distance to boundaries, building typologies), direct sunlight requirements, noise reduction and other factors. The work of BIG Ideas represents a clear example of the fact that building design can be generated by new digital tools rather than by human creativity. The role of human designer is, therefore, translated into the role of creative organiser of environmental parameters rather than intuitive thinker of top-down ideas (Figs. 3-4).

Finally, the third design area, which highlights the existence of *digital anonymity*, is morphogenetic design. As explained by Michael Hensel, Achim Mendes and Michael Weinstock (Hensel, Mendes and Weinstock, 2004), morphogenetic strategies for design introduce into architecture concepts and procedures from disciplines such as biology, physical chemistry and mathematics. Such strategies refer to evolutionary processes typical of natural systems, and their introduction in the architectural discipline implies the consideration of buildings as dynamic ecosystems rather than static entities. In doing so, the building itself becomes a body of irreducible complexity where the properties of the whole system cannot be deduced from the properties of the single parts, which compose such a system. This aspect of novelty produced by increasing levels of complexity reflects the definition of *digital anonymity* itself, and underlies an ongoing shift in architectural design from the production of iconic buildings – the so called "buildings from archistars" – to the creation of intelligent ecosystems.

Material synthesis offers an interesting example of the above. Combining morphogenetic strategies and computation within a new design approach driven by an expanded understanding of materialisation and the idea of material as «active matter» (DeLanda, 2015), material synthesis shifts the rule of the human designer from «the controller of the constructional system, to that of a forecaster of possible spatial and structural formations» (Dierichs and Menges, 2015). In this regard, aggregate systems and granular morpholo-

05 | Aggregate architecture: digital model recorded with laser-scanning techniques, University of Stuttgart, © Karola Dierichs and Institute for Computational Design and Construction (ICD), Annette Scheider and Institute of Engineering Geodesy (IIGS)

06 | Aggregate architecture: full-scale structure, University of Stuttgart, © Karola Dierichs and Institute for Computational Design and Construction (ICD)

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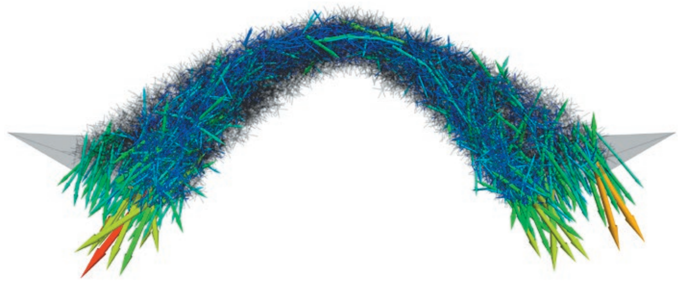

gies are examples of the fact that even if the initial components are known, the final result can be totally emergent and independent from the human designer's intention. Aggregate systems are examples of how new advancements in additive manufacturing and emerging capabilities in materials science and synthetic biology nowadays allow design to move from top-down design procedures - led by the human author - to bottom-up digital and physical processes. Therefore, morphogenetic design is an appropriate example of the existence of *digital anonymity* in contemporary design practice (Figs. 5-6).

Conclusion

The architectural examples summarily analysed contain principles that show the measure of human-machine interaction in the current digital era, a time based on complementation, augmentation and interaction between human creativity and artificial creativity. *Digital anonymity* emerges through decontextualisation and depersonalisation, giving life to a new emergent and autopoietic condition of architectural design. The traditional design approach based on acquisition, sedimentation and reinvention of knowledge – which characterises the intuitive approach of human creativity – is now substituted by algorithms, which can produce endless variations starting from a given set of data. Such translation is based on the intentional approach of artificial creativity and, in this transformation, the context is condensed into a series of parameters. Moreover, the visionary work of human beings is substituted by endless – and potentially random – combinations produced by the generative independence of algorithms.

