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TEACHING URBAN AMBIANCE DESIGN WITH PARAMETRIC MODELING

(Research article)

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Abstract

This pedagogical paper presents an approach to urban design taught in the "Complex Densities Studio" CDS of the Institute of Architecture and Earth Sciences of Setif (IAST). This approach is based on urban analysis and scenario building, the use of parametric tools, and the constitution of reusable "parametric actions". The parametric approach invites students to state their project intentions. Parametric computing allows building a digital model from certain parameters. The digital model aims to verify the interactions of the student project in the urban context dynamically and iteratively. It offers the possibility of identifying the most efficient models concerning the stated criteria. The urban typologies and ambiances are evaluated throughout the design process, thus allowing for permanent adjustments. The chosen context is the El-Harrach district in the city of Algiers: the population density and the rapid transformation of urban areas offer a stimulating framework to experiment with a parametric approach to the student project. The approach of the CDS is based on numerous and diverse data, transcribed in diagrams, pre-formal plans, and parametric models, allowing to move from an abstract and quantitative dimension to the formalization of urban ambiances in a progressive and qualitative way.

Keywords: Parametric modeling, Urban design, Dense sustainable city, informal housing

1. INTRODUCTION

Parametric modeling has been taught in several architectural design studios around the world. But generally, parametric modeling is considered as a component of a design method taught to students. Most of the design methodologies are focused on sustainable design or CAD/CAM technologies. When the design method is focused on sustainable design, the pedagogical goal is to teach the possibilities of parametric architectural design, such as adapting form to climatic conditions or designing building forms inspired by the shapes and structures of nature (Matcha 2007). Typically, parametric modeling tools are used in conjunction with environmental performance assessment tools (Holzer 2008). When the design approach is focused on CAD/CAM technologies, the teaching objective is to provide a thorough understanding of CAD/CAM technology and how it can be used in contemporary architectural design practice (Bechthold 2007; Karzel and Matcha 2009). The same teaching methods are commonly used. Students are first trained in the use of the tools required by the design methods (parametric modelers, environmental performance assessment tool, or CNC fabrication devices) and in the communication of data between these tools. Studio instructors provide this training or, sometimes, bring in expertise from outside the studio. Often, the developer's or supplier's training staff provides the training, but consultants can also be found at other academic institutes. Sometimes, before this training, studio teachers provide introductory courses to introduce the parametric modeling software, the use of parameters, and their impact on the geometry.

This paper presents an original teaching method carried out at the Institute of Architecture and Earth Sciences of Setif (IAST) whose objective is to prepare future architects for parametric design. Unlike most parametric design studios, we do not want to teach a specific design method. We believe that students should find their method. This pedagogical practice uses two didactic methods together: Teaching and training. Teaching is done in the theoretical courses of the graduate program and training in a studio at the same level of study. Architecturologie is taught in the theoretical courses as a basic knowledge of architectural design and as a method of introspection and verbalization to analyze architectural design activity. Students are led to study the functionalities of software tools using parametric modeling techniques to discover their potential to assist in architectural design. In the studio, students use parametric modeling software tools (such as Grasshopper, Generative Component, or Digital Project) to design their architectural projects. We train students in the use of parametric tools in specific courses related to the studio. The objective of this pedagogical approach is to lead students to discover the impact of these software tools on their production and to build new design methods. The work carried out by the students in the courses and the studio raises new questions for the Habitat and Environment Research Laboratory (LHE) and constitutes the basis for the creation of new parametric architectural design software tools.

The paper presents a research work that relies on the educational practices carried out by the Complex Densities Studio (CDS) of IAST Setif; they are part of an experimental and scientific approach that extends the axis "Ambiences, innovative devices and sustainable city" of the research Laboratory Habitat and Environment. The paper reports on work carried out by the CDS since its inception in 2010, which proposes to experiment with new methods of parametric modeling of urban fabrics to reconcile urban density and energy optimization at the micro-climatic scale. The students are introduced to parametric computer tools and are led to experimenting with the urban project from quantitative data to produce a measurable and qualitative project. The CDS also questions the strategies to be put in place for the teaching of parametric in a pedagogical framework. These strategies are based on the creation of "parametric actions" constituting a reusable database. After having presented our work in its general context, we will describe the CDS and some of the work done by the students. In terms of conclusion and perspectives, we will see to what extent parametric computing can help sustainable urban design.

