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Parametric Urbanism: A New Frontier for Smart Cities

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Abstract

In public opinion and on international political agendas the phenomenon of Smart Cities is fast becoming an innovative response to the need to increase the efficiency of tomorrow's cities: improving their performance and diminishing the resources they consume. The wealth of information and real-time data provided to the study of urban phenomena by new technologies (mobile phones, urban CCTV, networks of sensors, satellite navigation, digital control panels, GIS, Wi-Fi, smart grids, etc.) is rarely employed in a systematic and selective manner, and even less so by architects and urban planners. There is a sense that innovations in ICT move faster than our ability to find a use for them.

A new frontier of research within this scenario may be represented by the utilisation in urban design of parametric software, in other words, digital tools used to generate form as the result of the adaptive logical processing of selected information and data. With parametric platforms design does not offer a univocal response to a group of pre-established conditions, but instead becomes a dynamic model able to rapidly respond to input provided by the designer.

This paper delineates a possible line of research that applies the techniques and methodologies of parametric design in the field of urbanism. The aim is not only that of generating simulations at the urban scale of events in the fields of architecture and design, but also of assisting planners and public administrations involved in processes of decision-making related to the development of urban planning instruments.

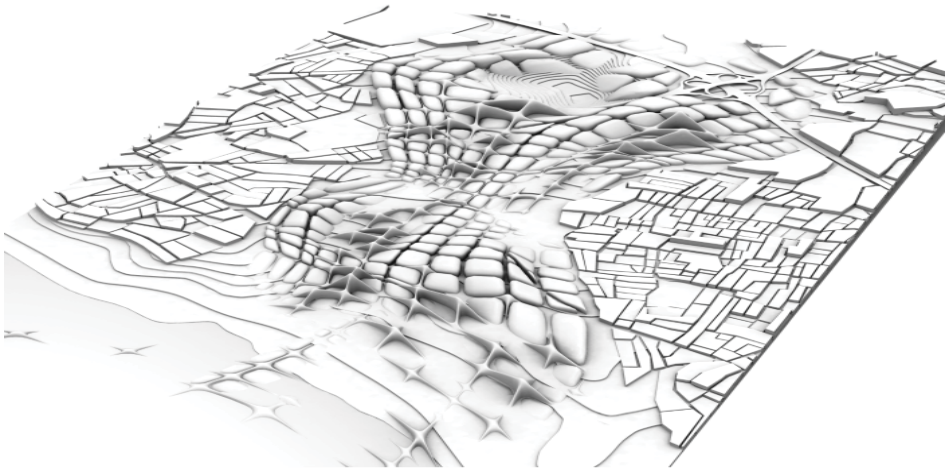

Figure 1. Kartal-Pendik Masterplan, Zaha Hadid Association, 3D model

In only a few short years the concept of *Smart Cities* has evolved from an evocative representation of futuristic digital metropolises into an overblown term used to indicate all manner of virtuous processes: economic, environmental, technological, social, etc. It now appears that any human activity we wish to qualify in positive terms cannot avoid being tagged with the adjective "smart".
This induces a reflection: on the one hand the fact that *smart thinking* applied to cities and territories is becoming "trendy" can be considered positive as it contributes to raising public awareness about such issues as environmental sustainability and technological innovation. On the other hand, the *smart phenomenon* induces a form of disorientation for the abusive use of the term and the consequent dilution of its importance to research.

