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THE ROBUSTNESS OF CITIES
2030 Contended Visions

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ABSTRACT
The Robustness of Cities – 2030 Contended Visions will tackle the main dominant factors of 2030 agendas of different governments and institutions. These multiple factors can sometimes present a form of rivalry. As in La Città Contesa (lit. The Contended City), where Zucconi describes how, after the unification of Italy in 1861, it was necessary to define a new approach to Italian cities and territories with a succession of dominant criteria along half a century, raising the necessity to hierarchize different competing factors. The essay will expose the Robustness Theory – developed by Japanese engineer and statistician Genichi Taguchi – and how it could be applied in architecture. By adopting the 3-phases methodology Combinatorial Architecture developed by the author as Director of the Research Lab Non-Linear Solutions Unit (NSU) at Columbia University, C.A., the contribution will approach some of the 2030 most relevant factors in New Cities, Smart Cities, Small and Smart Settlements as well as how to combine Human Atmosphere and Cultural Heritage, Technology**,** Sustainability and Natural heritage and how to mitigate the difference between priorities.

KEYWORDS
combinatorial, atmosphere, cities, architecture, robustness

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In La Città Contesa (lit. The Contended City), Zucconi (1999) describes how, after 1861, it had been necessary to define a new approach to the cities and infrastructure of the young country, Italy. The book exposes how, between 1865 and 1942, different factors such as hygiene, viability, military control, social housing, cultural identity could vary in time. For example, at the end of the 19th century, in Naples, urban transformations were driven by the topic of hygiene associated to real estate, similarly to the Haussmann's interventions vividly narrated in Le Ventre de Paris by Emile Zola in 1863 (Zola, 2009). In the following chapters, Zucconi exposes a sequence of historical moments in which the different factors change their value in time. A significant factor approved in Italy by the law 1908 was the emergence of Social Housing.

Similar turning-points have vibrantly animated the last century's architectural debate. In Programs and Manifestoes on 20th century Architecture written by Conrads (2002) in the late 50s, the author exposes a testimony that many of the master builders of this century have held passionate convictions regarding the philosophic and social basis of their art and visions. In chronological order, the most influential visions from 1903 to 1963 are: van de Velde and Loos about ornament, Wright in 1910 Organic Architecture, Gropius's program for the Bauhaus founded in 1919, Towards a New Architecture, Guiding Principles by Le Corbusier, the basic principles of Constructivism formulated by Gabo and Pevsner, Universal principles by Buckminster Fuller, Mendelsohn, Van Doesburg, Mies van der Rohe, El Lissitzky, and Kahn. There are also many collective or group statements, issued in the name of movements such as CIAM, De Stijl, ABC, and the Situationists.

Analysing differences and similarities of the 2030 agendas from governments and international agencies such as the UN, UNESCO, NATO, EU, different topics are listed, amongst which zero hunger, good health and wellbeing, education, affordable clean energy, industry, innovation and infrastructure, crime prevention and criminal justice, narcotics, drugs, statistics, the status of women, sustainable development, and built and natural heritage. When analysed together, how can these factors be compatible? The following paragraphs will explore the theme of Robustness and the 3-phases methodology Combinatorial Architecture (C.A.) as a tool to mitigate possible incompatibilities between all drivers.

Robustness | The idea of Robustness concerns a system that can merge different requirements and offer a set of solutions, partially absorbing possible incompatibility between criteria, despite any unexpected noises and perturbations. According to Kitano (2004), Robustness facilitates the evolvability of complex dynamic systems. Evolution, given enough time, might select a robust trait that is tolerant against environmental perturbations. The author affirms that developing solutions with a solid mathematical foundation that can realistically represent complex systems is a difficult challenge. For this reason, the research into non-linear dynamics, control theory and non-equilibrium theory is relevant. Besides this, capturing the essential structural complex-

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Fig. 1 | Robustness (credit: W. S. Y. Wang, 2005).

ity and heterogeneity of the systems is a critical feature that will be approached in the following paragraphs as Phase 1 – Creative Reductionism. Furthermore, the idea of Robustness is strongly present in business and management environments. According to Swan, Kotabe and Allred (2005, p. 1) «[…] With the increasing desire for products [as well as for building], suitable for widely varying markets worldwide, this study offers insight into capabilities associated with successful robust-design in the global environment. These robust-design capabilities (i.e., the possibility for success under varying circumstances or scenarios) are a potential organizational response to rapid change and uncertainty».

In the image Robustness of the Language by William S. Y. Wang (1976, 2004, 2015), Chair Professor of Language and Cognitive Sciences, Hong Kong Polytechnic University and Emeritus Professor at Berkley, the concept of Robustness appears as (Fig. 1). The image demonstrates how a word maintains readability as far as the proper factors are adequately settled. For example, the three fixed criteria: the first and last letters have to keep the same position in the original version of the word, as well as keeping the exact number of letters permits the achievement of a large variety of combinations. This idea can be defined as a kind of formula in which the level of freedom is N-3 Variables, where N is the number of letters, and -3 is the number of constraints. The first two are the correctness of the first and last letter position, and the third constraint is the use of the same letters, that further on in the text will be defined as Phase 2 – New Population of Solutions. This flexibility leaves open the freedom to fit other criteria or requests.

Transfer of methodology between Robustness theory and Architecture | The previous paragraph exposed the concept of Robustness based on the definition of some fixed variables as in the case represented by Wang: the initial and final letters need to

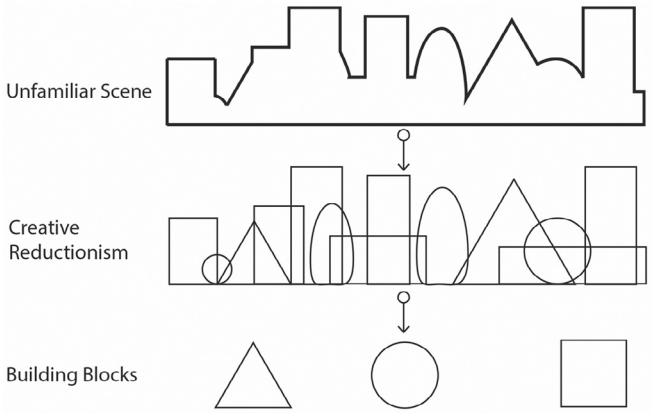
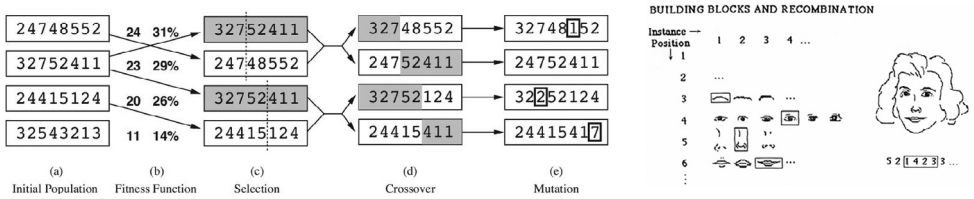


Fig. 2 | Phase 1 – Creative Reductionism (credit: C.Tiazzoldi, 2016).

be in the exact place, meanwhile, other parameters can achieve broader flexibility. This recalls Martì Aris (1993) definition of 'type' in architecture, where 'type' is a formal structure, an analytical key leading to the peculiarity and specificity of the project. This also permits to connect the research of Robustness to other fields such as philosophy, mathematics and linguistics. 'Type' exists from the moment in which the existence of 'structural similarities' is recognised – 'invariable factors' between architectural objects, beyond their differences on the most apparent and superficial level. 'Type' fosters the problem of form in terms of maximum generality (beyond eras and styles). 'Type' is not a mere classification; it describes differential features and establishes a 'classifier' of differences: 'Type' expresses the permanence of essential aspects and highlights the formal structures' variable character. Furthermore, Martì Aris's defines 'Type' as a structural mind-setting; such a fundamental tool can blend with the site and cultural specificities via a process of contextualisation.