2. GENERAL CONTEXTE OF THE RESEARCH

2.1 State of the art

As Jean-Pierre Traisnel of the CNRS points out, the urban form directly influences the energy consumption of buildings (Huang, 2010). It can therefore be designed in such a way as to allow better exploitation of natural resources, even in a context of densification. This is addressed empirically and essentially on the criterion of sunlight and natural lighting in some projects, but no systematic method is yet available. The state of the art on these methods is difficult to make as this subject is both recent and very vast. European and international research on building thermic focuses on the effect of the microclimate on a building ("CitySim", developed in Ph.D. theses (Robinson, 2009) for the effects of solar masks, "Green Canyon" developed by the University of Seville for the canyon street effect (Sanchez de la Flor & al., 2004). Some rarer, researches introduce a coupling between building and microclimate, but with the sole purpose of analyzing the impact of uses on the local climate (Asawa, 2009 or Chen & al., 2007). A new field of research is emerging at the building/urban interface, whose results clearly show that the thermal problem of the building must take into account in a more precise way the thermal of the urban environment, which strongly modifies the flows to which the building is subjected (Malys, 2012; Bueno, 2011). In an urban site, the bioclimatic potential of a building is strongly modified by its environment. This modification can be characterized at different scales: the city or the district to characterize the heat island phenomenon, the closer area to better appreciate the convective and radiative exchanges between the building walls and their environment. It involves different characteristics of the environment: urban form, materials (including vegetation and water), and activities. These evolutions appear in an urban context that has evolved, the design combines scales.

Indeed, if architects and urban planners want to respond to the challenges of sustainable development and environmental quality, the design can no longer be limited to the scale of buildings alone but must be perceived in a broader and more global conception of the "Habitat" on an urban scale. Our "Habitat" can indeed play a decisive role in the emergence of new forms of solidarity that make it possible to reconcile environmental preservation, economic efficiency, and social equity. European and international research on building thermic focuses on the effect of the microclimate on a building ("CitySim", developed in Ph.D. theses (Robinson, 2009) for the effects of solar masks, "Green Canyon" developed by the University of Seville for the canyon street effect (Sanchez de la Flor & al., 2004). Some rarer, researches introduce a coupling between building and microclimate, but with the sole purpose of analyzing the impact of uses on the local climate (Asawa, 2009 or Chen & al., 2007). A new field of research is emerging at the building/urban interface, whose results clearly show that the thermal problem of the building must take into account in a more precise way the thermal of the urban environment, which strongly modifies the flows to which the building is subjected (Malys, 2012; Bueno, 2011). In an urban site, the bioclimatic potential of a building is strongly modified by its environment. This modification can be characterized at different scales: the city or the district to characterize the heat island phenomenon, the closer area to better appreciate the convective and radiative exchanges between the building walls and their environment. It involves different characteristics of the environment: urban form, materials (including vegetation and water), and activities. These evolutions appear in an urban context that has evolved, the design combines scales.

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2.2 Objectives

The morphological characteristics of buildings have an obvious influence on their bioclimatic potential and that of their neighbors. The proposed methodology should allow defining the main morphological characteristics to be adopted to maximize the exploitation of environmental resources, to minimize the energy needs of the new buildings as well as, which is rarely taken into account, the climatic interactions. Concerning European and international research on building thermic, our positioning is original because it proposes a real coupling between building and environment in an optimization perspective at the microclimatic scale.