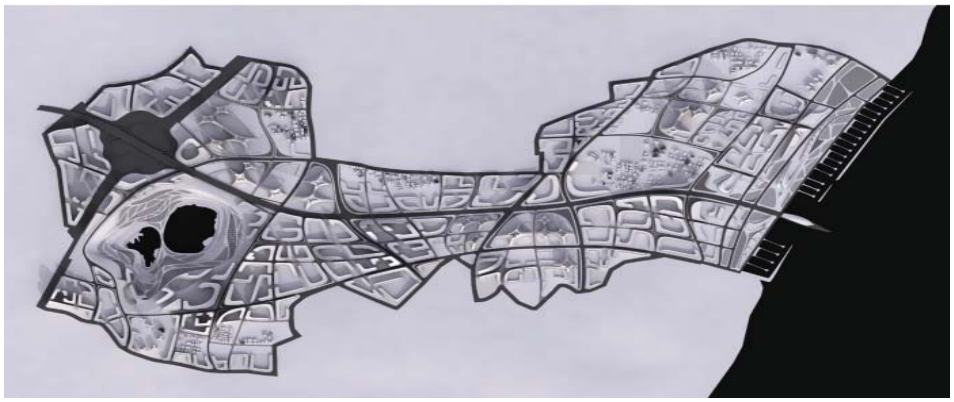

Figure 2. Kartal Pendik Masterplan, Istanbul, Zaha Hadid Architects

The *European Smart Cities*[1] inter-university project, focused on defining the concept of *Smart Cities* and elaborating a ranking of "intelligent" European cities, utilises the term smart to refer to cities "*well performing in 6 characteristics: 1) Smart Economy 2) Smart Mobility 3) Smart Environment 4) Smart People 5) Smart Living 6) Smart Governance*". Such a vast definition provides an understanding of the degree to which this theme has expanded since the early reflections presented at the end of the 1990s by W.J. Mitchell in *E-topia*[2] on digital networks and the changes induced on the cities of the future by innovations in ICT.
Recent branches of research into *Smart Cities* have been enriched by a new frontier: the application of parametric design to the development and management of the city. Examples can be found in the experiments of Zaha Hadid Architects in Istanbul (*Kartal Pendik Masterplan*), those of Carlo Ratti in the desert of Riyadh, Saudi Arabia (*King Abdullah City Masterplan*), the housing project in Seoul by Urban Future Organization (*Voronoi City*), the research being conducted by Patrick Schumacher in the *Design Research Lab* at the Architectural Association in London, and, finally,

1 European Smart Cities project, http://www.smart-cities.eu/, Centre of Regional Science at the Vienna University of Technology, OTB Research Institute for Housing, Urban and Mobility Studies at the Delft University of Technology and the Department of Geography at University of Ljubljana.

2 W. J. Mitchell (1999), E-topia: Urban Life, Jim – But Not As We Know It, MIT Press, Massachusetts. According to Mitchell, smart places are those spaces where "where the bits flow abundantly and the physical and digital worlds overlap, at points where we plug into the digital telecommunications infrastructures". In turn these spaces are inhabited by smart people, that is, "people capable of benefiting from the potentialities offered by new technologies, with elevated levels of flexibility, capable of concentrating their creativity and talent on producing innovation".

various experiences being pursued by international research teams.

Figure 3. King Abdullah City Masterplan, Carlo Ratti Associati

From our point of view, a less explored, and thus even more interesting frontier, is that which can be defined as *Parametric Urbanism*. In other words, the use of parametric software in urban design, not only to three-dimensionally represent projects at the urban scale (as the abovementioned examples), but precisely as part of the processes of developing the tools of urbanism, as an instrument for assisting the planner in evaluating diversified scenarios and making informed decisions.
For example, it would be interesting to understand what contribution can be made by parametric *tools* to the construction of effective models of compensation (options on permutations, flexible distribution, etc.), or what assistance they can bring to the rationalisation of the layout of services within a territory, based on the real needs of users and surpassing the quantitative regulations imposed by Italian Ministerial Decree 1444/68 (Town Planning Standards). Or further still, the simulation of alternative scenarios to urban transformations based on a choice of diverse building typologies or densities of inhabitation (for example, the effects of the application of the *Decreto Sviluppo* in Italy and its volume bonuses). Or, the optimisation of diversified infrastructural options: viability, parking, mobility, etc.
Let us proceed in steps. We will begin by clarifying a few key concepts of parametric design.

From Typological to Procedural Thinking

The use of the computer in the world of design has accelerated a direction of research culturally rooted in the avant-gardes of the 1960s. This branch recently arrived at the elaboration of theoretical apparatuses constructed around a notion that compares architecture to systems in evolution and mechanisms of self-regulation. The research focuses substantially on the pragmatic passage from the concept of the *type* to one of *process*. This involves overcoming the logic of composition to the advantage of a "neo-positivist" vision founded on a multiplicity of interconnected elements (objects, materials, data). Through a propagation of effects, the variation of one single element can bring about a modification to an entire architectural or urban organism. Hence the final form is an output generated by a procedure, almost as if it were unknown inherent to the system. Design is thus transformed into a sort of "definition of intelligent rules".