The existence of *digital anonymity* highlights the action of an ongoing digital progress, which is already producing a new «paradigm shift». The use of the expression «paradigm shift» refers to the evolutionary approach explained by Thomas Kuhn in his seminal book *The Structure of Scientific Revolutions* (Kuhn, 1970). Among a series of remarkable intuitions addressed towards a new vision of scientific revolution, Kuhn describes the period of crisis, which leads to scientific revolutions through the definition of four symptoms:

The proliferation of competing articulations, the willingness to try anything, the expression of explicit discontent, the recourse to philosophy and debate over fundamentals, all these are symptoms of a transition from normal to extraordinary research (Kuhn, 1970).

Interestingly, all these symptoms perhaps belong to our current era too. The similarity is clear and it cannot be a simple coincidence.

| 06

It is more appropriate to say that nowadays all these symptoms of transition from normal to extraordinary research «may very well be linked to the confused feeling that we have entered a new enchanted realm» (Picon, 2010), a world characterised by the dichotomy between what is real and what is virtual.

Above all the theoretical constructions and critical considerations that can be defined, it is important to remember that architectural design is something real and – as Mark Wigley was already reminding us almost thirty years ago – «critical work today can be done only in the realm of building» (Wigley, 1988). Hence, the built environment is a field of action where our digital society can be shaped, a land to be constantly designed from scratch, a place characterised by *digital anonymity* and by the fact that – first and foremost – anonymity emerges only through alienation, manifested case-by-case, against a background provided by autonomy.

NOTES

[0] The paper, proposed by an under 35 researcher, has passed the acceptance phase of the abstract and consequently the "double blind review", obtained, on the part of the Techne Board, a positive evaluation for the publication with the No-Pay logic.

REFERENCES

Boden, M. (1983), "Creativity and computers", in Harold Cohen (Ed.), *Exhibition catalogue*, The Tate Gallery, London, pp. 18.

Boden, M. (1990), *The Creative Mind. Myths and Mechanisms*, Weidenfeld and Nicolson, London.

Burry, M. (2016), "Antoni Gaudí and Frei Otto. Essential Precursors to the Parametricism Manifesto", in Schumacher, P. (Ed.), *Parametricism 2.0. Rethinking Architecture's Agenda for the 21st Century*, AD Profile 240 (March-April 2016), pp. 30-35.

Carpo, M. (2017), *The Second Digital Turn in Architecture. Design Beyond Intelligenc*e, The MIT Press, Cambridge, USA, p. 4.

DeLanda, M. (2015), "The New Materiality", in Mendes, A. (Ed.), *Material Synthesis. Fusing the Physical and the Computational*, AD Profile 237 (September-October 2015), pp. 16-21.

Dierichs, K. and Menges, A. (2015), "Granular Morphologies. Programming Material Behaviour with Designed Aggregates", in Menges, A. (Ed.), *Material Synthesis. Fusing the Physical and the Computational*, AD Profile 237 (September-October 2015), p. 87.

Hensel, M. and Menges, A. and Weinstock, M. (2004), "Introduction", in Hensel, M. and Menges, A. and Weinstock, M. (Ed.), *Emergence: Morphogenetic Design Strategies*, AD Profile 169 (May-June 2004), pp. 6-9.

Kuhn, T. (1970), *The Structure of Scientific Evolution*, The University of Chicago Press, Chicago, pp. 91.

Mueller, C. (2017), "Distributed Structures. Digital Tools for Collective Design", in Tibbits, S. (Ed.), *Autonomous Assembly. Designing for a New Era of Collective Construction*, AD Profile 248 (July-August 2017), pp. 94-103.

Peters, B. (2018), "BIG Ideas: Information Driven Design", in Peters, B. and Peters, T. Computing the Environment. (Eds.), *Digital Design Tools for Simulation and Visualization of Sustainable Architecture*, AD Smart 06, Wiley, London, pp. 150-62.

Picon, A. (2010), *Digital Culture in Architecture. An introduction for the design professions*, Birkhäuser, Basel, p. 216.

Von Neumann, J. (1958), *The Computer and the Brain*, Yale University Press, New Heaven.