3. PEDAGOGICAL FRAMEWORK

3.1 The Complex Densities Studio (CDS)

The CDS teaches the urban project in Master's degree at IAST of Setif. Its objective is to raise awareness of the issues of densities approached from the city scale. An in-depth analysis of existing urban typologies from a morphological point of view as well as from a socio-economic and demographic point of view allows the students to link a spatial device, a digital density, and a way of living in the city. The students are invited to observe all of the urban fabrics present to understand them, measure them, and verify their qualities of use and ambiance. The CDS is particularly interested in the effects of migration flows on the urban structure of cities facing a large increase in population. After Setif in 2015, Ghardaïa in 2018, CDS has chosen to work in the district of El-Harrach in Algiers in 2020. The CDS proposes to closely associate the process of densification of a territory, an in-depth reflection on the support systems to be put in place to meet the food and energy needs of new inhabitants and habitats. The student project is approached as a living ecosystem. This approach is based on numerous and diverse data that are transcribed in the form of diagrams and pre-formalized diagrams that allow students to proceed from an abstract and quantitative formalization of their project intentions to a progressive and qualitative formalization.

3.2 Parametric approach to the CDS Parametric model

A parametric model can be defined as several heterogeneous elements put together in a coherent whole (Barrios, 2007; Gane & Haymaker, 2007; Woodbury & al. 2007). This parametric modeling work induces two levels in the architectural design: the design of the parametric model and the design of an instance (de Boissieu & al. 2010). In the CDS, the parametric approach invites students to state and transcribe their project intentions in modellable parameters, which allows them to build a parametric model specific to their urban project. The parametric model aims to verify the interactions of the project in the urban context dynamically and iteratively. It offers the possibility of identifying the most efficient models concerning the stated criteria. The urban typologies and ambiances are evaluated throughout the design process, thus allowing for permanent adjustments. For each density test, the definition of fullness and emptiness, the building impact on the ambiance of the interior and exterior spaces, and the evaluation of the density and right-of-way coefficients must be made explicit. The computer allows first to implement these data to create a parametric model, then to test different variants (the instances) that result from the hypotheses made, to produce a measurable and qualitative project. This parametric and iterative process is characterized by (Figure 1):

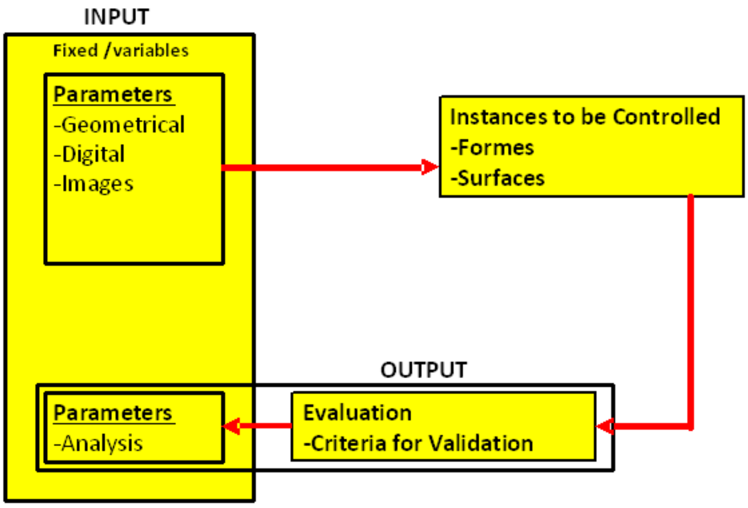

Figure 1. Parametric iterative process.

Three software packages are associated: the algorithmic software Grasshopper combined with the geometric modeler Rhino 3D, and the climate simulation software Diva. The students are gradually introduced to the use of these software packages, which are directly associated with the work of urban analysis and design.

3.3 From a quantitative approach to the definition of qualitative ambiance

The CDS proposes to start the design process from a programmatic scenario intended to accommodate 10.000 new inhabitants. The students propose a territorial strategy and urban devices capable of responding to these new needs and generating new urban ambiances. The student project considers the local climate to develop adapted urban devices aiming to reduce the impact of urban densification while proposing an improvement of the local context.