The concept of uncertainty or factors adaptations recalls the Deleuzian notion of 'difference and repetition' (Deleuze and Patton, 2014): «Normally, the difference conceived of as an empirical relation between two terms each has a prior identity of its own ('x is different from y'). Deleuze inverts this priority: identity persists but is now a something produced by a prior relationship between differentials (dx rather than not-x)» (Smith and Protevi, 2018).

Combinatorial Architecture (C.A.) | Developed by the author as Director of the Research Lab NSU at Columbia University, C.A. is an educational and professional decision tool and heuristic device, assisting the decision-makers in fixing the priorities related to urban morphology, architectural design, functional, technological, or engineering problem. Combinatorial Architecture includes a method in which quantitative – predictable – and uncertain qualitative intangible and variable parameters (i.e., so-



Figg. 3, 4 | Genetic Algorithm and attributes manipulation to Create a New Population of Solutions by combining the different Attributes and Building Blocks (credits: J. Holland, 2008).

cial, physical, sensorial, cultural, and economic) lead to a structural adaptation, emphasising the concept of formal adaptation to include the intangible aspects of atmospheres. The objective of developing C.A. is to create a connection between specific expectations: functional, formal, aesthetic and also emotional. In fact, the method aims to include the design process, the impalpable conditions of urban atmospheres, with the capacity to influence our feelings. Making an urban atmosphere means creating an impalpable condition by executing a series of specific operations: spatial, geometrical, sound acoustic, and climatic. This operation signifies the qualitative feeling's transformation into the quantitative, the non-measurable into the measurable, and the intangible into the tangible.

From a methodological standpoint, Combinatorial Architecture process takes advantage of research carried out in other scientific fields. C.A. is a 3-phases process inspired by genetic algorithms. Phase 1 is the Creative Reductionism, Phase 2 creates New Populations of Solutions, and Phase 3 selects the Solution that better performs in a given context. Creative Reductionism recalls the 17th century Discourse on Method, Descartes (2019) and the late 60s Deleuze, G. and Patton, P. (2014) methodological guidelines in the field of philosophy, the 80s Munari (2017), Cache (1995), Mayne (2011) in architecture and urban design, Holland (1995), Nicolis and Prigogine (1992) Bertuglia (2000; Bertuglia and Vaio, 2005) as well as Jafari-Marandi (2017) in the field of sciences of complexity.

Phase 1 – Creative Reductionism. According to the Nobel Prize winner Prigogine, the transition from the determinist paradigm to the science of complexity implies a radical attenuation of the distinction between hard sciences (mathematics, physics) and soft sciences (biology, social sciences and architecture). Such a paradigmatic switch (Kuhn, 2012) blurred the limit between the subjective and the objective. In fact, after Boltzmann, Poincarré and Einstein, the sciences became subjective 'per se'. Hence, it is necessary to clarify the role of scientist and designer in every modelling process, a form of 'Creative Reductionism' according to Holland's definition (Holland 1995, 2000; Dye and Flora, 2015).

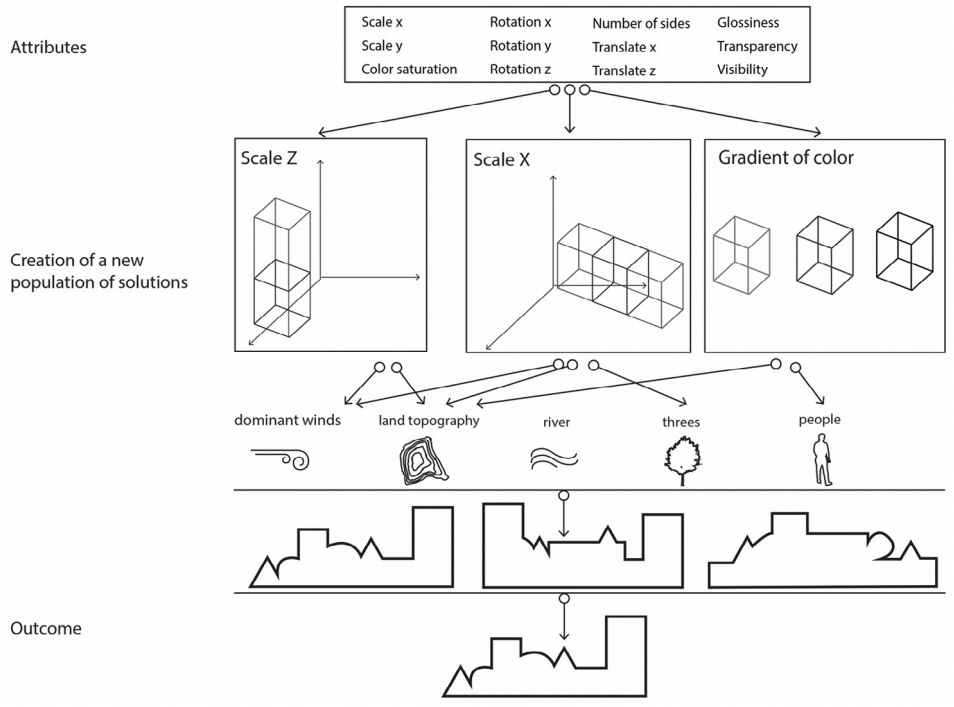
When applied to Cognitive Sciences, 'Creative Reductionism' consists in analysing some of the environmental conditions and in translating them into adjustable elemen-

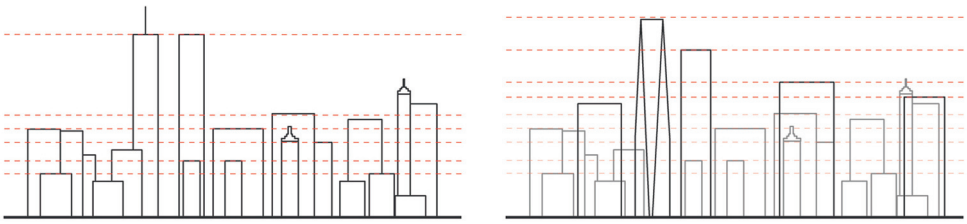
tary units: attributes and 'building blocks' – reusable categorical parts. According to Holland (1995), it is possible to fragment a non-measurable item into a set of numeric data and to identify the logic connecting them and transforming them, to change the non-measurable into something measurable such as trees, buildings, automobiles, other humans, specific animals, and so on (Fig. 2). This quick decomposition of complex visual scenes into familiar building blocks is something that computers cannot yet mimic; introducing then the need of a human factor which leads to a creative process, rather than a deterministic one. Inoue, Rodgers, Tennant and Spencer (2015), in 'Creative Reductionism' describe how decreasing levels of information can stimulate the designer's imagination. This recalls Kitano's statement about the impossibility to have a pure mathematical approach and emphasizes the need to reduce a model in structural elements. In literature, Italo Calvino (2016) approached his work with a form of creative reductionism; writing is 'reduced' into five properties: lightness, speediness, exactitude, visibility and plurality.

When applied to Architecture and Design, the phase of 'Creative Reductionism' consists in decomposing a given reality into a set of elementary units: walls, windows, openings, slabs and their attributes such as thickness, length, XYZ rotation, scale, position in addition to reflectivity, transparency, porosity and sound absorbance. 'Creative Reductionism' permits to approach a given problem by unfolding new fields of the measurable, an approach also shared by Munari (2017) when he refers to the four Cartesian rules to divide each of the difficulties under consideration into as many parts as possible and necessary for its adequate solution. Also, Safran (2016) in 12 Dialogical and Poetical Strategies recalls Calvino's Six Memos for the Next Millennium methodology to analyse architectural properties applied to architecture.

Phase 2 – New Population of Solutions. It is the process by which Combinatorial Architecture creates a 'new population' of possible solutions by associating the different attributes and building blocks, and by defining a variety of rules and a proliferation of similar units (Figg. 3, 4).

