Generative computational tools for the design of Urban Morphology

Mateos Shehu¹, Anna Yunitsyna²
¹,²Department of Architecture, Epoka University, Tirana, Albania
¹,²{mshehu11|ayunitsyna}@epoka.edu.al

Today more than 50% of the population is located in cities. This is an essential need, considering the facilities that urban life offers in contrast to the rural one. But, despite the benefits this migration brings to the individuals, it is also associated with some degree of unpredicted behavior which harms the community. In the recent years Albania, like most developing countries, has been facing problems with both informality and the inability to come up with concrete design solutions to adapt quick changes. From this perspective, this paper illustrates a research done to encompass new tools in the urban design practice of Albania for the overcoming of the current design difficulties. It describes a new approach to assess the problematics in the city of Tirana, and implement an algorithmic procedure which creates urban design proposals similar but not limited to the existing ones. Together with other evaluation tools, these new proposals can be tested in terms of energy efficiency, solar access and ventilation performance with the ultimate goal of creating a unified work model which not only will speed up the process but also improve its overall design efficiency.

Keywords: Parametric Urbanism, Urban Morphology, Sustainability

INTRODUCTION
Urban design involves a multitude of elements, thus it requires a lot of time and effort to predict an end result. As a consequence, in order to deal with the infrastructural sprawl in Albania, many proposals have just an outline of the end product to maintain the needed flexibility for the eventual changes. To continue, these issues are so problematic that by the time a solution is found, new complications might emerge, which themselves would require extra time to be solved and also further interventions in the original proposals. Thus, conventional ways of city planning in this country, bring non-flexibility, which in the process of urbanization is never ending. To address these issues, a new approach may be needed, which is able to compute variables faster and more accurately, is adaptive to the changes, and requires less efforts spent.

As a result, the solution this paper proposes is the usage of parametric design tools to automatize the major part of the design process. By hypothetically assuming that these tools can indeed drastically shorten calculation times and aid designers, the paper tries to assess a new and easy way of doing so.
Specifically, the Grasshopper plugin for Rhinoceros was used, though any scripting language available in other CAD applications will do as good.

To deliver a concrete model, research was done only on the morphological aspect of a neighborhood based on the context of Tirana. Other constrains like social, political or legal, pose difficulties to manage from the parametric design point of view. On the contrary, urban morphology is the part of urban design which is quantifiable, thus manageable in terms of mathematical relations and therefore suitable for algorithmic processing. Morphological parameters alone have proven to influence other practices which deal with comfort, sustainability, lighting and ventilation. The breakdown of this elements will serve as input for the script to generate the desired urban patterns but also as the criteria to evaluate their overall efficiency.

HISTORICAL AND ACTUAL CONTEXT

After the 90’s Albania has been facing multiple problematics with land administration however, differently from other countries, here we may find it as a result of a more particular issue. For fifty years, being in a rigid dictatorial system, Albanian citizens had lost all their belongings to the central power together with their sense of private property. People lived in groups of two to three families under the same shelter due to the lack of habitations. With the removal of the communist system, these citizens found themselves unprepared and with no monetary or land capitals. Dwelling for millions of citizens without jobs were needed, together with assets to generate income. Land seen as free was occupied and buildings were erected without concerning about the urban environment. The newly developed state couldn’t re-establish order, thus following for a transitional period of time the “laissez faire” principles bringing cities to slump conditions. These new created slumps became impossible to deal with, and often are the reason for diseases, disorders and social problematics. Tirana, as the capital, was in the center of this disorder, and is by far the most damaged city due to informality. People were allowed to build, and later houses were legalized, only to form the most unsustainable development with one story villas occupying land which is very valuable in a small territory like Albania. Tirana has always been the center of attention in planning, where the major territorial developments involved it as a pilot project. The number of inhabitants is more than 2/5 of the entire Albanian population. Nevertheless, despite all the efforts the situation is not changing. The issue can be addressed to the poor management of the initial state, which by bringing the city to the current situation makes it challenging to adapt. The study hypotheses is that the situation can improve if new modern tools are implemented in the urban design phase.
As case study, an area of 430,000 m² plot is taken in consideration, located only 3.5 km from the historical and economical center of the city. It is important to note that despite the informality of this zone, the urban pattern is structured. This because the occupied land, being previously an agriculture land, created a sort of ordered sprawl due to the existence of the irrigation system. This will serve as one of the inputs for the script, for the sake of maintain the said order and preserve some beneficial existing infrastructure. The surrounding neighborhoods which are already developed lack unity between each other and within themselves. This context varies from urban blocks to tower typologies which will be part of the generated design models. (see Figure 1)