The parametric approach invites students to state their project intentions. Parametric computing allows building a digital model from certain parameters. The digital model aims to verify the interactions of the student project in the urban context dynamically and iteratively. It offers the possibility of identifying the most efficient models concerning the stated criteria. The urban typologies and ambiances are evaluated throughout the design process, thus allowing for permanent adjustments. For each density test, the definition of fullness and emptiness, the building impact on the ambiance of the interior and exterior spaces, the evaluation of the density, and right-of-way coefficients. Computation allows first to implement these data to create a specific parametric model, and then to test different instances (De Boissieu & al., 2010) that result from the hypotheses made, to produce a measurable and qualitative project.

3.4. Student Project measures and quantification of needs

The first phase of the CDS consists of an in-depth analysis of the urban structures of Greater Algiers, and of knowledge of local society to identify all the components of the city, constituted as much as those of the "informal" city which is developing rapidly in its periphery, its interstices, and its neglected areas. The informal city of southern Algiers mainly takes the form of vernacular and spontaneous housing, most often built by the inhabitants themselves. In a systemic approach, oscillating between the scale of the large territory and that of the habitat, the first measures concern the physical data of the place: climate, topography, energy, water. (Figure 2).

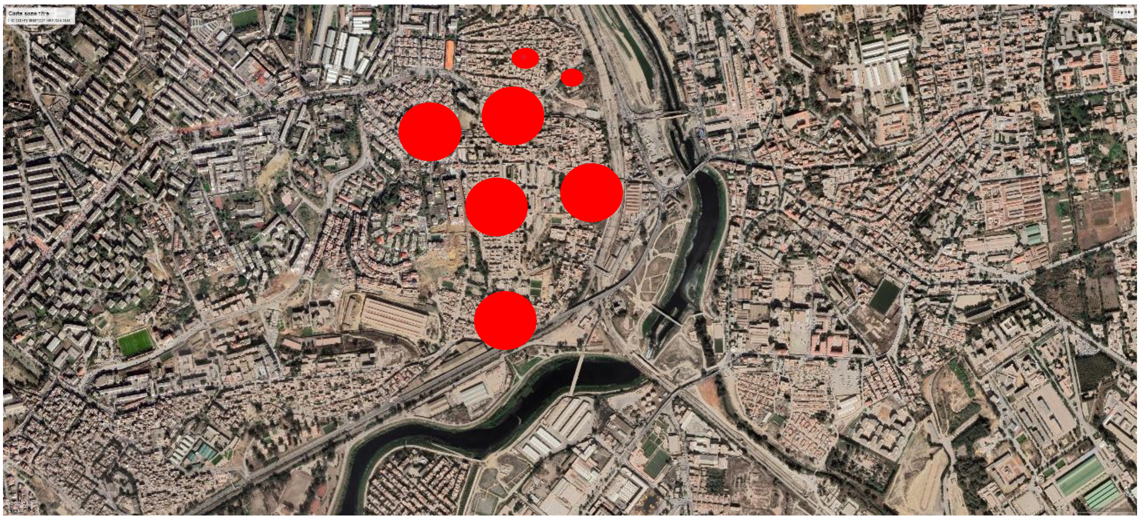

Figure 2. Location of slums in the district of El-Harrach in Algiers and rising waters in 2010 with a temperature of +4 °.