Phase 3 – Selection. The third phase consists in the Selection of the solutions that better fit with a specific context, in response to the most relevant factors for a given culture and physical environment as listed in the 2030 agendas of different countries. The result of the third phase is to drive the Solution from generic to specific. By recalling the Robustness theory «[…] Consider a wooden table with 4 legs, each with a diameter of 20 cm and a tabletop that is 10 cm thick. 10 people are sitting at the table, telling jokes and having a good time. Suppose that the uncontrollable factors such as bumping and pushing against the table hardly moves the table. The table can be called robust since the desirable table properties such as stability and maximum weight support appear not sensitive to the considered uncertainties. Consider a similar table, where the mentioned dimensions are twice as big» (Olieman, 2008, p. 1). This phase identifies those configurations, among the solutions tested, which can provide an appropriate correlation between the input and the possible Solution of an architectural





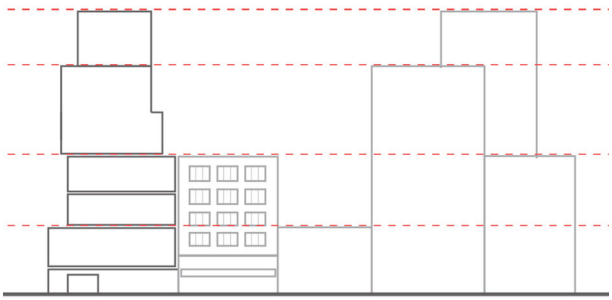


Fig. 5 | Combinatorial Architecture Phase 2 and 3 (credit: C. Tiazzoldi, 2008).

Fig. 6 | Creative Reductionism: analysis of the height variation in the New York Skyline (credit: C. Tiazzoldi, 2016).

Fig. 7 | Creative Reductionism applied to SAANA New Museum of Contemporary Art (credit: C. Tiazzoldi, 2016).

question and local priorities (Fig. 5). Ultimately, this phase focuses on the selection of the Solution that better responds to the qualitative or quantitative parameters defined by a given location, local priorities or resources.

The method presents several similarities in philosophy, for example in Descartes and Deleuze work. Descartes identifies four rules: «[…] the first is never to accept anything as truth which you did not know to be such; that is to say, carefully avoid precipitancy and prejudice and to comprise nothing more in one's judgement than what was presented to the mind so clearly and distinctly as to exclude all ground of doubt. The second cartesian rule 'the creative reductionism', is to divide each of the difficulties under examination into as many parts as possible. It might be necessary for its adequate solution – the creation of attributes and building blocks. The third 'creation of new populations of solutions', to conduct the thoughts in such order that, by commencing with the simplest and easiest to know objects, I might ascend little by little, and, as it were, step by step, to the knowledge of the more complex; assigning in thought a specific order even to those objects which in their nature do not stand in a relationship of antecedence and sequence. And the last, in every case to make enumerations so complete, and reviews so general, that you might be assured that nothing was omitted» (Descartes cit. in Watson, 2020).

For Deleuze, there are three rules: «1) Designation or denotation, which is the relation of a proposition to an external situation (theory of reference, with its criterion of truth or falsity). 2) Manifestation, which marks the relationship of the proposition to the beliefs and desires of the person who is speaking (with its values of veracity or illusion). 3) Signification or demonstration, which is the relationship of the proposition to other propositions (the domain of logic, with its relations of implication and assertion)» (Smith and Protevi, 2018). This method lends itself to address the work of architecture – also including some intangible aspects of architecture or some non-measurable qualities of the space – a topic that will be revisited in the next paragraphs and refers to the work on Ambiances and Urban Atmosphere initiated by the network Ambiances at the laboratory Le Cresson and including an international network of researchers, De Matteis (2019), Thibaud (2015), Tiazzoldi (2020), Tixier (2017).

The World Trade Centre and Twin Towers case studies in New York City are the first examples of the interpretation of an atmosphere with C.A. «[…] By this time, the Port Authority had decided that the trade centre should replace the 1,250-foot-high Empire State Building, built-in 1931, as the world's tallest building. To fulfil the Port Authority's requirement, architect Minoru Yamasaki designed two towers of 110 stories each» (History.com Editors, 2009) by applying the creative reductionism, outstandingness through the following equation: Outstanding = H1-H2, where H1 represents the height of the Twin Towers and H2 the average height of surrounding buildings (Fig. 6). The same set of variables (H1-H2) was used to achieve the opposite result in Daniel Liebeskind's project for the World Trade Centre. In the essay Ground Zero – The Socio-Political Minefield of Symbolic Architecture (Liebeskind and Cairns, 2013), the

Fig. 8 | Masdar City by Foster + Partners (source: www.fosterandpartners.com).

Fig. 9 | Masdar City by Foster + Partners: section (source: www.fosterandpartners.com).

Fig. 10 | South Sabah – Al Ahmad, section by Foster + Partners (source: www.fosterandpartners.com).

master plan and skyline were intended to merge the new project with the skyline of the city (Vinnitskaya, 2013). The design objective was to reach an 'unassuming' presence of the towers in the city. Oppositely to the Twin Towers, the 'un-assuming-ness' was achieved by strongly reducing the height difference (H1-H2) between the seven new towers and the surrounding buildings. With a small height increase of 100 feet per tower, the new skyline merged with the downtown landscape (Fig. 6). The case of the World Trade Centre shows the implementation of two opposite visions.

The New Museum of Contemporary Art designed by SAANA[1] presents two qualities almost incompatible: to be at the same time outstanding and unassuming. In other words, it is a building belonging to the Bowery neighbour and to the group of the tallest buildings in New York. The 'reduced' attributes are the building's absolute height, the relative height and the size of the intermediate partitions. The massing of the building is a sequence of polygons that respond to the surrounding buildings' rhythm. The horizontal partitioning and the horizontal dislocation on the 'x-axis', permit to perceive a vertical fragmentation, reducing the visual impact at the local scale.

The New Museum can be considered as an example of the Deleuzian concept in which, rather than the expression ('x is different from y'), the philosopher introduces the concept of variation and attributes modulation, described as (dx rather than not-x). The New Museum is an example where the idea of robustness and C.A. permit to merge two incompatible qualities of the project: being at the same time outstanding and unassuming (Fig. 7).

2030 Contended Visions: New Cities, Smart Cities, Broadacre City, Small Settlements, Smart Settlements | The previous paragraphs demonstrated that a Robust Design approach could overcome conflicts between factors. The 2030 agenda of several countries and agencies seems to conceal four main factors: massive urbanisation, safeguard of the cultural and intangible heritage, sustainability – preserving or creating an atmosphere of the city and biosphere – and hygiene – a topic that the Covid-19 pandemic has drastically reintroduced worldwide.

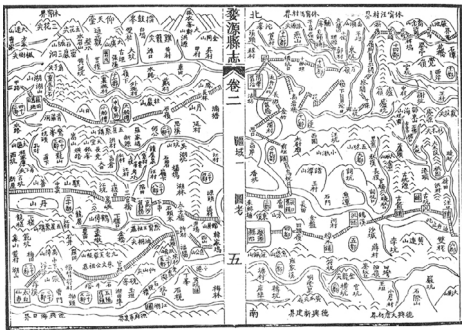
Massive Urbanisation. The beginning of the 21st century is characterised, especially in the pacific area, by a real need to design for massive urbanisation and the development of some rational often if not alienated abstract settlements. «[…] Between 2000 and 2018, the population of the world's cities with 500,000 inhabitants or more grew at an average annual rate of 2.4 per cent. However, 36 of these cities grew more than twice as fast, with an average growth of over 6 per cent per year. Of these, seven are located in Africa, 28 in Asia (17 in China alone) and 1 in North America. Among the 36 fastest growing cities, 25 have a long history of rapid population growth, with average annual growth rates above 6 per cent for the period 1980-2000» (United Nations, 2018, p. 7). This phenomenon is recurrent in different historical periods, like the

Fig. 11 | Urban Section by Nicolas Tixier, Video Installation (credit: G. Meigneux, 2017).

