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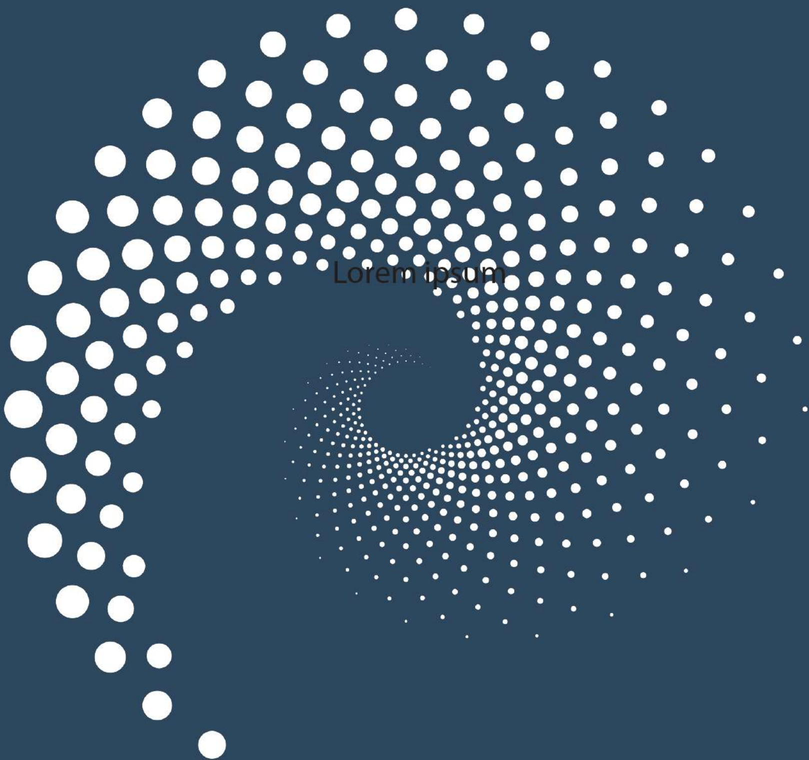
FROM MEGA TO NANO
THE COMPLEXITY OF A MULTISCALAR PROJECT



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Francesca Scalisi

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Volume 4

Edited by Francesca Scalisi

FROM MEGA TO NANO: THE COMPLEXITY OF A MULTISCALAR PROJECT

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MULTISCALARITY OF ADAPTIVE ARCHITECTURE
The efficiency of micro and the resilience of macro in contemporary design

Bianca Andaloro

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ARCHITECTURE

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ESSAYS & VIEWPOINT

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ABSTRACT
Dealing with the multiscalar approach of contemporary architectural design raises the question of which architecture today is willing to accommodate a constant comparison between different scales, materials, and practices. It is believed that the processes that best show this purpose are related to resilient architecture, which elaborates innovative features through adaptive processes. With the introduction of external factors to the building as design materials, adaptive architecture can be considered as a transformative condition for some invariants of the discipline. The resilient and adaptive approach, therefore, uses technological elements, whose scale is Micro, embedded in the building and operating at the medium scale, to capture information from an external basin and return an improved response to environmental and human conditions.

KEYWORDS
adaptive architecture, resilient architecture, responsive architecture, interface architecture, digital infrastructure

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Defining and identifying the contemporary architecture project, which is increasingly confronting and integrating with urban systems now progressively Smart or Intelligent[1], appears today a topic of fundamental importance for our discipline. In fact, the concepts of scale and measurement have always been fundamental tools for the project, because of their capacity to relating the particular with the general and to setting hierarchies and relationships between different built systems. Nowadays we can use the notion of multiscalarity, which is a predominant feature of some architectures, as a means to understand the relationships between architecture and the macro and microsystems with which it dialogues and interacts. It is therefore intended here to refer to processes of adaptive or responsive architectures, capable of responding to the needs of resilience to which environmental circumstances and contingencies refer today, in order to prepare an early reaction to environmental changes. Adaptive design, in fact, implies the integration of material and immaterial elements of different nature and scale into the architectural project constitute an integrated, adaptive and therefore resilient result.

Implementing these processes, however, does not mean to attribute an exclusive design scale a contemporary project, but, on the contrary, it implies to find in the multiscalarity an element able to define it: from the immateriality of the digital infrastructure and information to the complexity of specific territorial and environmental contingencies, the adaptive architecture incorporates systems of integration and data processing, to elaborate projects with a strong systemic complexity, that are also multi-dimensional, multi-scalar and multi-material. Through the study of three emblematic projects for their spatial and systemic complexity, such as the Generator (Hardingham, 2016), the Currie Park (Carlo Ratti Associati, 2016) and Reset (UNSense, 2017), it is intended to show the complexity of the adaptive approach operating in the interrelation between elements of different scales, in order to highlight the related characteristics and methodology.

Evolution of Adaptive Architecture | Nowadays adaptive architecture is considered as an evolution of the Responsive Architecture[2] (Negroponte, 1970), a field of research and application of processes that, starting from the identification of certain external environmental conditions, elaborate adequate response systems capable of modifying the shape, colour or, more generally, specific characteristics of the building[3]. In these projects it is possible to always recognize two fundamental elements: the inputs, i.e. those technological components, usually sensors, that capture information from outside, and the outputs that, on the contrary, process and allow the response of the building.