DEVELOPMENT OF THE FRAMEWORK
For the continuation of the project, it was uneasy to state beforehand which topological pattern was better performing in the current situation. Moreover, if this “universal” working model is to be implemented in other cities of Albania, there is no way to develop a one fit all solution. The advantage of parametric tools lays in the fact that if instructed properly, can develop multiple proposals which can then be tested to find the most convenient solution for a given site. The tower topology together with the urban block are taken as reference to create either uniform morphological neighborhoods or mixed systems between towers and blocks. The research sets as goal the creation of five different proposals trying to include most possible scenarios in Albania. The scenarios are namely: a- Tower typology with strict rectangular grid, b- Mixed typology, Towers and Urban Blocks with strict rectangular grid, c- Urban Blocks with strict rectangular grid, d- Urban Blocks with random pattern of streets, e- Urban Blocks with random pattern of streets + predefined major circulation axis. Other remaining combinations like Tower typology with random pattern of streets are seen as uninfluential, thus not taken into account

The second step consists of breaking down the structure of these proposals in order not only to create the input for the script to run, but also to have the criteria by which these proposals will be tested to find the most successful proposal for a given site, and, furthermore to find the most appropriate variation of the successful proposal. Multiple elements are studied like building height, width, length, surface to volume ratio of the building, proportions, density, site coverage of different elements, solar and wind orientation, porosity of the neighborhood and sinuosity of the roads. All these parameters will influence the design in such a way to promote natural light and ventilation, thus increasing sustainability. In order to channelize the focus on finding which urban morphology performs best in terms of efficiency and natural light/ventilation access, it is necessary to maintain some of these parameters unchanged during the whole experiment as well as across all proposals. Namely: building width, building height and road dimensions are set in the initial stage and remain fixed. The towers will have dimensions of 20x30m while the urban block will have a width of 14m in order to have a minimum passive to non-passive ratio. [Steadman et. al., 2000]. The building height will remain random across all the proposals specifically between 7-9 floors in order to have a minimum passive to non-passive ratio. [Ng 2010] improved solar access [Cheng et. al., 2006], and also a sustainable high density [Salat & Nowacki, 2010]. The height of the floor, which directly influences the passive zone of an apartment will be 3 m [Ratti, Baker & Steems, 2005], which also complies with the actual regulations in the Tirana urban development policy. The road dimension will be 20m from building to building (including pedestrian and vehicular) in order to have an Height/Width ratio of 1.2 which is favorable for good ventilation [Ng, 2010]. Also, this angle between 46-53 degrees is appropriate for non-solar extrusion proposals. The rectangular street patterns will be rotated from the Y axis with approximately 30 degree to follow the predominant wind flow in summer for better ventilation during hot days. On the other hand the specific factors which are taken in consideration and which vary from case to case constitute on elements like building dis-
SOFTWARE INSTRUCTION

Following the development of the framework for generating the proposals, research was carried out to determine basic parameters of the surrounding existing models, in order to unify the existing with the proposals. An average plot area of urban blocks was extracted from different cases and inserted as the first input in the script. Based on this average plot area, the number of plots which will fit in the given site is defined. The script then creates a rectangular grid, with as many subdivisions as the number of plots which is rotated in order for its axis to overlap with the prevailing winds. The new grid will serve as the base for the a, b and c proposals. For the development of the random urban patterns namely d and e, the script extracts the centroids of the generated rectangular plots which are then shifted randomly in the X and Y direction. These new points will serve as centers for a voronoi structure which will partition the plane into regions with areas near to the average plot area. (see Figure 7) After the base structure for both the major typologies is set, the program performs the remaining commands of offsetting the roads, creating the building patterns and extruding the 3d shapes based on the rules above mentioned.