Wigley, M. (1988), "Deconstructivist Architecture", in Johnson, P. and Wigley, M. (Eds.), *Deconstructivist Architecture, Exhibition catalogue*, The Museum of Modern Art, New York, pp. 19-20.

A Dialogue of Ingrid Paoletti and Maria Pilar Vettori with Gerard Evenden (Foster + Partners)

The idea of the Special Series 'Future Scenarios' is to put the architectural project at the centre of debate as a complex phenomenon, able to build a synthesis of scientific, social, political and cultural points of view, in a period where the anthropocentric perspective has radically changed our approach to the environment, to construction, to technology and materials, given their impact and effects on scarcity of resources and moreover today to urban health.
Gerard Evenden is Senior Executive Partner Head of StudioBSc, BArch (Dist), RIBA. Gerard Evenden has worked on a diverse range of projects during 26 years at Foster + Partners. Graduating from the University of Wales Institute of Science and Technology, Gerard's interest in innovation, materials and new building techniques, is evident in his global experience and demonstrated by award winning projects across the world. Gerard led Masdar City and has developed pioneering high-rise towers and transportation buildings. He named his children, Florence and Sydney, after two competition wins. Gerard enjoys a family life in Wiltshire.

Cities in transformation: environmental and social design and large scale perspective

Ingrid Paoletti and Maria Pilar Vettori T*he last pandemic event has raised the need to re-consider the phenomena of fast urbanization and the future scenario start from the attempt to work with this uncontrolled expansion. What will be the role of mobility?*
Do you believe that design as an inclusive approach for the transformation of cities, is providing appropriate answers either to the emerging energy and environmental needs but also to social questions of how these transformations will impact on urban life, also after recent pandemic event?
Can you tell us something about the Mobility Pavilion for Expo2020 Dubai?
Gerard Evenden The pandemic has had a huge impact on the way people think about mobility in cities. All over the world, people have been encouraged not to use public transport and not to gather in large numbers. It is very interesting that in London, where access to public transport was severely restricted during the lockdown, two major changes have taken place – firstly, people started noticing that the air was a lot fresher, and secondly, a lot of people have taken to the bicycles as their primary mode of transport. Mobility will be in sharp focus over the next few years as people look to alternative ways of getting around.
A lot of people have also realized that they do not need to travel to their offices every day to go to work. We are going to see a lot more flexibility in the way people work and travel. Moreover, people have understood the importance of space. The majority of homes in London do not have a garden or an outside space. Many people have started considering if they should move outside London and work remotely, or go to the office for one or two days a week, rather than being there every single day.
The question on everyone's lips is, how the world is going to change? One way is that it will all go back to where we were, but I do not believe it will. The question for me is, how big the shift will be. We have been focusing for a long time on autonomous vehicles, how the advent of self-driving electric cars will interface with our built environment. Now we will have to think of ways to deal with that very quickly.
The Mobility Pavilion for the Dubai EXPO is designed with three arms that represent the past, present, and future. But what is the most exciting about the pavilion is the track and the public space surrounding the building. This brings me back to my original point about how buildings respond to the changes in mobility, how these are reflected in the architecture of the future.
This is also related to sustainability, thinking about the health, about the impact that we are having on the planet. If somebody told us a year ago that a tiny virus would have such a massive impact on our world, anyone would have said "That is impossible!" Yet, this has happened and the effect, rightly, is a movement towards positive change in relation to the issue of sustainability.
Sustainability has underpinned our work since the very beginning of the practice. We have always advocated for the need to build more sustainable and efficient buildings with fewer materials. A similar movement is seen in transport and mobility. There is a demand for systems that are better, cleaner and healthier. Suddenly, we are seeing a conflation of mobility, built environment and sustainability. All coming together with one focus. That would not have happened as fast as it is without the pandemic. It will force designers to really investigate what they are doing and how that is affecting the planet.
We have already been commissioned by many clients to help them to develop new approaches towards the future. For example, we participated in a study which showed that with current social distancing measures, we may be able to accommodate only two people in a lift car at one time. This means it will take seventy hours to fill the office tower. So, what does it all mean? How do we create the system that will work in the future? We are going to have a massive period of change. I think that change will be good.