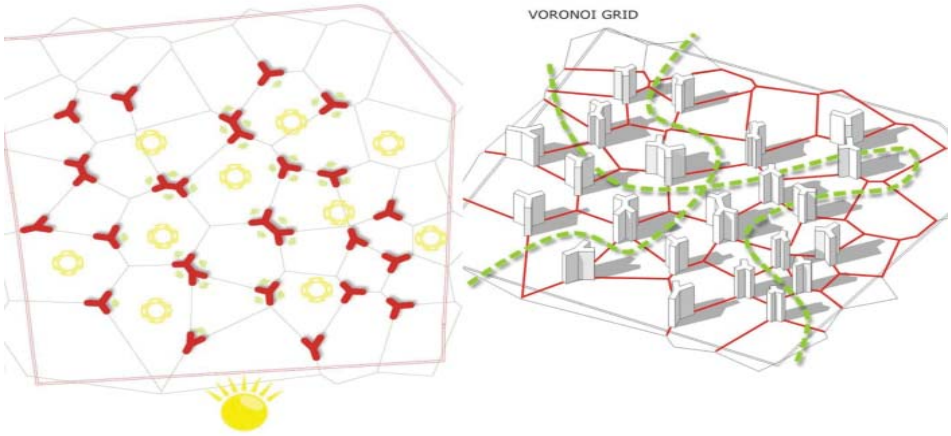

Figure 4. Voronoi City Seoul, Urban Future Organization, design diagrams

"Instead of assembling rigid and hermetic geometric figures – like all previous architectural styles –Parametricism brings malleable components into a dynamical play of mutual responsiveness as well as contextual adaptation. Key design processes are variation and correlation"[3].

The reciprocal fecundation between architectural theories and the possibilities offered by digital technologies consented the rapid extension of the utilisation of the computer. From a simple tool of production (focused on increasing the speed of operations) it has evolved into a refined system of control that permits previously unimagined formal explorations. The introduction of complex programming techniques and parametric software offers designers unexpected possibilities, making it almost impossible to predict the effects these tools will have on design simulations. Simplifying to a great extreme, parametric software can be considered a programming platform – working within three-dimensional CAD environments – capable of generating form through the definition of a conceptual diagram that becomes the only "drawing" developed by the designer. This diagram explicates the associative

3 Patrik Schumacher, "The Parametric City", in Zaha Hadid – Recent Projects, A.D.A. Edita, Tokyo 2010.

ties between a range of *input* data, and generates an *output* that is a system of dynamic and modifiable forms.

From Reactivity to Proactivity

Networks of communication, sensors and *smart objects* are able to gather consistent masses of data. This data is in turn filtered through specific software created precisely to organise this material and facilitate its comprehension. A challenge to multinational digital companies of the future will lie precisely in the development of systems with an ability to define relations between heterogeneous data and create innovative forecasting models. Models will no longer be elaborated according to statistic methods, but instead through the *real-time* evaluation of significant parameters and indicators capable of influencing the design process at the urban scale.
For example, the overlapping reading of data as information alphabetisation or the offering of on-line services and relative user feedback, may suggest the territorial decentring of services that no longer require direct relations with users. To the same degree, data related to *co-working*, when compared to correlated parameters, may offer important indications on urban mobility and energy consumption. Or, data from external sensors used to measure air quality, solar heat gain, ventilation, acoustic pollution, etc., may indicate solutions that optimise the energy efficiency and comfort of settlements.