In the end, a rule runs which eliminates all the 3d volumes with a base area lower than 350m2. After the full generation of the proposals, the script extracts all the necessary data for each proposal like overall area of the occupied by roads, landscape, and surface coverage, general volume of the buildings, surface exposed together with annual radiation and ventilation data, taken respectively form Autodesk Ecotect and Autodesk Flow Design.

SELECTION OF THE MODEL

In order to select the best solution for this site, it is necessary to compare the proposals in scientific quantifiable terms. The patterns are evaluated in four major categories like: efficiency from morphology, efficiency from site usage, solar exposure performance and natural ventilation exposure.

Data about Floor Area ratio, Surface to Volume ratio are directly calculated within the script where
the Floor Area Ratio is preferred to be 1.6 to 1.8 for having both a high density together with good solar access [Capeluto and Shaviv, 2001] while the Surface to Volume ratio is preferred to be high in order to have less energy loss. The site usage area informs the user of the denser environments which is generally preferable for higher efficiency.

Regarding the solar exposure elements like thermal gains are not considered since depend on other factors like material absorption, insulation etc. The focus remains in the building exposure as a broader term since this characteristic is inherited to the building by its morphological construction and sun orientation. This criterion selects buildings which receive the less amount of heat/light during summer when it is not needed and the most during winter.

The final step involves quantifying the ventilation exposure in terms of porosity (total open volume/total volume of the site) [Adolphe, 2001], Width of airflows (building height/street width) [Ng 2010] and air tunnel simulations. The greater the porosity the greater space for wind to flow while the greater the H/W ratio the slower the wind flow will be on the ground. On the other side, the wind tunnel simulation can only process graphic results which are enough to determine a successful proposal. (see Figure 8)

As a final result a table is constructed where for each optimal factor a given proposal receives a “+” whereas for inconvenient factors it receives a “-”. Since it would be impossible to create a ponderated value system which can select the best proposal across all possible given sites, due to the high number of possible scenarios, it is thought to let this part of the process unautomated. This also gives the opportunity of the user to use his design experience as well as take in consideration other social factors which otherwise would not be possible to calculate. (see Table 1)
CONCLUSIONS
The final table (see Table 1) displays all the output generated from the process. However the final decision remains to urban designer. By also taking in consideration other design factors like economical, cultural or environmental the selection process will be complete. For Tirana, which is subjected to a hot climate, pattern 1 seems to perform best. Not only it has the highest amount of absorbed radiation in winter and the lowest in summer, but also has the highest ratio of exposed area which makes it easier to cool down during the days. On the other has it also has the lowest density which translates in cost. All these specific factors supported by the exact mathematical data provided by the script create an enhanced habitat for the urban designer to operate.

To conclude, the research started with the question, if the computational design tools could aid urban designers come up with fast and reliable proposals. The answer is in the affirmative where for the whole part of this work, a process of task automation was created and urban technical data was translated into understandable visual graphs, all of which required little or no time. Continuing in this field many scenarios can be achieved which makes possible a real natural selection of the best proposal. The benefit of this method, as opposed to manual techniques, is that at each phase of development and design variation, both the input and output data are tabulated and easily accessible. This research constitutes a step forward in rethinking the Albanian planning culture and hopefully in other developing countries. Further work may include the development of a larger platform in order to encompass other design influential factors as well as more automatization in the stages of data collecting.

REFERENCES