Project for climate change: policy and technology for adaptation and mitigation

I.P. and M.P.V. *Strong scarcity of resources and radical climate change constitute a complex scenario with which design and project activities will have to face in the near future. Designing buildings and spaces is more and more an activity that involves different figures, included final users and policy makers. In your experience, which are the possible scenarios of cooperation among different figures, that can really foster a roadmap to change?*
G.E. One of the projects in which we began to tackle about the climate change in a big way was Masdar City in Abu Dhabi. Our approach was inspired by the principles of renewable energy and sustainability, which influenced the design of every element in the urban environment – we raised the ground plane, separated vehicles from people, created buildings that could have been prefabricated and constructed in new ways. We also created that buildings in a way that they can be taken down and recycled. We looked at the critical

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| 02

01 Foster + Partners, Riverside Office, London (credits Nigel Young, Foster + Partners)

02 Foster + Partners, Riverside Office, London (credits Nigel Young, Foster + Partners)

relationship between buildings in terms of the solar incidence, with buildings shading the streets. We tried to bring the street temperature down by controlling the materiality of buildings so that they did not radiate heat. The architecture emerged from the science, as opposed to it being just an artistic idea.
Something that is fast becoming an area of renewed focus is building reuse. When we calculate the impact of buildings on the planet, we have to think about the overall lifecycle of the building and how it can be extended and maximised. If your building cannot be re-used, then it may not be as attractive to developers and clients in the future. We have to react to the changing world. The design principles will be much more scientifically and technologically orientated in the future.

New challenges for technical innovation: production, techniques and materials

I.P. and M.P.V. *In a back casting perspective, new production methods, construction processes, advanced materials and experimental technologies have to consider environmental protection and people's health and well-being as a priority goals.*
Foster + Partners is famous for its bottom-up and top-down innovation of technologies and materials in scientific research and in industrial experimentation. How do you interact with companies and industrial sector to develop products nowadays? What's on the air at the moment?
G.E. Collaboration is at the heart of all the work we do at Foster + Partners. To produce innovative building elements, the transfer of design information to contractors and other suppliers and the form in which this takes place is crucial. This is something that we continue to explore and work on.
The idea of innovation and technology is something our Mobility Pavilion explores as well. The overarching theme of mobility runs through three key elements: people, goods and transportation, and data. As a sequence, it is data that you give, that enables the transportation of the goods, which then people use.

Architects of tomorrow

I.P. and M.P.V. *The challenges of new domains and fields, where innovation seem arising in new territory, digitalization gain ground, practice and theory merge, method and tools change, roles reverse, require to the architect completely new expertise and skills.*
Which figure will be the architect of tomorrow from the perspective of such a cutting edge studio as F&P? Which challenges a young architect is going to face and how to tackle them?
G.E. The good news for architects is that the profession is changing and changing for the better. I think that is because of the need of linkage. The architects' role is becoming of pulling those links together. The architect coordinates and brings together structural engineers, a civil engineers, electrical and mechanical engineers. Now we have a greater and greater linkage because we now collaborate with other fields such as biology, technology and all other aspects affecting design. It is the architect's job to bring all these links together and to make sure they sit together comfortably to make the project successful.
We are not just talking about building, we are talking about the whole environment, looking at bigger projects around the world, on the structures of cities, structures of communities. Look at the pandemic and the effect of that on the communities. Before the pandemic, people in the UK were talking about the death of the high street. During the pandemic everybody was almost forced to explore their immediate surroundings. People realized that keeping the local communities together is incredibly important. All these linkages are the architect's responsibility in terms of the production of the build environment and buildings which we live and occupy. We must take a lead in that. We become a key part of making sure that things don't go back to the way they were.
A successful architect is one who thinks in a lateral way, as opposed to a vertical way, it's not good to focus only on your own subject, because you are a part of something that is bigger. My interest extends to vehicles and anything to do with technology. So, the thing that any student must not do is to restrict the mind. They should expand their mind, explore materiality, explore the economy, anything that interests them.