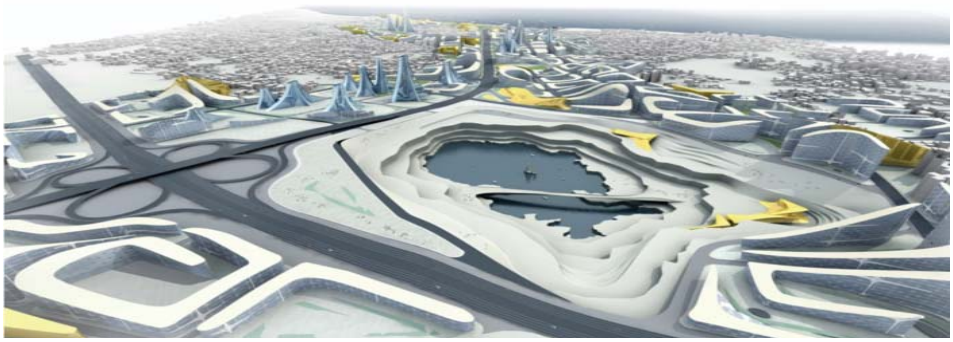

Figure 5. Kartal Pendik Masterplan Istanbul, bird's-eye view

Within scenarios of this type, parametric software may even serve as a tool for experimenting with "new models of Urban Plans". No longer comprised solely of a series of "routine" drawings produced to satisfy normative requirements, they become a dynamic three-dimensional representation. These models can be constantly updated by *smart data*, which thus assumes a "proactive" role, anticipating phenomena and future changes in order to implement rapid and opportune actions and decisions. No longer a traditional "reactive" system controlled by mechanisms of consequential decision-making, but almost a new paradigm of planning supported by a collective intelligence that is the fruit of choices, decisions and interactions supported and guided by technology.

"The same theoretical resources and computational techniques that allow meteorologists to reconstruct and predict the global weather system and scientists to speculate about the earth's evolving climate are available to contemporary urbanists and architects in their effort to meet the challenges posed by the ongoing Postfordist socio-economic restructuring"[4].

The use of parametric software may thus offer designers a very interesting tool for experimenting with new methods of designing. Projects employing parametric logics are distinguished, in their form and content, from those developed according to traditional methods. The first important difference is conceptual, as mentioned: the final result is not established by the designer *a priori*, but is the result of a process of elaborating selected *smart data*. The second difference lies in the vivacity of the system that structures it: the passage from a static to a dynamic system. The formal result is no longer the definitive crystallisation of a particular line of reasoning, but instead a "snapshot" that captures the status of a process in continuous evolution. It is generated to react to variations, autonomously adapting to stimuli it receives in accordance with the rules established by the designer during the phase of concept design. Projects thus evolve on their own, almost demonstrating a capacity for *self-organisation*[5]. Despite their adaptive capacities, it is clear (and this is directed at those sceptics already thumbing their noses at the thought of substituting the designer during the "creative" process) that parametric platforms always require an *a priori* selection of data to be processed. It is precisely through the control of *input data* that designers are able to evaluate alternative solutions, utilising a "snapshot" of a *work in progress* to satisfy desired qualitative performance values.
The phase of data selection and reactive control thus represents a crucial moment within the entire process.

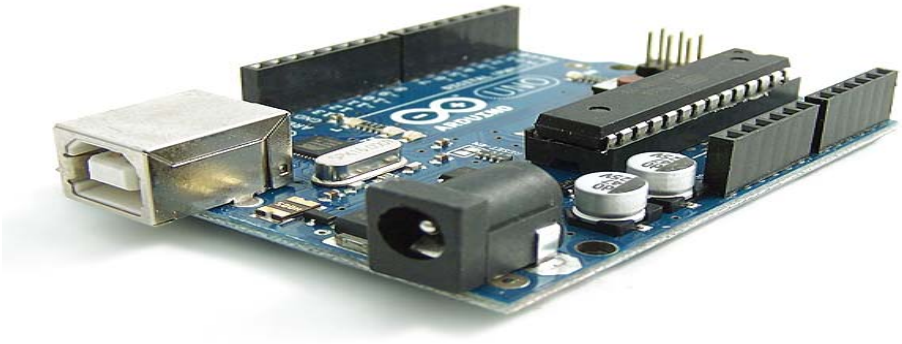

Figure 6. "Arduino" is a simple-to-use open source hardware platform able to integrate with the environment in which it is placed and receive information from a wide range of sensors

4 *Ibidem*.

5 Brian Team Consulting, "Teoria della complessità", from http://braint.net, last view on 5th July 2013.

The Parametric Approach to Urban Design

While the application of parametric modelling in the fields of architectural composition and design, defined by a more immediate relationship between the form and function of an object, was more immediate, this approach is also beginning to take hold in the field of urban planning[6].