Roman Camps or Castrum between the 2nd and 1st century B.C. and during the industrial revolution. This massive urbanization required cities to provide a safe environment for the incoming population, as per the concept of 'zoning' by Tony Garnier (Garnier, 1918). Nevertheless, the massive housing and rapid urbanisation created relevant problems by transforming some city's areas into dormitories without any form of human atmosphere and often became an object of criminality.

At the beginning of the 21st century, the same question appeared in the development of Asia Pacific cities. If, in the beginning, the core issue was related to providing infrastructures, housing, hospitals, schools and universities, the topic of sustainability massively entered in the design of new urban settlements as per the case of Masdar City, developed by Foster + Partners. Masdar City was achieved by combining «[…] state-of-the-art technologies with the planning principles of traditional Arab settlements to create a desert community that aims to be carbon neutral and zero waste. The city is conceived as a centre for the advancement of new ideas for energy production, with the ambition of attracting the highest levels of expertise. Knowledge gained here has already aided Abu Dhabi's Estidama rating system for sustainable building. The masterplan is designed to be highly flexible, to allow it to benefit from emergent technologies and to respond to lessons learnt during the implementation of the initial phases»[2] (Figg. 8-10). The Masdar project is a revolutionary approach to the city from a sustainability standpoint, although it raises the issue «[…] to maintain the potential of the intangible components of daily urban life by transforming pure sensations in a design tool that can be elaborated with attributes and building blocks. These situations are defined by the need to move through the city, respect coding, queueing at the post office, sharing resources etc. Now, the question would be how to create a similar urban atmosphere; how to design new urban spaces allowing the connectivity to intangible heritage, creativity etc.» (Tiazzoldi and Elshater, 2020, pp. 199, 220).

For Francesco Bandarin, Special Advisor to the Director-General of ICCROM, Heritage is a priority and a guide in safeguarding the idea of collective identity. This issue also extends to maintain the potential of the intangible components of daily urban atmosphere (Bandarin and van Oers, 2015). In response to the topic and research on the urban atmospheres that the Laboratory CRESSON was founded in 1979. CRESSON is a centre focusing on time and culture-sensitive approaches to inhabited spaces. The research relies on original multidisciplinary methods at the crossroads between architecture, social science and engineering. With these considerations, nowadays, CRESSON's work questions social, ecological, aesthetic, numerical, political and ethical issues regarding the atmosphere theme and recently founded the International Ambiances Network[3]. It is in this context that Tixier (2017) developed the technique of the Transect Urban – Urban Section (Fig. 11) to represent and articulate the urban milieu components often considered separately: built objects, sensory realm and social practices. The increasing research of the quality of daily life is also visible in Foster's work in Masdar City and sections of the city South Sabah – Al Ahmad.



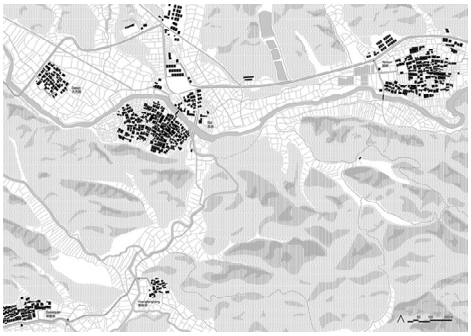


Fig. 12 | Map of Age from the Wuyuan Xanzhi (source: A. P. Pola, 2019b).

Fig. 13 | Topographical map of a tract of the rural landscape in Wuyuan county showing the villages of Datian (credit: A. P. Pola, 2019b).

Fig. 14 | Daily life in Sixi, Wuyuan county, 2018 (credit: A. P. Pola, 2019b).

The previous paragraph exposed the relationship between new settlements, hygiene and the urban atmosphere. According to Verdini and Ceccarelli (2017), while reporting the message of the Global Report Culture for Sustainable Urban Development, which UNESCO has coordinated for the UN-HABITAT III Conference «[…] Culture can play a fundamental role in fostering sustainable patterns of urban and regional development. The Global Report shows that a promising culture-based vision of urban development is flourishing in different forms in several cities across the world» (Verdini and Ceccarelli, 2017, p. 9) Even small and medium settlements located at the periphery of large cities or within their metropolitan areas, and generally associated with marginalization or deprivation, have the potential to fully utilise their cultural resources, in both tangible (urban and architectural heritage and cultural infrastructure) and intangible forms (skills, knowledge, competencies), as explored in Foster's case studies about radically new settlements. However, these small settlements and their communities require different analytical tools to understand their complexity, to develop ad-hoc policies and to manage their assets in a sustainable form.

This research report aims to show ways to understand Culture and Creativity in small settlements, by collecting a series of international case studies that form the backbone of chapter 10 of the UNESCO Global Report on urban-rural linkages and titled Culture as a Tool to Achieve Harmonious Territorial Development. The challenge

is to exploit smart technologies, initially envisioned in the sixties by McLuhan's (and Lapham, 1994) and Pierre Lévy (1997) with the concept of Collective Intelligence as well as Ratti's Senseable City Lab at MIT (Claudel and Ratti, 2015).

In fact, Pola (2019a, 2019b), a researcher at the World Heritage Institute of Training and Research Asia and Pacific under the Auspices of the UNESCO, affirmed that China's growing attention towards villages in recent years has contributed transforming the concept of built heritage and helped in disseminating a holistic idea of territory that has prepared the ground for the environmental turn the country is now experiencing. This conceptual transformation was carried on by several converging – although independent – initiatives from different governmental institutions and has been driven by multiple factors, of which the most important is the need to mend the development gap between urban and rural areas, and the wish to rediscover the cultural heritage of the country. «[…] The Chinese experience in village preservation was conceived as an important component of a much wider corpus of measures, driven by the rural revitalisation discourse, and should therefore be situated within this broader conceptual framework. This perspective leads to a distinctive approach to the concept of heritage and outlines a type of protection […] with Chinese characteristics' that will increasingly influence the international context» (Pola, 2019a, p. 64; Figg. 12-14).

Almost like a story, the map (Fig. 12) looks like a narration of the intangible heritage and human activity layering's, exposing like a poem the constructive details or tectonic inhabiting environments that can be still desirable for 2030 visions. «[…] The high walls surrounding the residence acted as firewalls protecting the wooden load-bearing structure as well as guaranteeing the safety of the family members – women, children and the elderly – left alone while their husbands and brothers travelled. The buildings, which usually consisted of two or three residential storeys on a relatively small plot of land, had […] private water gardens, wells and public pools structured the village's open spaces. […] The surrounding landscape is bounded by forest laden hills and mountains where tea plantations grow on relatively small plots of land. In the past, the management of the land and of its timber resources, which were so important for the local economy, was regulated by a complex network of ownership agreements that benefitted from a highly dynamic market governed by a business logic rather than traditional agroforestry practices» (Pola, 2019b, p. 171).

The previous idea to merge the reuse of the built heritage with new infrastructure and potential of smart-working (Pola, 2019a; Verdini and Ceccarelli, 2017; Bandarin and van Oers, 2015; Tiazzoldi, 2012) embeds multiple factors of 2030 agendas from different institutions. Although, younger generations are not yet ready for this step, as reported in a conversation between the author and Honchao Wang, Principal of the design firm Benwu Studio and a faculty member of Xian Jiaotong-Liverpool University. Educated in China, United States and Europe, and now working for local and international clients, the designer affirms that his international colleagues and clients often ask him why young Chinese generations do not desire to inhabit historical heritages.