Born as a pioneering approach referring in particular to energy improvement systems for buildings, today, thanks to the rapid technological evolution, it is no longer limited to regulating the interaction between the building and the outside exclusively with a passive approach. On the one hand, in fact, recent adaptive systems allow the building to communicate with its users, capturing data and adapting its characteristics to them in real-time; on the other, the building itself can be connected through IoT (Internet of Things) systems to a virtual network of information that changes over time and is capable of revealing changes at different scales. The purpose of this experimentation, initially developed as an exclusively technological artefact, but that today reveals strong socio-cultural implications, is to guarantee a higher performance to the buildings – in the beginning – and to the individual devices – nowadays. However, the application of such a system within a widespread digital infrastructure network reveals an intent to share information to contribute to the improvement of all aspects of individual users and communities' lives under loads of aspects.

It is therefore essential to clarify, through two concepts, the passage of scale from Responsive Architecture to Adaptive Architecture: the first one reflects the ability of architecture to be constantly connected to a network, physical or digital, capable of managing a multiplicity of data over time; the second, however, shows the duality of the relationship between the data and the project. This aspect is revealed in the nature of the project itself to be able to develop an adequate response to the data collected. Moreover, since the time factor is crucial in the definition of this process, it is possible to consider this field of research in close relation with a design process that aims to be resilient, in which the building should face, for example, catastrophic environmental conditions. As it will be seen later, the frequency of natural disasters must be a warning event for architecture to carry out transformations that are not only political and community-oriented but that rather have a semantic nature. It is believed that, by incorporating the macro-processes of infrastructural digitalization and by embedding micro-devices capable of communicating with the external entities, the architecture project can provide a resilient response to natural events.

It is, therefore, now possible to better specify what is meant by adaptive architecture: defined among changing architectures[4] (Fig. 1), it is an architecture capable of reacting independently, dynamically and in real-time to oscillations in certain environmental conditions. It is possible to always recognize five main elements: the adaptive components, the ability to perform reactions, the intentionality of the process, the preservation of renewable resources and adaptation to environmental factors and/or catastrophic events. In particular, spatial configurations, enclosures and structures are considered as adaptable components, in other words, all those elements capable of reacting through the material properties of actuators (Schmidt III and Austin, 2016; Fig. 2).

The technological and digital elements, however, are no longer post-design components, but they should be considered as fully-integrated features: one, as a means of data capture and a vehicle of interpretation, the other, as a necessary condition for the elaboration of the response, capable of defining a real learning process for men and buildings. In this way, the building becomes part of a living data network that can itself contribute to forming, generating information about what happens inside it – the temperature, the variation of influx according to events, etc. – and defining itself as a multimaterial element, made up of physical elements and immaterial data.

At the same time, with a multi-scalar approach, the architectural space exploits technology to build connections and interfaces, to respond both to the bio-physical needs of its inhabitants and to external living conditions or environmental disasters. A continuous succession of scales connected by bonds and interdependence relationships is thus emerging. If we consider the relative character of the design scalarity, it is evident how the project of a single building reveals both an individual and collective dimension: on the one hand, through the relationship with the large scale (not only of the natural and urban environment in which it is inserted but also of the virtual and digital environment that composes it), on the other hand, through the relationship with the users who interact with it. Thinking of architecture as a multiscale mixture of complex and heterogeneous materials and phenomena, finally, represents a way to constantly integrate the physical, material, and visible spatial components with the immaterial, invisible dimension of data and users that are the main protagonists of space.

In the reality of contemporary built architecture, there are lots of projects shown as the results of researches focused on the ability of the digital element to be able to induce the adaptive transformation of such architectural elements canonically considered fixed, as the horizontal surfaces of the floors or even the structural systems[5]. Designing this type of response determines a necessary transformation, semantic and spatial, of these building materials after external stress. Therefore, the new definition of these elements is part of a design process that must use computational components to plan, verify and manage all the changes in advance. Some elements, as mentioned above, lend themselves more than others to hosting this technological upgrade: understanding what adaptivity implies and

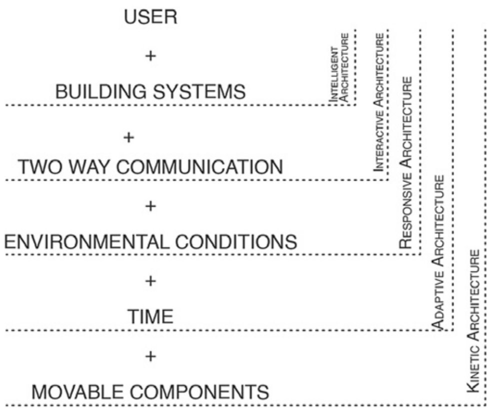
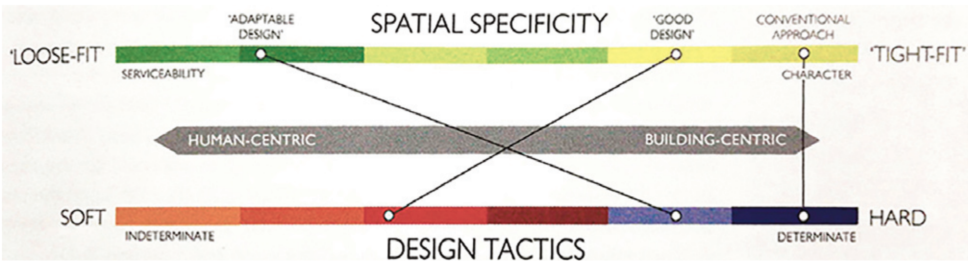


Fig. 1 | Elaboration of the relations generated by the different degrees of interaction between architecture and user/environment (graphic elaboration by the author based on Elmokadem, 2016).

Fig. 2 | Harmonizing approaches model (credit: R. Schmidt III and S. Austin, 2016).



how it modifies the architectural element through interscalar ideation and cognitive process, allows us to understand the contemporary evolution of resilient architecture. However, it is necessary to understand which process has guided the insertion and the subsequent definition of digital culture in architecture and how it has influenced the processes of defining space. This makes it possible to define the systemic design complexity that implements the reflections on the multi-scalarity of contemporary design.