During the early 1990s scholars began to test the terrain of parametricism, most likely without imagining the possibilities offered by new generative software programs, and seeking solutions focused on the quantifiable parameters of urban phenomena and their interrelations[7]. The effort lay in recognising the parameters that constitute urban fabrics, observing the complex processes that occur within them, and seeking to capture the complementariness and interrelations at the base of each urban system, to be translated into mathematical rules defined by algorithms. The objective was that of identifying the virtuous processes that, once triggered, could render a system capable of self-adapting to future needs introduced by changes for which designers, only with great difficulty, could develop trustworthy forecasts *ex ante*, even using sophisticated statistical projections.

Employing these methodologies when working with the urban system signifies substantially understanding its intrinsic behaviour: the process of adaptation and the self-organisation of the system is triggered only if the rules imposed by the designer are capable of conditioning its behaviour, provoking a sort of "imbalance" in the system itself that induces each elements of which its comprised to recreate a new "balance" that reflects the best conditions of coexistence with the other elements.

One example of how this can occur is represented, in the field of urban design, by so-called *Swarm Urbanism*. Very interesting experiments have been made by Kokkuggia, a group of young architects that utilises the concept of *Swarm Intelligence*[8] as a tool of research. Their interests focus on the creation of a flexible urban system that responds to a "collective self-organised intelligence". Less of a *Master Plan* and more of a sort of "*Master Algorithm*", capable of generating a complex urban system adaptive to stimuli.

Figure 7. Swarm Intelligence, the flight of a flock of birds

6 See the graduate thesis by Andrea Galli, Faculty of Engineering, University of Messina (2010-11), the source of selected images presented in this text.

7 One of the earliest was Luigi Moretti who founded the Istituto per la Ricerca Matematica e Operativa applicata all'Urbanistica (IRMOU, Institute for Mathematical and Operative Research Applied to Urbanism) to study so-called parametric architecture and introduce the results of mathematical research into the field of urbanism.

8 "Swarm Intelligence" refers to the study of self-organising systems in which a complex action derives from a collective intelligence, similar to what occurs in nature in insect colonies, flocks of birds or schools of fish.

The parametric approach to urban design requires *Open Data*, of a diverse nature, selected by the designer in relation to pre-established objectives, which represent the factors conditioning the design process. They may be strictly urban parameters, such as building or environmental restrictions and density. They may be bioclimatic factors such as conditions of solar heat gain or wind speed in urban canyons. They may be data related to the energy efficiency of buildings, real estate values, levels of urban safety, etc. The collection of *Open Data*[9] may represent a first obstacle to be overcome by the designer: while many, they often lack any form of systematic organisation given their variegated origins.
Having collected the data it is possible to commence applying parametric techniques for the definition of the urban morphology. These techniques may respond to restrictions imposed *a priori*, such as land use maps, height-to-width ratios for buildings, urban planning limitations, landscaping requirements, solid/void ratios or conditions relative to infrastructural networks, building typologies, etc.
Data and restrictions are compared using mathematical rules (algorithms) with the aim of organising the information inserted into the system, and elaborating organic design solutions that respect pre-established objectives and restrictions. The designer (part *planner* and part *urban designer*) has the opportunity to make real-time comparisons between a series of scenarios, producing different combinations of the parameters inserted in the system, and varying their reciprocal influences.