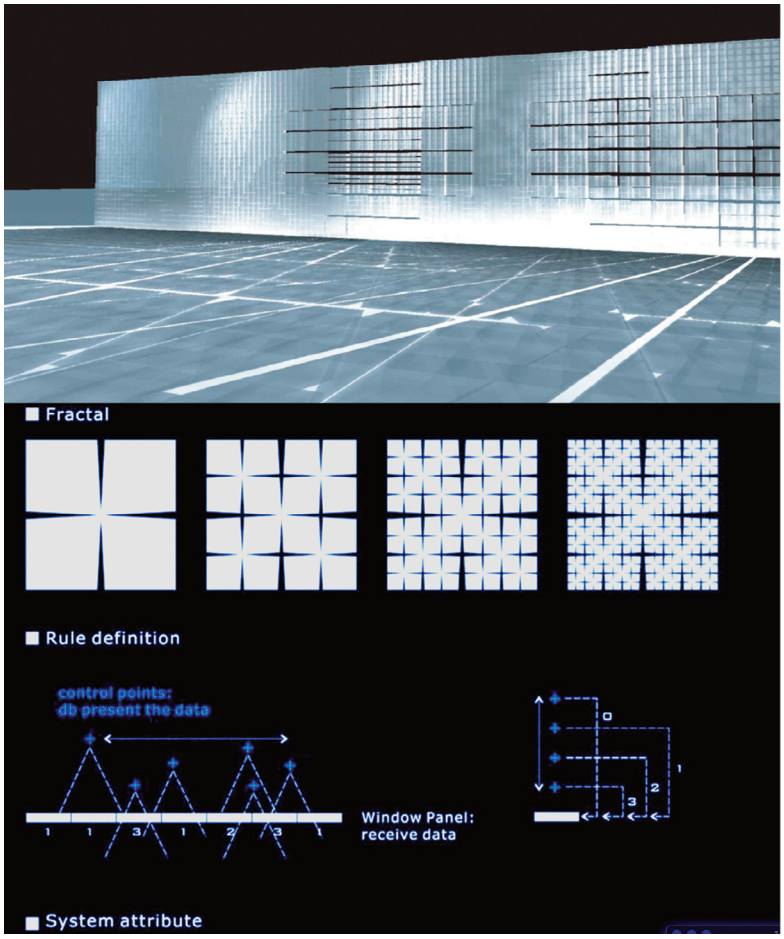


Fig. 15 | Northwell Health, Katz Women's Hospital and Zuckerberg Pavillion by SOM, 2011 (credit: E. Hueber).

Fig. 16 | Preparatory Drawings and Algorithmics by SOM and NSU – GSAPP Columbia University (credit: C. Whitelaw and C. Tiazzoldi, 2006).

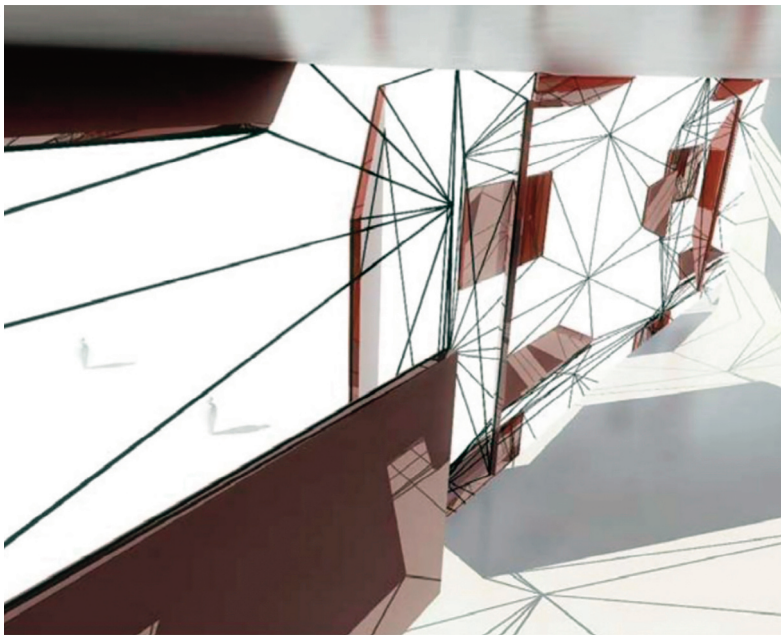
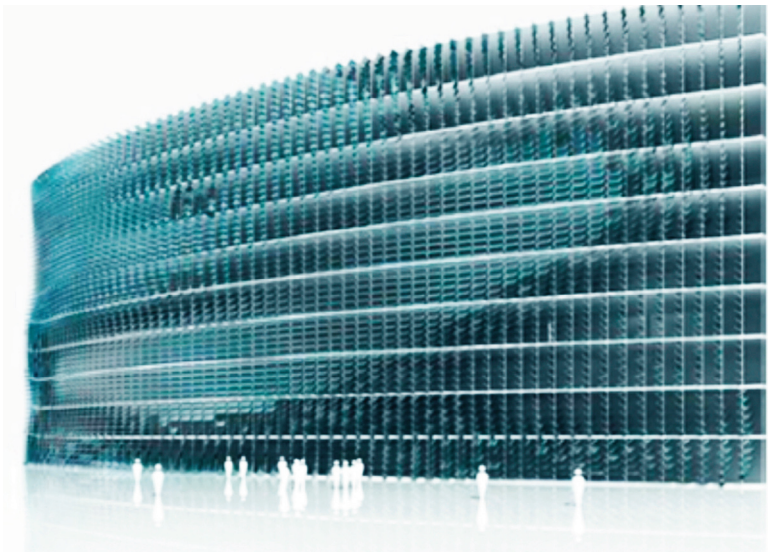


Fig. 17 | Diamond Shape with Solar Panels in the Centre by SOM and NSU – GSAPP Columbia University (credit: W. Tracy, 2006).



Figg. 18, 19 | Proposal of Po Chen algorithmic device modulating vertical glass partitioning and the shade requested by SOM and NSU – GSAPP Columbia University, 2006 (credit: P. Chen); Montage associating the vertical shaders proposed by Po Chen with the SOM final solution designed with vertical glass shaders, 2011 (credit: P. Chen, E. Hueber).

Nevertheless, he considers that his generation is not attracted to re-inhabit historical buildings, as what happened in Europe after the Second World War when the remembrance of poverty and the lack of hygiene were too strong to tempt communities to immediately re-inhabit historical heritages.

Technology and Tectonics | By recalling the topic of the need to build new habitats for the massive urbanization process, another question would be how to approach the relation between technology, habitat and local traditions. In fact, at the end of the 19th century, the impact of technology such as the first elevator installed by Otis in Chicago radically transformed Cityscapes world-wide (Frampton, 2007; Goodwin, 2001). Although, by introducing the topic of critical regionalism, Frampton in the early eighties criticised the risk of banalization of an architecture merely based on technology, non-relating to the site and culture or genius-loci (Frampton, 2007; Sassen, 1999). Such topic was recalled by Robert Maulden (1986) in his PhD theses Tectonic in Architecture – From the Physical to the Meta-Physical. There, he defines Tectonic as «[…] the science or art of construction, both concerning use and artistic design. It refers not just to the 'activity of making the materially requisite; construction that answers certain needs, but rather to the activity that raises this construction to an art form'. It is concerned with the modelling of material to bring the material into presence: from the physical into the metaphysical world» (Maulden, 1986, p. 1; Frampton, 1995). In this regard, this concept has been interpreted in different historical phases and contemporary exploration, including 2030 visions. For example, in the sixties, the Pritzker Prize winner Louis Barragan exploited the cement sharpness to emphasize the uniqueness of Mexico sunlight. Local temperatures and moderated rains also permitted to avoid some window framings, thus making sunlight even crisper, and embedding the attributes of the territory.

Similarly, in the 1930s, Konrad Wachsmann (1995) approached with a completely new language the wooden structures. He addressed the traditional US Balloon Frame with a contemporary language and plans. Wachsmann demonstrated how new forms can be achieved when modern manufacturing processes are adapted to traditional building material such as wood. Similar manipulation of a set of technological attributes was developed by the author with a group of students in the context of the Columbia University studio Formal Modulation for Light Mitigating in collaboration with architecture firm Skidmore, Owing, Merril in the project Northwell Health, Katz Women's Hospital and Zuckerberg Pavilion (SOM, 2011). The goal of the research directed by the author (Tiazzoldi, 2008) was to create a direct connection between advanced computational design techniques, studied in an academic setting, and professional reality (Figg. 15, 16).