Influences and processes of the digital approach | The definition of a multiscalar idea of the architectural project, that takes into account infrastructures or superstructures of different nature, material or immaterial, requires a comparison with projects from the Sixties and the Seventies between Europe and America. With the overcoming of certain characteristics of the Modern Movement, the exaltation of the concepts of self-determination and individual and collective responsibility and the birth and development of numerous avant-garde movements, there has been a prolific production of projects whose value lies in the mixture of different scales, i.e. the relationship between two and three-dimensional planes. It is easy to mention projects such as the Archigram Group's Plug-in City (1960-74), Yona Friedman's Spatial City (1958-59), or the projects of the Japanese Metabolists, to realize how central the interrelation between the small, human scale and the large scale of urban infrastructure was.

However, the crucial moment that more than any others has guaranteed the development of a thought that would transport the infrastructure from a real and material dimension (the city and its physical networks) to an a-dimensional one (related to information) has been due to the introduction of digital systems. The development of information technology, which took a rapid leap forward during the Second World War and the Cold War, made it possible to introduce some of the guiding principles of these new technologies into the architectural field. Norbert Wiener's theories[6] on the relationship between the environmental and natural world which resulted in the first scientific applications of cybernetics, opened the way to new experimentations, starting from Gordon Pask's theories about the real possibility of applying these concepts in architecture (Picon, 2010).

One of the first personality that understood these theories was Cedric Price, undoubtedly a point of reference for all those who, still today, want to deal with architectures capable of changing (in time and space) and of being related to systems and procedures of different nature. The insertion of a physically micro dimension, but referring to a macro-structural system, into architecture has largely allowed identifying new design components that have contributed to the redefinition of spatial and temporal conceptions. These elements can be summed up with themes such as language, command, control and the ability – both active and passive – to learn. The latter, which in Price's projects becomes the main guide to understanding space, today is fundamental, as mentioned above, for understanding the mechanisms that make adaptability and reactivity of changing architectures possible.

In fact, many of Price's projects modify their spatial conditions by adapting the building to the users' needs, constituting a real learning process by the building. In addition to making these changes physically feasible, in fact, these mechanisms give further value to adaptive architectures, making them a means of knowledge of the environmental facts, of the conditions inside the building, and even of the (inter)relationship with the users, through interface devices. Adaptive architectures, therefore, constitute a means of understanding reality and contributing to its augmented restitution (Fig. 3). It should also be specified how the transition from the information age, with reference to the period between the two wars, to the digital age also marked an evident passage of scale – interdisciplinary – from the culture of the anonymous consumer masses to the individual dimension of the individual (Negroponte, 1970). This passage is relevant in the reading of adaptive multi-scale projects, harbingers of further twofold interest, on the one hand for the communities, to which the projects are destined, and on the other for individuals, whose individual needs may be the reason for architectural changes.

The dimension of Resilience and interscalarity in Architecture | For some decades now, the theme of resilience has been a key theme of contemporary architecture that is called to confront a natural environment increasingly dangerous and unpredictable. The

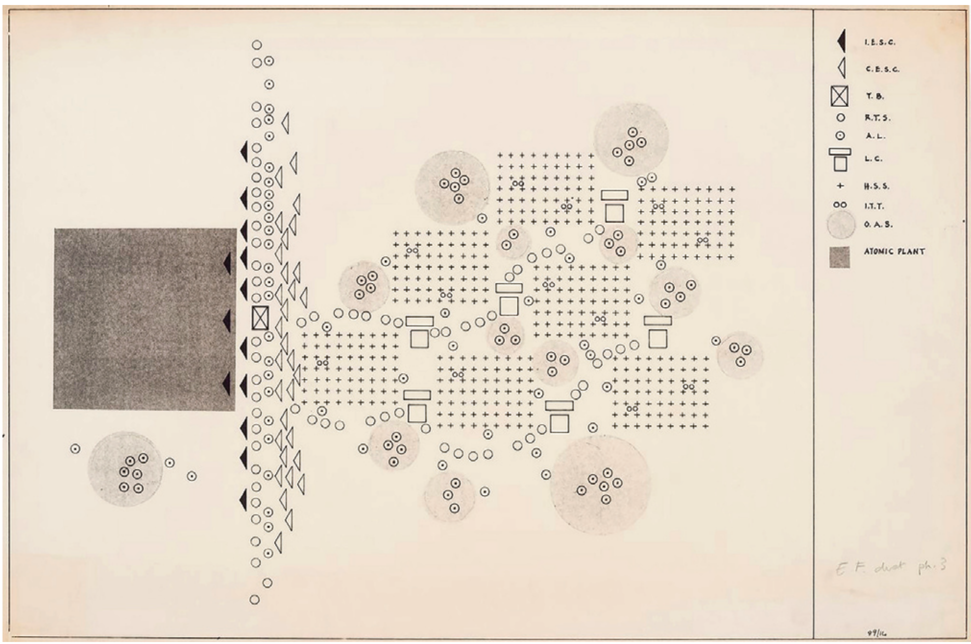


Fig. 3 | 'Atom: diagram illustrating the distribution of educational facilities throughout the town in phase 3', ATOM by Cedric Price, 1966 (credit: CCA Canadian Centre for Architecture, Montreal, 'Cedric Price fonds, 1903:2006, predominant 1953:2000', DR1995-0233-020).

sequence of natural disasters that we have witnessed in the last twenty years, starting with the Tsunami in Thailand in 2004, passing through Hurricane Katrina in 2005 up to the recent earthquakes in Albania (2019), is a sign of an increasingly rapid climate change whose effects prove to be exponentially dangerous. After Hurricane Katrina, which destroyed the United States and has had economic and social repercussions for a long period, resilience has been considered as a design theme also in the architectural field, thanks to the institution of the design competition.[7]