03 | Foster + Partners, Riverside Office, London (credits Rudi Meisel)

04 | Foster + Partners Mobility Pavilion Dubai Expo 2020 (copyright holder Asymmetrica and Foster + Partners)

My daughter was talking to me about becoming an architect. I told her to go to study economics, understand art, and then investigate the science behind architecture. Because those three things are really the key components to what we do – one does not happen without the other. Lastly, as architects, it is our responsibility to advocate for change. It is the resistance to change that leads to stagnation and it is vitally important to embrace change to remain relevant and progress.

Expo2021 Dubai and the role of Expo's in the future

I.P. and M.P.V. *Universal Exposition have been since the beginning a very peculiar field for architectural practice in terms of opportunity of experimentation both in material and theoretical approaches.*
How do you think Universal Exposition have become drivers of change and forecasting of socio-technical scenarios? Will it be the same for Expo2020 Dubai now in 2021? How Foster + Partners will contribute?
G.E. I have now been involved in three EXPOs: in Shanghai, in Milan and Dubai. I think they are incredible opportunities to showcase innovation from around the world. The most important thing that comes out of EXPOs is the debate they generate and the way they bring people together. Personally, I found it incredibly exciting to work on all three so far.
Winning the Mobility Pavilion for us is a great opportunity to educate and entertain. In my experience, if there are too many complex messages very often the pavilion becomes filled with information that you forget very quickly. But if you ask me which pavilions I remember, they are always the ones that have very simple clear stories. If you think about any iconic piece of architecture, it is something that a child could draw. We all know what the shape of the Eiffel Tower is. We all know what the shape of the Burj Khalifa in Dubai is. This is because they embody very simple and strong ideas. That is what the EXPO very good at. In Milan, we did a pavilion for UAE that was inspired by the shape of a sand dune. When you walked in the pavilion you could experience a piece of desert. It is a very simple thing.
Hopefully, people will go to the pavilion in Dubai and they will test some transportation systems to understand the different forms of mobility, whether they are physical or digital. These subjects now in sharp focus globally. The questions on everyone's minds are – how do we want to live in the future, how do we want to work in the future? The architect is right in the middle of this discussion. We are at the right place at the right moment. Being an architect today is a fantastic opportunity to enable positive change!

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Authors

Andrea Campioli
Full Professor at Politecnico di Milano, Italy

George Katodrytis
Professor at American University of Sharjah, United Arab Emirates

Stefano Converso
Researcher at University of Roma 3, Italy

Federico Leoni
Researcher at University of Verona, Italy

Gerard Evenden
Senior Executive Partner and Head of Studio Foster + Partners, London, United Kingdom

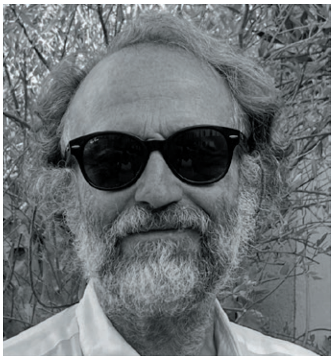
Maria Teresa Lucarelli
Full Professor at University Mediterranea di Reggio Calabria, Italy

Emilio Faroldi
Full Professor and Vice Rector at Politecnico di Milano, Italy

Kas Oosterhuis
Professor at Delft University of Technology, Netherlands

Ingrid Paoletti
Associate professor at Politecnico di Milano, Italy

Maria Pilar Vettori
Associate professor at Politecnico di Milano, Italy



François Penz
Professor at University of Cambridge, United Kingdom

Telmo Pievani
Full professor at University of Padova, Italy

Carlo Ratti
Director of the MIT Senseable City Lab, Massachusetts Institute of Technology, Boston, United States of America

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