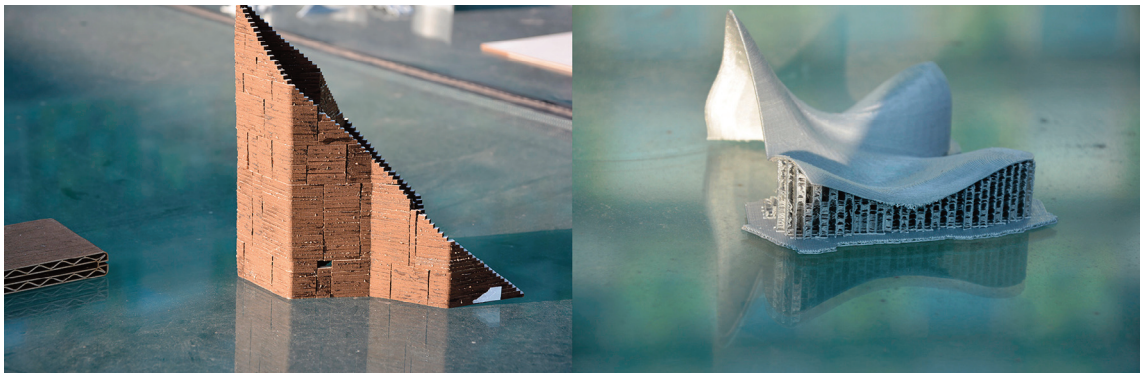
Each project developed by the students focused on the qualitative and quantitative understanding of algorithmic responsive devices applied to the constructive reality of façade systems. A curved glass façade with appearance – rhythm, frame partitioning

Figg. 20, 21 | Real Scale 3D Printing resolution by Winsun: 21 Winsun Office in Dubai (credits: Winsun).

and size- reflects the diverse functions housed in the building. The goal of the project was to explore the capacity of architecture to answer specific environmental requirements through the use of responsive algorithmic devices. In the case of Northwell Health, Katz Women's Hospital, the algorithmic attributes' manipulation was finalized to modulate the shade in relation to the organizational plan and room requirements: single-occupancy birthing suites, rooms for overnight stays for new fathers, large lounges for additional family members.

By applying the Combinatorial Architecture methodology, the researchers isolated a series of attributes with the goal to produce a digital model having the capacity to quickly adapt to the possible design variations. Projects were not conceived to be dynamic once built. Williams Tracy developed a system of diamond shape windows embedding solar panels in the centre (Fig. 17). Tracy's variable attributes were the level of extrusion of each window, that could create some kind of loggia, their size, and the size of the solar panels. This permitted to control how much shadow was required in each room and to augment the energy efficiency of the building. The proposal of one student Po Chen was based on vertical glass panels as shaders: the variable attributes were the spacing and rotation of the shader according to the rooms' functions. In the final solution realized by SOM in 2011, it was possible to identify some of the attributes of both proposals: Tracy's loggia type windowing system with variable size to fit different functions and Po's vertical glass shaders with variable partitioning (Figg. 18, 19).

The following paragraphs address how C.A. and Robustness can support research in innovative materials while managing economical and logistical the risk of full-scale prototypes applied to the relationship between architecture and Computer Numeric Control (CNC) full-scale production. Combinatorial Architecture and Robustness permitted to verify and identify similar and repeatable parts between small, fast prototyping machines and how 3D printing can affect the relationship between the material tectonics' and new forms of the liveability of the space. Printed Spaces was a master



Figg. 22, 23 | Printed-Spaces (credits: A. Zuccolo and B. Who).

studio lead by the author with a group of students of Printed Space in the second year of their Master's programme at Xian Jiaotong-Liverpool University.

The brief challenged how the potential full-scale Computer Numeric Control Techniques (CNC) could share some attributes of fast-prototyping, considering that full-scale prototyping had limited accessibility from a technical and economic standpoint. By adopting the method of Swan, Kotabe and Allred (2005), the students explored which attributes of a model realized with a fast-prototyping machine could reflect the state of the art of full-scale 3D printing (Figg. 20, 21). This research studio enabled students to research how full-scale 3D printing could develop new tectonics. At this time, full-scale 3D printing was mostly used to emulate traditional or high-tech buildings (Stott, 2015). This research, developed in 2016, explored new languages as a kind of 'brutalism' deriving from the properties of the material itself (Figg. 22, 23). For example, by slowing down the machinery speed and cooling process, and by simulating the type of CAD-CAM trajectories that the full-scale production would allow, rapid-prototyping started to acquire some of the 'melting' qualities of the real scale 3D printing extrusion process, somehow behaving like a gigantic toothpaste. Such a combinatorial approach permitted the creation of an exciting analysis: the structure developed with the small-scale 3D printed model enabled the production of new tectonic potential.

In the following paragraphs, the author will explore how the previously mentioned human factor Kitano, Holland, Swan can provide a positive variation of the idea of tectonic as esprit du lieu, consisting in the integration of the population into the construction and learning processes. An example is the project Za'atari Classroom launched by NGO Emergency Architecture and Human Rights[4] (Figg. 24-26). The technique the project chose was one familiar to many Syrians, selecting a combination of the Superadobe technique – a NASA and UN approved home building method which uses filled sandbags, barbed wire and traditional beehive vernacular techniques seen in Africa and the Middle East, similar to the techniques used to construct the

Figg. 24-26 | Classroom (Za'atari, Jordan) by Emergency Architecture & Human Rights, 2017 (credits: M. Rubino, 2017).

Great Mosque of Djenne in Mali. The design is conceived to ensure that structures retain up to 5 °C of heat in Winter and are 7 °C cooler than outside in Summer. The case study showed how the integration of human factors, rather than being a limitation for the execution of a building, enhancing its design robustness. It provided the possibility to access to local materials and the use of technics familiar to the local population, together with the intensification of the sense of belonging to the community. Ironically, all these factors, from an engineering standpoint, could be a cause of perplexity about the perfection of buildings' final execution. Therefore, robustness aims to maintain a certain level of control, deriving from the repetition of well-known tools or building blocks, while tolerating mistakes, innovation and human factors.

The case of the Fass School and Teachers designed by Toshiko Mori adds a new variable in the participatory architecture process. It combines some traditional attributes of space and local materials with innovative procedures and shapes. «[..] In the design, four classrooms and two flexible spaces are arranged around an interior courtyard. The oval shape fosters easy circulation between classrooms, allowing the schools' teachers to move quickly between classes. The variation of the perimeter walls in terms of height and proximity to one another creates a wide variety of sections and experiences through the building. Fass School's shape was inspired by vernacular precedents, while its construction utilized local, traditional skills and materi-

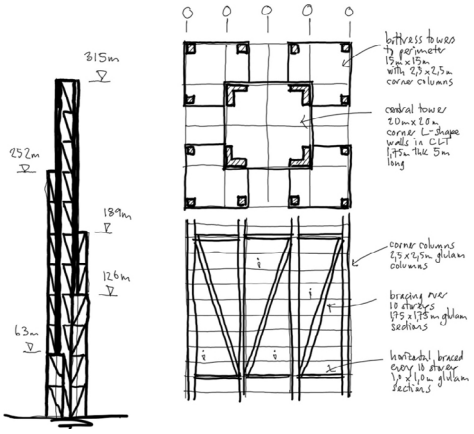
als. The local construction team was provided with instructional diagrams to assist with the sequencing of the structure's precise geometry – community involvement throughout every phase allows for easy maintenance over time. Small steel members and bamboo support mud-brick walls were used, which were painted white to deflect heat and perforated to allow for ventilation and airflow throughout the building. An inversion of the traditional pitched roof, the thick thatch roof, reinforces climatic comfort by providing effective insulation against extreme heat. A stack effect allows hot air to rise into the peak of the roof while inviting cool air into the spaces. With a roof pitch consistently 45 degrees or greater, the unique form also maximizes rainwater runoff, diverting water into a channel that encircles the building and empties toward an existing aquifer» (Mori, 2019; Figg. 27, 28).