These data are also the starting point for the parametric project work. The parametric simulation of the rise in water levels over time, in the El-Harrach district of Algiers, makes it possible to evaluate the number of flooded surfaces (ground surfaces and roof surfaces) and thus to deduce the number of people to be rehoused (in addition to the 10,000 new inhabitants), as well as the number of new surfaces to be projected (Figure 3). The following measures concern the quantification of needs per inhabitant, concerning consumption or production (drinking or domestic water, electricity, food, waste...), the deducted collection surfaces (rainwater recovery, solar or photovoltaic panels...), the deducted number of collection points (waste collection centers, recycling centers...), the deducted surfaces of the program (dwellings, shops, agriculture, equipment, public spaces...). The student urban

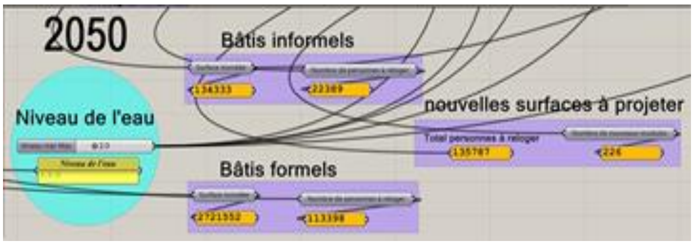

Figure 3: Parametric model evaluating the flooded surfaces in the district of El-Harrach in Algiers, the number of people to be rehoused and the new surfaces to be built according to the rise of water.

project will use these data as possible conceptual and physical materials. As the analysis develops, parameters are progressively associated with the intentions of the student project, which will ultimately have to reach a level of complexity commensurate with that of the context in which it takes place.

4. URBAN AMBIANCE

The parameters chosen for the student project are those of the sustainable and intelligent city ("Smart City"). Some parameters acquire a predominant position in the project and contribute to giving it specific characteristics and a singular identity. Some parameters can be digitized and are the object of a computer design allowing a spatial translation of a conceptual model. This is where the creation of ambiances takes place. Resulting from conceptual intentions crossed with contextual data, the parametric approach allows the construction of spatial models that can be analyzed quantitatively from the digital tool (densities, sunlight, illumination...) and qualitatively from a visual analysis that refers to a subjective and emotional perception of the model obtained. The passage by the physical modeling of the digital model is one of the means which allows this qualitative evaluation of the student project. The manufacturing of physical models completes the digital modeling. The perception of the physical model of the student project makes the transition towards the real and the scale 1. The representation work is also completed by a plastic approach in two dimensions whose objective is, on the one hand, to state intentions (visual translation of an abstract concept) and, on the other hand, to give to the digital representation of the student project an intelligible dimension, evocative of the desired ambiances. The intentions are translated by collages that state the desired ambiances. These visuals combine existing or imaginary ambiances. The visuals produced from the digital model are situated in the context of the student project and seek to represent the future of the place in terms of ambiances (Figures 4) by seeking to demonstrate the qualities generated by the student project and to make the densification acceptable insofar as it brings more qualities than it takes away from the initial context.


Figures.4: The visuals produced from the digital model are situated in the context of the student project and seek to represent the future of the place in terms of ambiance.

4.1.Parametric actions

The teachability of the parametric approach in the context of a CDS urban project was immediately obvious. The work of urban analysis and design is directly associated with the use of parametric computing, it was a question for each student to reinterpret his design intentions in simple geometric transformation operations. This was done to identify the "parametric actions" and their parameters capable of describing their project. Thus, each student project required the creation of specific or generic "parametric actions" (2D grids, cloud point, subdivided surface, bitmap image, extrusion, random, multiplication, FAR, FSI dispatch, occlusion, illumination, ...), implemented in Grasshopper, and connectable. The complexity lies in the numerous combinations of possible connections, describing geometries (instances) visible in Rhino 3D. The instances evolve when the model parameters are modified and are then part of a field of possible solutions to be evaluated and selected (Figure 5). From year to year, the parametric actions created constitute a database accessible to all students.