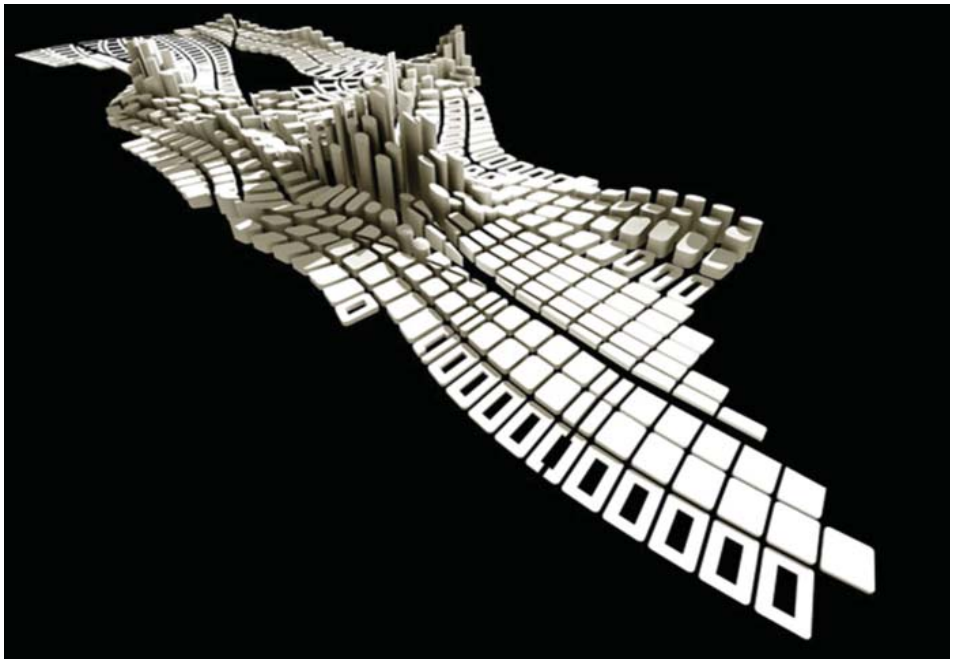

Figure 8. Ant urbanism - Taipei - Annie Chan, Ykai Lin, Sci-Arch University - 2009

9 The term "open data" refers to particular typologies of data that are freely accessible to anyone, and free of patents or other limits on their reproduction and use.

It is possible to distinguish between at least three applied fields in which to test the used of parametric methodologies in urban design.

1. The first and probably most familiar is related to the development of the *Master Plan*. The examples mentioned above can all be referred to this field: the use of parametric instruments to design a unitary urban element, be it a neighbourhood in an existing city or an entirely new city.
2. A second field is represented by the elaboration of scenarios. How many times, as part of the decision-making process related to the development of an Urban Plan, is it necessary to elaborate diverse scenarios to represent alternatives to be discussed with stakeholders? Parametric tools offer important assistance during this participative process, providing effective and controlled representations that help explain how the modification of select parameters can affect the entire system.
3. A third field of application is tied to the definition of thresholds. Examples include zones of strategic transformation in a metropolitan area, or more simply of the expansion zones typical of a Master Plan. It is often the case that urban planning forecasts for a municipality or homogenous geographic area are overabundant and potentially non-coherent with respect to one another and to real needs. Implementing particular urban planning forecasts in specific areas of intervention may in fact produce an imbalance in the market, rendering analogous urban forecasts for remaining areas of transformation less suitable (i.e.: the surplus of residential space during the current period of the crisis being faced by the building industry). Parametric instruments can offer real-time simulations of the effects of the implementation of individual urban planning forecasts with respect to a given context. This in turn renders the surpassing of limit thresholds explicit, consenting eventual corrections to the aim of decision-making processes. The theme of the threshold is clearly applicable to many sectors of the discipline of urbanism: from those determined by the real estate market to those generated by traffic flows, pollution factors, density, the distribution of services and uses, etc. This may produce two effects: the first assists administrators and technicians in making informed decisions; the second, perhaps even more interesting, is related to the perspective of a new paradigm of Master Plan that employs the dynamic representation of a work in progress and flexible implementation regulations that allow for constant adaptations to land uses and, in more general terms, urban planning decisions.

This is the programmatic structure of the research into *Parametric Urbanism* we intend to pursue. Naturally, we are well aware of the difficulties that lie ahead, beginning with exquisitely technical issues, such as the development of digital platforms suitable to our aims, or access to *Open Data*, which are almost never truly public. There is also a condition of mistrust, due for the most part to the digital divide, of a (fortunately) limited part of the scientific community that refuses to abandon more traditional procedures and techniques. At the same time, we are bolstered by the growing interest being generated by these themes among a network of younger researchers, now spread across the globe. This group is courageously attempting to introduce technological innovations in ICT within the procedures and techniques of the field of urbanism.
It is our conviction that this line of research will undoubtedly bear fruits, above all if it demonstrates an ability to maintain a healthy dialectic between the quality of

urban contexts and those made possible by the use of parametric models. Abandoning preconceived fears as we wander into unknown fields of experimentation, and without aseptically confirming "algorithmic" drifts that may cause us to lose sight of the objectives that serve as the foundations of our discipline. Simply by seeking to fully exploit the enormous potentialities offered by new technologies to govern processes of transforming the cities and territories of the future.