Talking about resilience in the architectural field, as a constitutive and transformative element, implies the involvement of all the elements that define the project, and therefore also the scales and the ambits, in order to constitute beforehand systems capable of absorbing changes and adapting proactively to them to configure a new state of balance. Resilience, design and environmental challenges are therefore three themes that are now increasingly interconnected and linked. It is possible to consider that, the main link between these three macro-environments that represent an innovation in the processes of project design is the presence of quantitative and qualitative information. The technological (non-technical) innovation applied to architectural design is, with speed and efficiency, collaborating in the definition of new paradigms of innovation, through the interscalar dimension of the project and the addition of intangible elements. Therefore, although it is known that resilience represents today a macro field of experimentation and research in different sectors, including architecture, it is interesting to deepen an approach that binds together different scales of the project, in few words, the connection between resilience and digital networks. This, not to propose a unique solution, but to read some architectures that cohesively incorporate the digital technological element, as one of the possible solutions for resilient design.

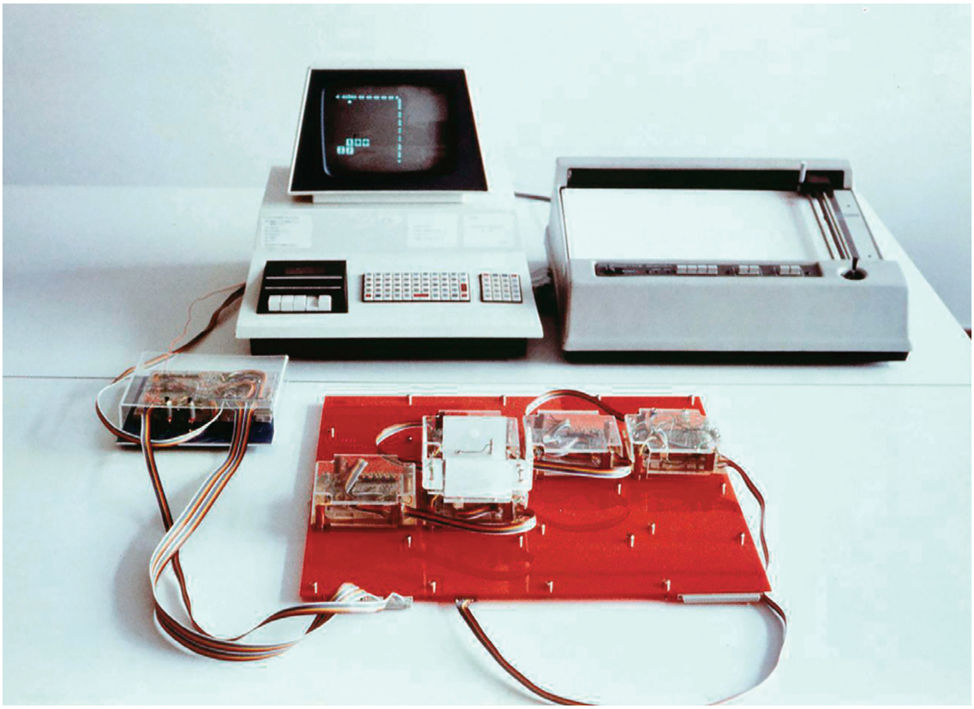
Resilient cities are cities where the smart city paradigm is already outdated: there is more and more talk of 'intelligent city' (Gausa, 2017) or 'senseable city' (Claudel and Ratti, 2016). Cities must not only process or read technological or digital data: they must be reactive, able to capture, understand, read and intuit the data. Three components can define their responsive and innovative character: digital communication networks, the ability to process data and the presence of sensors and project application software (Gausa, 2017). Big Data, today, are increasingly complex, complete and publicly available, and therefore can and must be put at the service of processes of a different nature.

In this sense, therefore, it should be considered the topicality of research about the multi-dimensional approach of adaptive architecture applied in resilient environments, considering as possible a greater or different interaction between architecture, the macro environment and the technological micro-sector of the digital infrastructure. The article then aims to show and compare some projects whose approaches are considered valid to outline and investigate the characteristics and constants that define adaptivity through multiscalar processes. The proposed projects – referring to a time horizon between 1976 and 2017 – are the Generator (Hardingham, 2016), the Currie Park (Carlo Ratti Associati, 2016) and Reset (UNSense, 2017): although in their dimensional and functional diversity, they show the methodological uniformity that guides the adaptive process. In this way, by capturing from the outside different types of information such as the presence, position or even the mood of a user, these examples show how it is possible to define a system of interscalar relations between different elements and contexts. Designing in a resilient way is certainly a topic that has been widely dealt with in different design occasions both by Carlo Ratti Associati, UNSense and UNStudio. These two projects have been identified because of their evident mixture between the technological element, that tends to an infrastructural macroscale, and the architectural element, that directly confronts the average scale of the user. The most distant example, instead, the Generator by Cedric Price, is a precursor of the interrelation between the external necessity and the architectural material, a project whose intent is to periodically re-establish a new balance to overcome a moment of boredom or, we would say today, of difficulty.