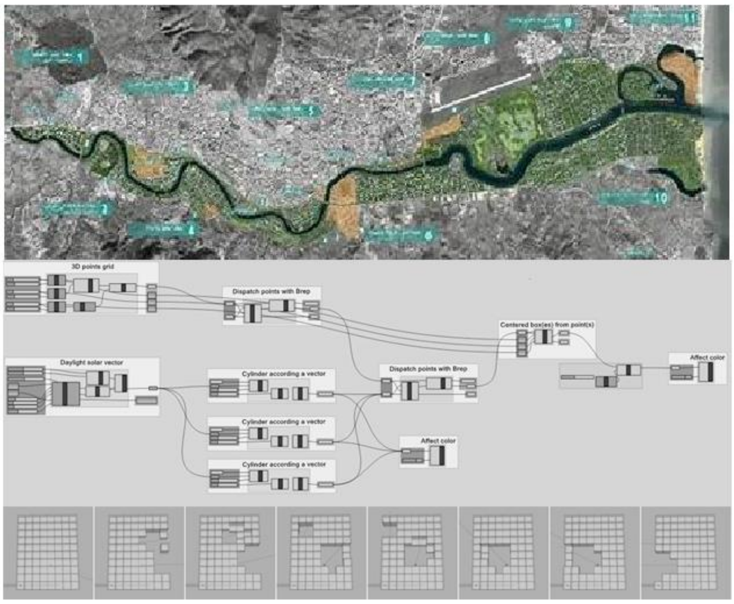

Figure 5: A parametric model consisting of "actions" (above) and geometric instances (below).

5 EXAMPLES OF DENSE URBAN SCENARIOS

The student projects presented here are approached in three ways:

- Project approach through understanding the context. Each student has a specific mission and is a specialist in one of the themes/subjects of analysis identified as essential for understanding the city.

- Parametric approach to the project: learn to define the parameters of a project and translate them into a digital format.
- Scenario approach to the student project: using a scenario, dive into the imagination of a project in a humanistic and poetic way. The aim is to define the program of a colony of inhabitants from different Algerian cities, sharing the same desire to settle in the district of El-Harrach.

5.1 Student Project illustrations

5.1.1 The urban project called "Oued El-Harrach", Algiers Example 1:

Disturbed urban grid (Sarah Hamzaoui)

The urban project called "Oued El-Harrach", initiated by a student (Sarah Hamzaoui) located on the eastern maritime fringe of Oued El-Harrach in Algiers, the concept of the project of this city designed to house about 10,000 inhabitants in nearly 2,000 high-standard homes. The site of intervention is based on a regular grid which is to be deformed based on urban analysis and design intentions defined (highlighting the center of activity and certain points of interest, the towers are higher going towards the banks, strengthening the views in certain places also allowing better natural lighting, location of major axes); and on the translation of these data into geometric elements disruptive (points and curves of attraction allow to control the heights, the distance and the scale of buildings). The evaluation of daylighting was carried out by taking into account different reflection coefficients of materials according to the orientation of the facades (Figure 6).

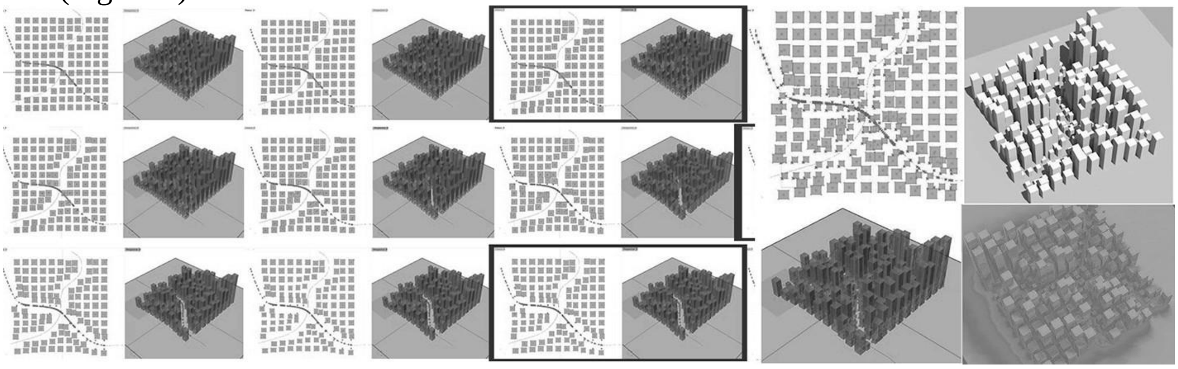

Figure 6. Disruption of the urban grid and parametric exploration of heights, distance, and buildings scale.

