The Language of Mozambican Slums

Urban integration tool for Maputo's informal settlements

Pedro Barros[1], José Beirão[2], José Pinto Duarte[3]
CIAUD, Faculdade de Arquitetura, Universidade Técnica de Lisboa, Rua Sá Nogueira, Pólo Universitário, Alto da Ajuda, 1349-055 Lisboa, Portugal
[2]http://www.urbangrammars.com/, [3]http://home.fa.utl.pt/~jduarte/
[1]prbarros.arq@gmail.com, [2]jnb@fa.utl.pt, [3]jduarte@fa.utl.pt

Abstract. *A shape grammar was developed for analyzing the evolution of Maputo´s slums with the strategic objective of capturing the evolution of house types and understanding the social agreements behind the spatial relations of their house elementary spaces in order to reuse such rules for the purpose of rehabilitation. This paper shows preliminary results of the research and aims at developing, based on the resulting grammars, a parametric tool able to execute morphological analyses, simulations and generate improved design solutions for the qualification of Maputo´s informal settlements.*
Keywords. *Shape grammars; urbanism; computation; regeneration; informal settlements.*

INTRODUCTION

This paper introduces a new approach for an urban simulation framework for deteriorating unplanned settlements in the city of Maputo (also known as Caniços), areas that often are regarded as 'slums'.

According to UN-Habitat's report (2003), *The Challenge of Slums*, in 2003, 31.6 per cent of the world's urban population lived in slums or squatter settlements. The 2010 report - The UN State of African Cities – states that Mozambique's urban population will raise from 9 million in 2010 to 15.6 million in 2025, confirming the country's position as having a significant growing of urban population for the next few decades.

The difference between an informal settlement, an unplanned settlement, a slum, or a deteriorated urban area is not always easy to define (despite the UN-Habitat (2006) definition). In reality all these areas often overlap in terms of their characteristics, function and appearance. Not always is an informal settlement a slum, or is a slum created in unplanned areas, but it is fair to say that in most cases slums happen to be informal or unplanned areas that are suffering from multiple physical or socio economic problems (Karimi and Parham, 2012).

RESEARCH PROJECT

This paper shows preliminary results of a PhD research aimed at developing a parametric tool able to execute morphological analyses, simulations and generation of improved design solutions for the qualification of Maputo´s informal settlements. The main goal is the creation of an integrated model that substantiates planning decisions and presents itself as a viable methodology in the search of more sustainable solutions.

This model is based on Stiny's shape grammars (1980) as means to elaborate plans capable of adapting to changes in premises without losing its urban,

civic and environmental integrity. It is claimed that such a model has the ability of maintaining the urban and aesthetic coherence and the harmony with the place of intervention due to the capability of shape grammars of capturing the morphological characteristics of house types and therefore the features which are inherent to the dynamics of use, to the cultural identity and social dwelling protocols (Habraken, 2000).

The work is structured on the hypothesis that there is a grammar capable of, in a common language, capturing simultaneously the intrinsic values of the informal the needs regarding infra-structure requirements and respond in general to local population's needs. For the latter purpose, the research proposes the use of urban design quality standards to constrain the grammar within qualitatively validated boundaries.

This methodology uses the Shape Grammar formalism resorting to its analytical and generative capabilities. The analytical process enables the identification of the rules that generate informal urban fabrics, hence it permits the description through Shape Grammars of the emergent phenomenon of the informal. It also identifies representative fabric samples that reveal objective qualities which will be used to reference the valuable boundaries for grammar parameters. Secondly, the generative process will aim at the creation of a design grammar that will adapt the rules inferred in the first process to the goals defined in a development vision. It will consist in the contextualized adaptation of the rules with the strategic objective of rehabilitation and infra-structuring in order to improve the cultural setting. Also, it is intended to develop an interpretative consistent model that allows the deduction of the syntactic and semantic rules by aggregating the analysis systems - Spacematrix (Berghauser-Pont and Haupt, 2010) and Space Syntax (Hillier and Hanson, 1984) - in a substantiated operational base for decision support. It can then check the validity of the interpretative model and of the proposed digital implementation in order to promote the generation of more sustainable urban solutions within the context.

Finally, by recurring to shape grammars and using them in a bottom-up fashion one may be able to deal more easily with the emergent phenomena that typically occurs in informal settlements by adding new rules which express a local emergent recurrent pattern without losing the main order intended for the planning strategy.

CONTEXT

Authors like Paul Jenkins (2012) and Isabel Raposo and J. Oppenheimer (2008) have been revealing a weak interest by Mozambique authorities in urban development and weak capacity of the programs of decentralization by the municipality of Maputo that underestimates the tendencies of expansion of these settlements (the foresight is of 2,5 million in 2010 growing up to 4 million in 2025 in the city of Maputo). *"Why do strategic approaches to urban development generally not recognize emerging peri-urban forms as valid and work with these, rather than assuming these need to be replaced?"* (Jenkins, 2012). Even The Challenge of Slums (UN-Habitat, 2003) report *"suggests that in-situ slum upgrading is more effective than resettlement (…)"* and that as *"(…) slums are in fact the dwelling places of much of the labour force in their cities, they provide a number of important services and are interesting communities in their own right.(…)"* (UN-Habitat, 2003).

It seems then necessary to find new ways to understand the qualitative properties of existing urban solutions so that we can consistently evaluate them and propose new ones. Such processes of revitalization can be modeled and simulated through generative systems in a bottom-up approach.