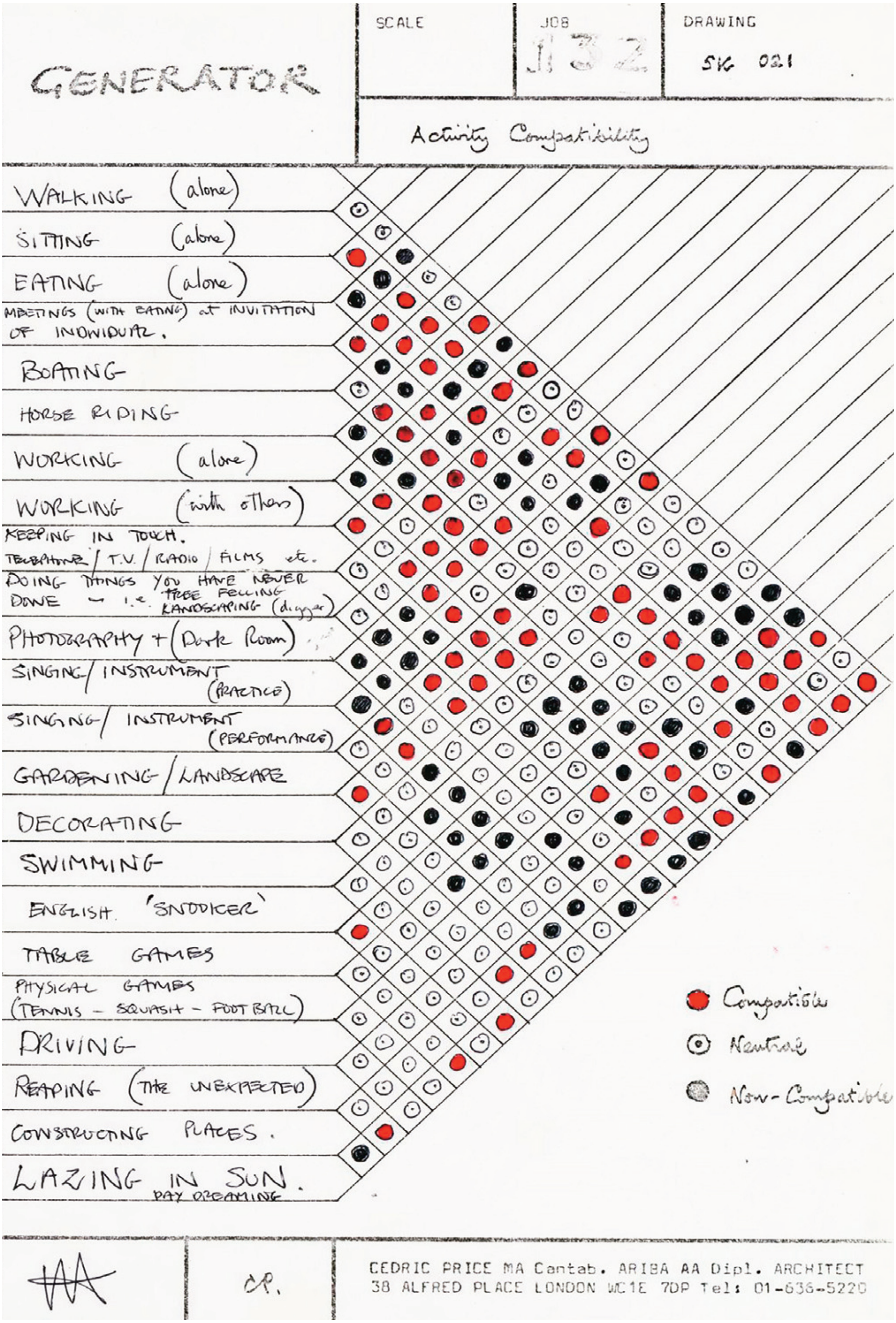
The Generator project: adaptability as a solution for boredom | In a mature phase of his career (1976-79)[8], Cedric Price developed the Generator project in collaboration with John and Julia Frazer, today considered the leading exponents and pioneers of intelligent and interactive architecture. The innovation brought by this project should be read as the result of long project experimentation that began with the Fun Palace (1960-66) and continued with the Potteries Thinkerbelt (1964) and ATOM (1966): although it was never completed, the Generator has made tangible the systematic and complex nature of the digital architectural design. It has therefore created a system capable of linking the scale of the micro technological components to the architectural scale of the building, and again to the macro scale of the digital infrastructure. The Generator prefigures, with clarity and simplicity, the ubiquitous computing and artificial intelligence systems that today architecture is (re)introducing in its spaces through IoT technologies. This space, in fact, is no more just the place of physical relations between the users but it also hosts interactiveness moments, between the building and the users.

By adding to the (inter)action-reaction capability of the Fun Palace the infrastructural complexity of ATOM, Price and Frazer defined the first intelligent building. With its silent and invisible data megastructure, almost an ‘omnipresent intelligence’ (Price and Obrist, 2003), the Generator constitutes its visionary value around the realization of interrelation through interface systems. These elements can also be considered in their dual, physical and digital, value: on a hand, the building becomes an interface with the man who is called to confront it and with the crane system capable of moving the one hundred and fifty cubic units that make up the project, from one point to another of the foundation grid; and on the other, the employee of the White Oak Plantation, for whom the project is intended, uses a digital interface to communicate directly with Factor, the mobile mechanism of the crane. The official presentation of the Generator[9], which has been the visual reference of the project over the years, has been made with a physical prototype of the grid and modular units, an inventory to provide feedback on spatial configurations (use and position), a microprocessor to communicate with the structure (through a screen) and a recorder to store possible future configurations (Fig. 4). Thus, the question of learning reveals again its importance, together with all the characters that cybernetics had introduced (language, command, control and the ability – active and passive – to learn) and that are fundamental for all adaptive and reactive projects where the digital component is preponderant.