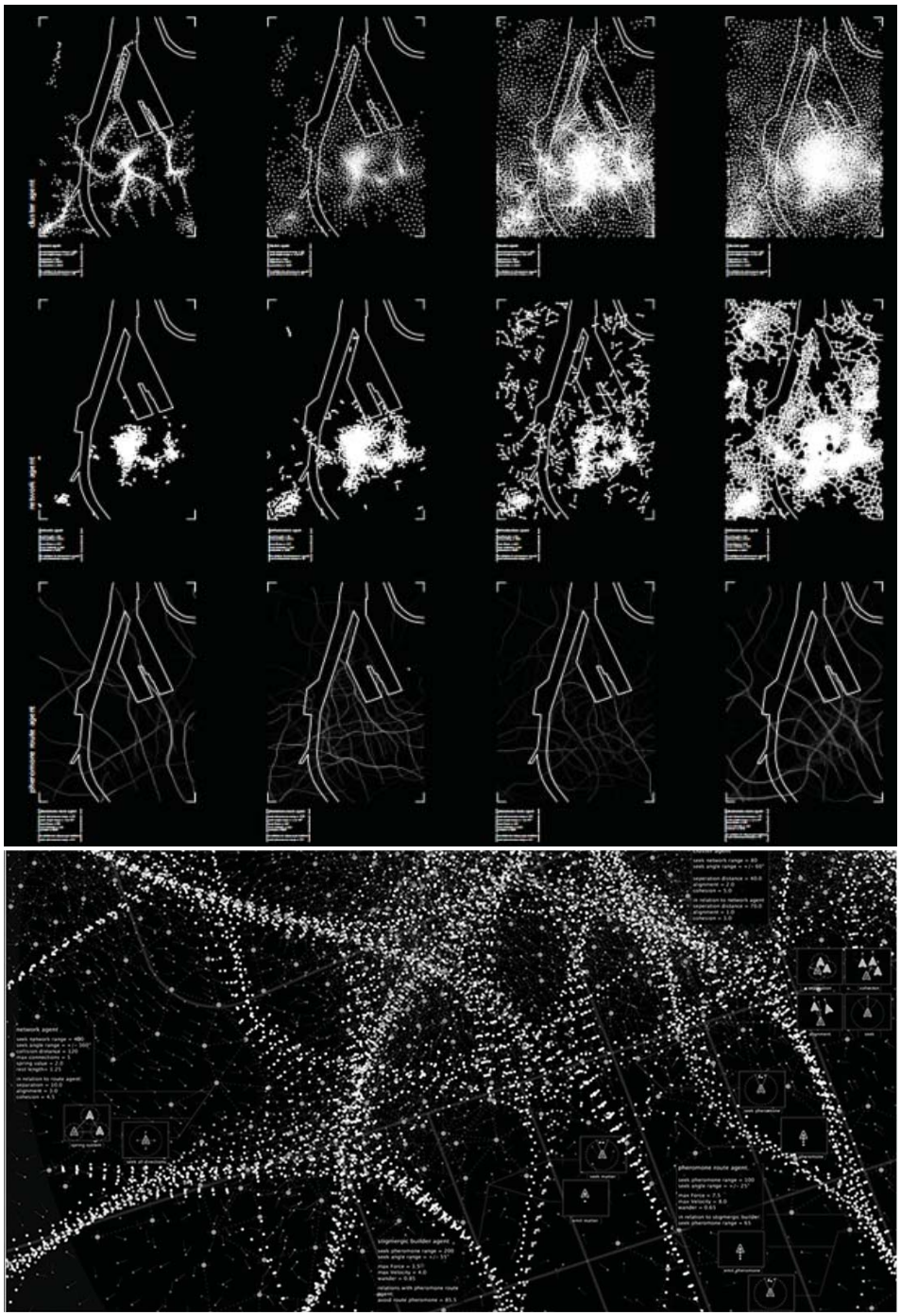

Figure 9. Kokkugia Melbourne Docklands Scheme 2008

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http://www.carloratti.com/project/ka-care/

Project included in the *Urban Future Organization (UFO)* portfolio.
http://www.au-urbanfuture.org/design/residential/city_project/index.html