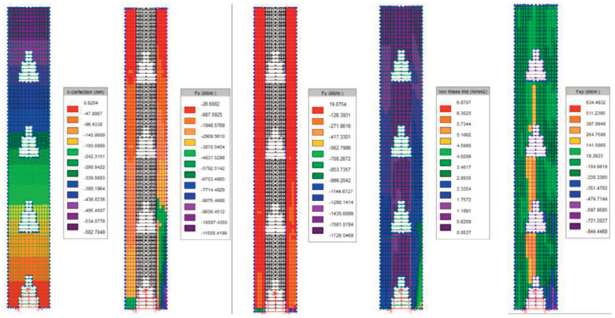
The case study of Za'atari Classroom shows how different factors were embedded into the relationship between technology, construction and expatriated community while privileging a traditional shape to recall their visual references and therefore the feeling of belonging. The example of Fass School and Teachers' demonstrates an interesting possibility to merge traditional and innovative shapes. By recalling Wang, Ke and Minett (2004) in Computational Studies of Language Evolution, Mori case study shows the opportunity to create an evolving language that enhances programmatic transformations – for example, the roof between the buildings creating a shaded public space. This prevents a stylistic crystallization or what Francesco Bandarin, would define as a folkloristic approach (Bandarin and van Oers, 2015; Ceccarelli, 2016).

Sustainable Energy Built Heritage and Human Atmosphere | Since early 2000, several countries' programs focused on the integration in the historical urban setting of sustainability, renewable energies and circular economy. In 2009, the Scottish and Irish Governments launched a campaign for the conservation and management of the

Fig. 27 | Fass School and Teachers' Residence (Fass, Senegal) by Toshiko Mori Architect (credit: I. Baan, 2019).

Fig. 28 | School and Teachers' Residence (Fass, Senegal) by Toshiko Mori Architect (credit: I. Baan, 2019).





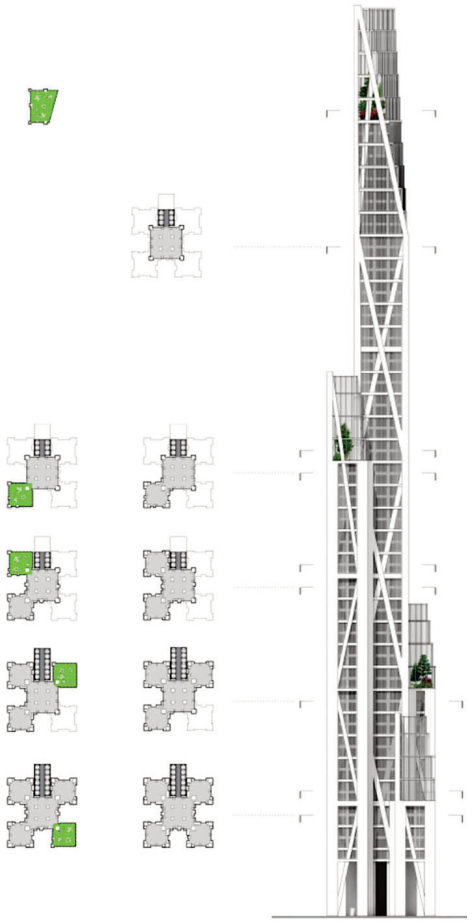


Fig. 29 | The Oakwood tower in London the notional site for the Oakwood tower, London's Barbican (credit: PLP Architecture); 3D finite element model for the crossed I-beam structural solution (credit: Smith and Wallwork); Buttressed mega-truss (credit: Smith and Wallwork); Floor plans at various levels highlighting sky gardens and core (credit: www.dezeen.com, 2019).

historic environment which contributed directly to sustainability in several ways (Changeworks, 2009). This included the energy and materials invested in a building, the scope for adaptation and reuse, and the unique quality of historic environments which provided a sense of identity and continuity in a period of rapid social and economic change. The report describes how the insertion of solar panels in the historical Dublin Downtown does not excessively affect the city landmark if done by studying a clear perspective. Oppositely, Cesare Sposito (2019) exposes an analysis on how a timber structure can become a landmark of the city, respecting bio-economy, circular economy, land use reduction, sustainable use of natural resources, reduction of CO_2 emissions in the atmosphere and recycling. Among the case studies cited by Sposito, the PLP Architecture (Fig. 29) unveils London's first timber tower showing the possibility to merge a building belonging to a sustainable cycle in London Cityscape. In a nutshell, Sposito explores the possibilities of timber as a sustainable building material throughout its whole life-cycle.

Natural Heritage, MAB and Human Atmosphere | The previous paragraphs analysed the possibility to integrate circular-economies and renewable suppliers' energy into the built heritage. The next paragraphs will question the relationship between massive renewable energy providers and the potential conflict they can create for the biosphere and human and wild environments. They spatially compete with agriculture and threaten wildlife. For example, desert tortoises were displaced by a solar plant in California's Mojave Desert and birds were burnt off by heat from the solar farm's mirrors which simulated a lake effect image from high up. Furthermore, these farms cause a landscape transformation, affecting the landscape perception for the whole population.

For this reason, UNESCO (2019) created the MAB Programme (Man and the Biosphere Programme), an intergovernmental scientific programme that aims to establish a scientific basis to enhance the relationship between people and their environments. MAB includes a series of biosphere reserves – 100% powered by renewables energies – to promote sustainable development based on local community efforts and government, science and knowledge: El Hierro, Jeju, the Galapagos Islands, Grosses Walsertal, Pellworm, Altaisky and the Lakshadweep Islands, as well as new initiatives at World Heritage sites such as Edinburgh and Aldabra Atoll. Also, MAB combines the natural and social sciences to improve human livelihoods and safeguard natural and managed ecosystems, thus promoting innovative approaches to economic development that are socially and culturally appropriate, and environmentally sustainable, usually disseminated in the occasion of the Renisla Forum. The Renisla Forums discuss key issues, including energy self-consumption and green building, sustainable electric mobility, renewable water strategies and collaborative opportunities with Africa.

In occasion of Renisla Forum 2014, the author was invited to present, as an example of good practice, the Whirlers project that she developed in collaboration with Duarte. Renisla 2014 took place the MAB site of El Hierro in the Canary Islands in

Figg. 30-32 | Wind Turbines and water reservoir, Gorona del Viento, Spain (credits: Renisla, 2014).

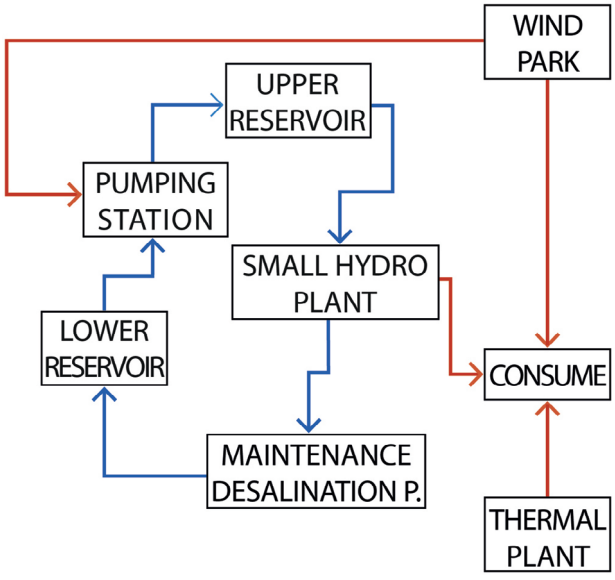


Fig. 33 | Scheme of the power exchange between Wind Turbines and Water reservoir, Gorona del Viento, Spain (credit: Renisla, 2014).

the occasion of the launch of the project Gorona del Viento: «[…] a wind-hydro system of a wind farm (11.5 MW), two water reservoirs, a pumping unit, hydropower plant, and seawater desalination plant. The wind farm supplies electricity directly to the network, and excess power feeds the pumping unit, raising water to a higher reservoir dam, which works as an energy storage system. The power plant uses the stored potential energy, ensuring power supply and network stability. The operation's philosophy is based on supplying the electrical demand of the island with renewable sources, thus guaranteeing the electrical network's stability. The diesel engine plant will only operate in exceptional or emergency cases when there is not enough wind or water to produce the required energy. This wind-hydro project will avoid the annual consumption of 6,000 tons of diesel, equivalent to 40,000 barrels of oil imported by sea to the island, saving over 1.8 million euros yearly if compared with conventional power generation costs»[5] (Figg. 30-33).