The intelligent system that defines the Generator is therefore endowed with the ability to learn: it has a memory system and the ability to process responses to external (user) stress as well as to redefine its limits or paradigms, through a continuous (generative) re-programming of transformation rules[10]. Finally, the system reaches the maximum autonomy of self-determination instead of the lack of interaction by users: if, in other words, the system does not receive any indication of movement within a given period of time, it can automatically generate, based on its experience, an adaptive response, and put it into practice through the mobile crane element (Fig. 5). The project reveals great potential in defining a very complex system that would lend itself well to reflections on the resilient purpose of adaptive architecture. In fact, combining the ability to store information and learn from it, with the possibility of acting simultaneously at



Figg. 4, 5 | Generator by Cedric Price, 1976-79: The working electronic model; Activity compatibility (credits: CCA Canadian Centre for Architecture, Montreal, ‘Cedric Price fonds, 1903:2006, predominant 1953:2000’, DR1995-0280-108 and DR1995-0280-651-004-007).


GENERATOR
SCALE
JOB
DRAWING
SK 021
Activity Compatibility
WALKING (alone)
SITTING (alone)
EATING (alone)
MEETINGS (WITH EATING) at INVITATION OF INDIVIDUAL.
BOATING
HORSE RIDING
WORKING (alone)
WORKING (with others)
KEEPING IN TOUCH. TELEPHONE / T.V. / RADIO / FILMS etc.
PHOTOGRAPHY + (Dark Room)
SINGING / INSTRUMENT (PRACTICE)
SINGING / INSTRUMENT (PERFORMANCE)
GARDENING / LANDSCAPE
DECORATING
SWIMMING
ENGLISH 'SNOOKER'
TABLE GAMES
PHYSICAL GAMES (TENNIS – SQUASH – FOOTBALL)
DRIVING
CONSTRUCTING PLACES.
LAZING IN SUN.
Compatible
Neutral
Non-Compatible
CP.
CEDRIC PRICE MA Cantab. ARIBA AA Dipl. ARCHITECT
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different scales according to different interfaces, foreshadows a perspective, a horizon, in which it is possible to delineate the shape of a contemporary architectural project capable of exploiting technological advancement following a computational process.

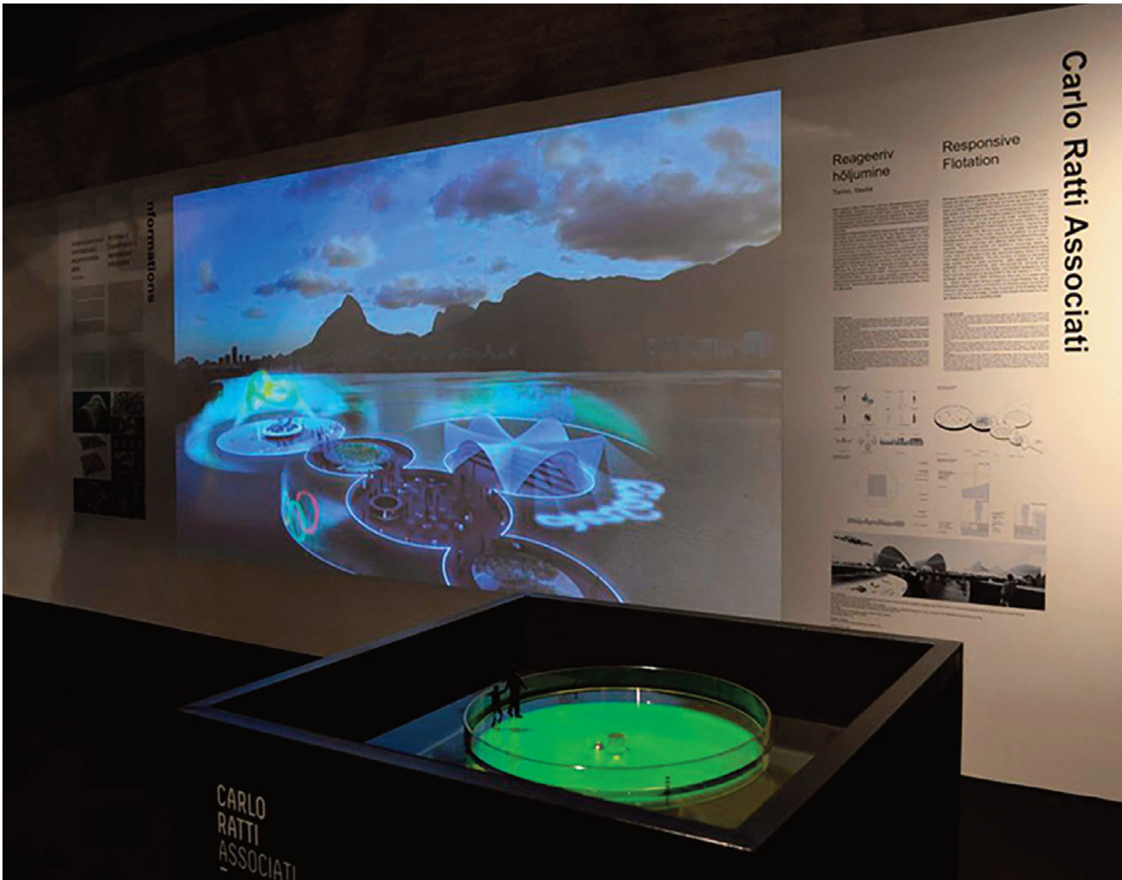
Currie Park and Responsive Flotation: experiments for adaptive structures | A different approach, instead, is shown in the project for the Currie Park Plaza, a part of the Masterplan for West Palm Beach (Florida, USA) developed in 2016 by the Carlo Ratti Associati firm (Fig. 6), whose construction should have been completed in 2018 but has not yet been completed. The Masterplan covers an area of nineteen hectares along Worth Lagoon and is expected to accommodate residential, commercial and low-density public space (Carlo Ratti Associati, 2016). What constitutes an interesting element, however, is the circular platform of the floating Plaza, straddling the water level and exemplifying the possibilities of applying adaptive digital technologies to a resilient purpose. The project is the result of researches conducted by the same studio in collaboration with the Senseable Lab of MIT and exhibited in 2015 with a prototype at the Architecture Biennale in Tallin (Estonia, EU) named Body Building (Carlo Ratti Associati, 2015).