5.1.2 The Project "in strips" Example 2:

Urban grid in strips (Mounia Zebar)

The project develops in programmatic strips, overlapping and mixing with the existing. The strips are first established opportunistically with a logic of sunlight: the agricultural and treatment strips (energy, water, waste) need light, the strips of housing, shops, and activities need shade. The parametric model makes it possible to determine the width of the strips and the total surface area meeting the needs. (Figure 7).

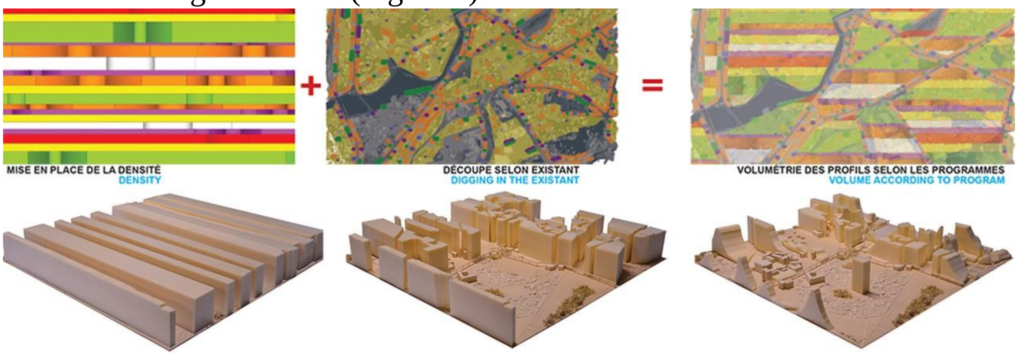

Figure 7. Programmatic strips and overlay to the existing context.

The profiles of the programs change depending on whether they are located near the waterfront (soft transition) or near a park (steep transition), creating different ambiances, proposing a city with diverse landscapes. The program then proposes a phasing on the territory to densify over time (according to the rise of the water). The project is refined according to 3 phases: first, the densification is done at the maximum; then, the density is reduced on the "quality voids" (banks, natural spaces, historical monuments, slums...); finally, the porosity of the project is reworked according to the sunshine. This systematic approach implies urbanization rules for the entire territory and proposes a generic profile for the Algiers of tomorrow. (Figure 8)

Figure.8: ambiances illustrations by collages

6. CONCLUSION

The CDS wishes to set up innovative pedagogical practices, extending into a scientific framework. The parametric actions created during the CDS constitute a database accessible to all and reusable in the framework of new CDS. This digital heritage offers a framework for the development of new urban and architectural design practices that can be used in various contexts. The interactions between the parameters and variables of the design process have become more complex. It is necessary today to represent this complexity by models capable of integrating the various spatial and temporal scales to the challenges of sustainable development and in particular to that of energy savings. The question of the integration of these practices in a BIM process arises here; among other things, the bidirectional connection between the database made up of parametric actions and the informed 3D models, between inputs/outputs and the attributes of urban elements. The question of habitat in an urban context where migratory flows are an essential component of the contemporary city is one of the priorities of CDS. The ambiances design in a dense urban context is based on numerous and diverse data which are first transcribed in the form of diagrams and pre-formalized diagrams, which are then implemented in the form of parametric models, allowing the students to move from an abstract and quantitative dimension to a progressive and qualitative formalization of their project intentions. In the long run, we want to demonstrate that an optimized design of urban projects through the use of parametric digital models could be a lever for the sustainability of our territories. The work of the CDS was the subject of a first exchange in Algiers in February 2016 at the EPAU (Polytechnic School of Architecture and Urban Planning), to discuss design practices in the context of urban hyperdensity. The projects developed in the CDS of the fall semester 2020 will serve as a basis for a CDS on Setif for fall 2022, involving students and teachers.

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