Whirlers is a visionary proposal which integrates sustainable energies with the public realm. For this reason, Whirlers was conceived to create a playful environment combining sustainable energy and public space. Its design consists of a micro-eolic plan that needs little wind for activation and therefore can fit different landscape types. The concept consists of a three-dimensional grid of Darrieus turbines (vertical-axis wind turbines with the main rotor shaft arranged vertically). Whirlers results from an implementation of the C.A. methodology in its 3-phases approach: Creative Reductionism, New Population of Solutions, Selection of the solutions better fitting with local factors (Fig. 34). It enables the adjustment and association of physical and measurable spatial attributes (scale, length, colour of wind turbines) to achieve a range of different public space typologies (with various thermal, chromatic, and density qualities) through the manipulation of rotational and relative distance values between specific building blocks (wind turbines; Fig. 35). Whirlers is still considered an excellent teaser to stimulate and propose a power plant that engages the public realm, integrating two factors that are usually incompatible: it can generate unprecedented types of public spaces applying the C.A. and to associate the physical and qualitative properties of public space with the quality of a renewable energies plant (Fig. 36).

Conclusions on long-term Robustness | Throughout this report, the author exposed how Robust Design and Combinatorial Architecture can mitigate and modulate the contrast between different visions and goals. The various case studies presented an increasing level of robustness deriving from integrating intangible qualities, human factors and the community feeling of belonging. The author has then exposed how the use of traditional techniques facilitates local populations to repair their buildings. Last but not least, the possibility to variate the forms with the same technology enables the adoption of new geometrical schemes and functions, preventing an over 'folkloristic' approach (Ceccarelli, 2016; Bandarin and van Oers, 2015), while maintaining the architectural flexibility of the 'type' described by Martì Aris.

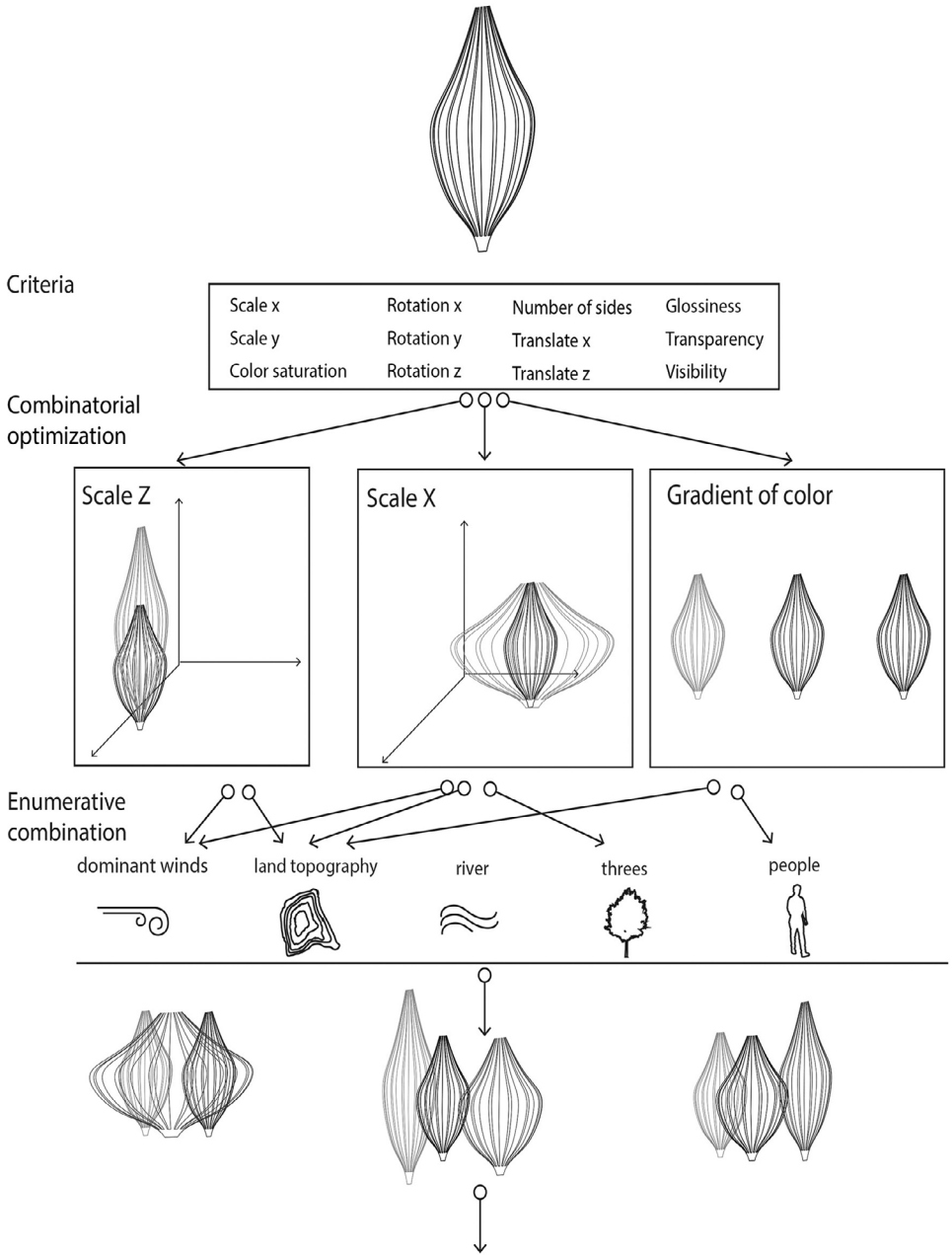


Fig. 34 | Different phases of the combinatorial method applied to the definition of a wind turbine population in the landscape: 1) creative reductionism; 2) creating a new population of the solution by adjusting the attributes and building blocks; 3) selecting the solution that better fits with the physical and sensible factors (credit: C. Tiazzoldi and E. Duarte, 2014).

Fig. 35 | Adaptation of the Scheme into Different Landscapes, Whirlers project by C. Tiazzoldi and E. Duarte (credit: C. Tiazzoldi, 2014).

Fig. 36 | Whirlers render by C. Tiazzoldi and E. Duarte (credit: C. Tiazzoldi, 2014).

The methodology cannot yet incorporate all the variables, as per the case of the designer Honchao Wang exposing the reticence of young generations to re-inhabit small settlements even if supported by smart technologies and infrastructure. For this reason, the idea of long-term Robustness was approached by a group of researchers at the Santa Fe Institute (Trancik et alii, 2005) and by Oilman (2008). This Robust long-term planning became relevant to mediate between the community's desires at a given time and long-term plans, permitting in this way history to sediment visions on the memories and lands. Robust or Combinatorial Approaches cannot manage and mediate all diversities in a short time frame. Nevertheless, the case of William Wang

demonstrates that it is possible to handle a consistent level of changes or noises having the flexibility to manage all the variables, thus leading to an optimal solution compatible with the uncertainty deriving from long-term visions.

Notes

1) More information at the webpage: archdaily.com [Accessed 23 December 2020].
2) More information at the webpage: fosterandpartners.com/projects/masdar-city/ [Accessed 23 December 2020].
3) More information at the webpage: ambiances.net/?fbclid=IwAR1IuUSTuLhnR3jMheq7JqW1MgW9OKZJupcQbbL8uz2GjAtZCvOGcL__EFw [Accessed 23 December 2020].
4) More information at the webpage: ea-hr.com [Accessed 23 December 2020].
5) More information at the webpage: goronadelviento.es/ [Accessed 23 December 2020].

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