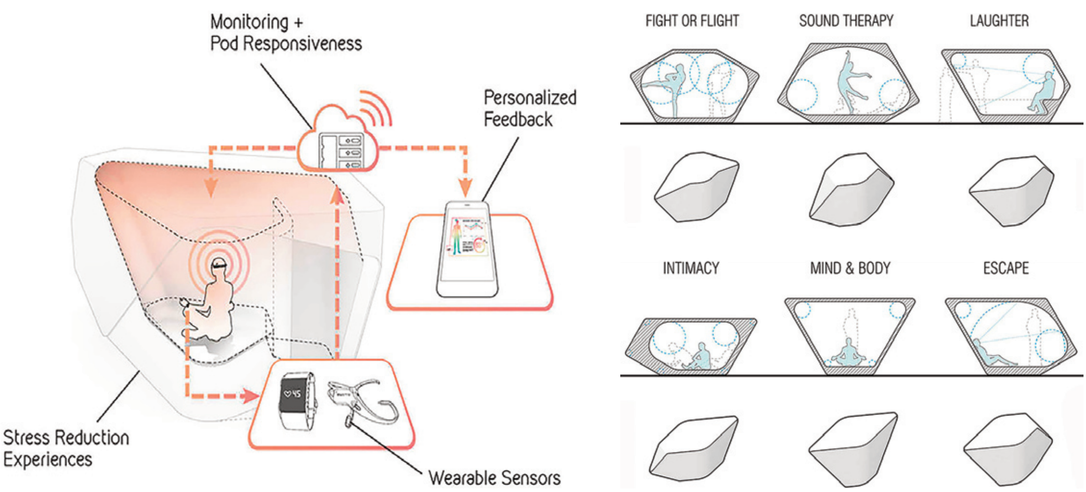
The prototype, called Responsive Flotation (Fig. 7), shows the operation of a floating platform that recalibrates its position in real-time, based on the number of occupants and other additional loads. The mechanism adopted is that of the submarines itself,

Figg. 6, 7 | Currie Park (Plaza) in West Palm Beach (2016) and Responsive Flotation Exhibition in Tallin (2015) by Carlo Ratti Associati (sources: carloratti.com).

which mutates the process of determining the equilibrium carried out also by the human body through the labyrinth of the inner ear. The actuators are therefore nothing more than a series of air chambers placed under the water level inside a shell, which open and close automatically, releasing or aspiring water as required. This allows the square to become a catalyst for activity, hosting public buildings, a restaurant, a swimming pool and an auditorium on the water surface.

This project shows us the adaptive architecture's propensity to intelligently process data, to put it into a system within a larger information network that can respond to phenomena such as rising water It is therefore interesting to read its potential, which certainly does not lie in the mere technology use, linked not only to the world of military naval engineering but also to a long tradition of construction on the water of which countries such as Holland are centuries-old references; the innovation brought by Ratti's project lies in the search for constant interactivity between the user, the environment and architecture. Making a public space accessible by overcoming the problem of the oscillation given by the unstable surface of the water, lays the foundations for a design that seeks a comparison with natural materials and adapts to them, modifying its spatial characteristics. Moreover, as the prototype Responsive Flotation had already made clear, the new stasis condition on the water's edge allows real-time monitoring of the natural elements through the collection of data on chemical pollutants, biological pollutants,





Figg. 8-10 | Reset by UNSense, Milan, 2017 (source: www.unstudio.com).

living conditions of plants and animals, temporal conditions, etc., all elements that can potentially be incorporated in the project and be useful for a future further definition. Once again, the interscalar potential of the adaptive approach, capable of creating links and relationships between materials belonging to different scales, can be noted.

Reset: the adaptivity of the human dimension | The last example gives a particular dimension at a different scale. Born from the collaboration between the Dutch studio UNSense (an experimental research unit of the architecture firm UNstudio, B. van Berkel) and the American architecture firm SCAPE (K. Orff), Reset is a modular and mobile unit conceived between architecture and design and created to provide customized space for stress reduction in the working environment[11] (Shelden, 2020; Fig. 8). It is made up by a series of small-scale architectural devices, real rooms, conceived in series according to modular modules and declined in six sub-themes or categories. The adaptability of the project lies in the response that each of these pods (the rooms) gives to the interlocutor, according to his specific physical needs.

Through the use of wearable technologies (head and heart sensors), able to detect the biological conditions of the user and to report the data to their reference pod, an adequate response is elaborated to favour the reduction of stress according to the specific theme of the space in which they are located. Reset (Responsive Emotional Transformation) is, therefore, presented as a device to rebalance, reorganize and reset (UnSense, 2017), showing itself as a study prototype for future devices useful in everyday life. The research carried out by UNSense, in fact, aims to explore the best blend of architecture and technology.

In addition, the data collected as a result of the application of these adaptive actions are communicated to the user who thus receives immediate feedback on their activity, as well as providing personal feedback. Especially in this project we see a double definition, physical and digital, of interactive action. If, on the one hand, the user is encouraged to experience the device through a sensory path, on the other hand, through the use of the de-stress app, he can retrace the path in digital form at a later time. Intimacy, Mind&Body, Escape, Fight or Flight, Sound Therapy and Laughter (Figg. 9, 10) are the six themes to which the six units correspond and that differ in terms of interior finish and spatial configuration, as well as the type of experience proposed. Also, in this case, it is possible to find some of the characters previously illustrated, which define complex and interconnected systems: among them, the different languages, in this case related to the senses, the control element, the feedback loop and the recursiveness of the modular feature. In conclusion, the algorithm measures 'the resilience of the user' to stress and identifies among its transformation possibilities the best method of resolution.

Conclusions | The comparative reading of the three case studies presented show the versatility of the results that an architecture capable of modifying its characters can tend to, keeping the interest for a resilient purpose. From this point of view, the theme of the scale of the project remains central and has to be understood more and more as a tool of the designer to implement and give value to his project. Designing with time and in a constantly changing space (both the physical space of the environment and the virtual and mental space) imposes a paradigm shift in order to create an architecture that is able to welcome a constant comparison between different scales, materials and practices.

From the three projects shown, therefore, there is a common divider in the mixture of the parts that make up the entire project and that are not limited to the technological elements, but rather to the dual reality lead by the introduction of the digital element. In this way, the multiscalarity, defined through the transversal relationships between the dimensional areas, is a necessary character of architecture. The dependence between the individual scales, in relation to the human component demonstrates the constant search for the interactive character of adaptive projects, both in their physical and virtual dimensions.

In all cases, however, the combination of material and immaterial characters allows an efficient interchange between the architecture project and the user who approaches it. Knowing how to establish a relationship between the different architectural components and the vast world of data is the challenge of contemporary architecture. Recent studies carried out at the University of Stuttgart, TU Delft and MIT, show a real and current interest in this field of research, which can lead to a real and fruitful integration in the architecture of reality, the digital one, which today has already spread widely in many areas of experimentation and production. This further shift of scale -the interaction of architecture with digital networks- allows identifying the last level, higher than the environmental Macroscale, that corresponds to the definition of resilient projects attentive to environmental dynamics.

Notes

1) The Smart City paradigm, which has spread rapidly among scientific communities in recent decades, refers to a Smart and Reactive City capable of integrating multiple levels of technology, information and communication, and managing urban practices. There is, however, a formal distinction between Smart and Intelligent Cities that attributes to the former the pure informational management of data and to the latter its organization and management in a network.

2) The first to speak about Responsive Architecture is the American computer scientist Nicholas Negroponte (1970) in The Architecture Machine, whose cultural heritage was recently collected by Tristan d'E. Sterk (2005). He showed the limit of Negroponte's definition as it does not yet include integration with robotics and artificial intelligence systems.

3) Among the reactive buildings that are now considered canonical, there are the Institut du Monde Arabe (J. Nouvel, 1980), the Blur Building (Diller & Scofidio + Renfro, 2002) and the Hyposurface (dECOi, 2016); among the adaptive ones, on the other hand, reference can be made to some of the winning projects of the Re-build by Design competition, including the Living Breakwaters (SCAPE, 2014) and The Big-U (BIG, 2014).

4) The classification of architectures capable of interacting at different scales with different levels of external agents allows identifying five categories: intelligent, interactive, reactive, adaptive and kinetic architecture. Each of these has different and unique relationships between the built, the user and the external environment (Elmokaden et alii, 2018).

5) In addition to the projects presented in the second part of the article as case studies, reference is made here to Bernard Tschumi's projects and experimental research realities in Stuttgart, the Institute for Lightweight Structures and Conceptual Design (ILEK) and the Institute for Computational Design and Construction (ICD) of the TU University of Delft and the Canadian Centre for Architecture.

6) Reference is made here to the volume entitled Cybernetics, or Control and Communication in the Animal and the Machine in which Wiener (1948) presented for the first time the relationships of correspondence and analogy between neuroscience and computer science, between the brain and the computer and therefore between neurons and bits of information.

7) A possible response to these phenomena began to take shape in the United States in 2012, following Hurricane Sandy, with the establishment of an architecture competition and the subsequent formal constitution of the group Re-build by Design, and the following year with the establishment of the group 100 Resilient Cities by the Rockefeller and Arup Foundation. Over the years, they both have set the goal of identifying strategies and designing projects capable of responding to future environmental and climate contingencies in a resilient manner. However, what emerges from the study of the work of these realities is a clear interest in intervening in a preventive manner on the urban fabric and soils and the practices of the citizens of the communities involved. An evident problem of scale is then outlined: we pass from the urban macro-scale to the small scale of the man to whom the practices are destined. Therefore, there is often a lack of in-depth analysis specifically referring to the intermediate scale of the building.

8) The project of the Generator was elaborated by Price starting from 1976 and only at the end of 1978 Frazer's consulting report became official. Moreover, although the project was completed in 1979, numerous writings testify a copious correspondence report until 1980 between the two, for a further definition of some aspects of interactivity of the Generator.

9) Between April and June 1980, the publications Building Design and RIBA Journal launched a long series of publications on the Generator that lasted until the following year, underlining the innovation brought by the 'first intelligent building' in history. In December 1980, however, an intervention by Price himself in the magazine Architecture d'Aujourd'hui entitled Au Delá du High-Tech, was necessary to underline the importance of the systemic complexity of the project, beyond mere visual characters (Furtado and Gonçalo, 2008).

10) Frazer's role in this sense was fundamental because it allowed the transition to an automatic-generative system based on the 'user- machine' dichotomy (Furtado and Gonalo, 2008).

11) The project was presented at the Salone del Mobile in Milan in 2017 (Work 3.0 – Joyful sense at Work); research funded by the Dutch Agency for Enterprises for the design and implementation of a prototype that applies the methodology of Reset in everyday situations is currently underway.

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