THE CANIÇO SHAPE GRAMMAR

The idea of defining a Shape Grammar applied to the structure of Maputo´s slums (so called 'Cidade de Caniço') appears, first of all, like an analysis of a social space displaced from the urban process and secondly, with the strategic objective of rehabilitation.

Here we present the preliminary results of this ongoing research. The shape grammar presented here is based on the *Built Environment Study* (An-

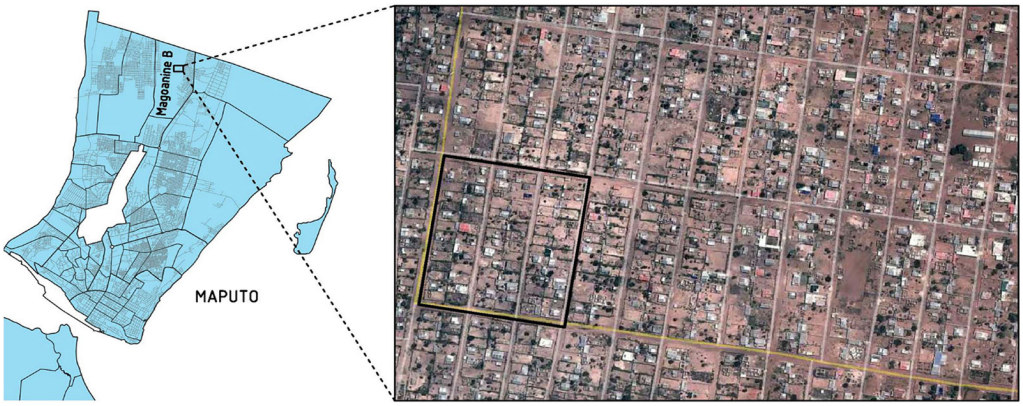


Figure 1
'Bairro' Magoanine B in the city of Maputo. Sample of 'Unofficial Planned fabric (Google Earth).

dersen et al., 2012) data which is part of the broader research program designed by Prof. Paul Jenkins – *Home Space Maputo*. It is based on what Andersen et al. and Jenkins (2012) define as 'Type A' houses. In *Home Space Maputo – Built Environment Study* (Andersen et al., 2012) the *"many different house plans have been divided into five general house types. It is however important to stress that many of the house types overlap each other; some house types become transformed into other types (…). These five general house types are classified as the most common."* (Ibid). Accordingly to this study, the first phase of the house building construction often is to start with the most basic type. Type A house is then the most simple, with only two divisions. *"The house is entered from the center of the long façade directly into one slightly larger room and with further direct access to a bedroom. The house has one private room while the 'sala' is for receiving visitors and at times acts partly as a kitchen"* (Ibid).

The plot and the block shape and size are taken from a sample of the 'bairro' Magoanine B (Figure 1) described in Home Space (Jenkins, 2012) as an 'Unofficial planned area'. This particular area was chosen because unofficial planned areas, *"which had community / private planning and sub-division interventions at some period, but were not registered formally in the land cadastre and/or registry"* (Ibid), show a certain level of regularity in terms of urban layout that facilitate the definition of the grammar at this stage.

In order to focus on the fundamental components that constitute a typical plot, other elements are considered such as trees (which can be pre-existent) and the toilets separated from the house buildings.

Designs are shown bi-dimensionally. The grammar develops by configuring the arrangement of the plots and then placing the basic form of the house (a 7m x 3.5m rectangle) in each one of them. Additionally, the rectangle is divided in two functional zones, as *"the most simple house type and in general has two divisions"* (Andersen et al., 2012) - private and social. Without any reference of construction timing or order, it´s here established that the placing of the outside toilets happens before any other extension of the house is made. The same order issue is presented with the trees, especially with the larger types. It´s assumed that most of them existed before any kind of land division. For design purposes it´s used the average treetop diameter of the three most common species to determine constraints regarding the placement of houses in relation to the tree's position.

GRAMMAR

The view of most informal settlements suggests an organic and almost chaotic land occupation. However, Paul Jenkins's (2012) studies identify four de-

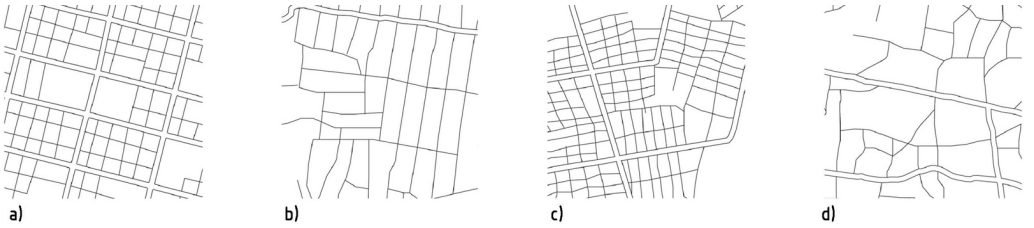


Figure 2
a) Officially planned; b) Unofficially planned; c) Upgraded; d) Un-planned (in Home Space Maputo, Jenkins 2012).

velopment statuses for land occupation in Maputo city, according to different criteria such as the level of planning, land registry and socio-economic conditions (Figure 2). Those statuses are:

"Officially planned – areas which had state planning and sub-division interventions at some period (…);

Unofficially planned – areas which had community / private planning and sub-division interventions at some period (…);

Upgraded - areas which had been unplanned but had state, community or private planning or sub-division (…)

Un-planned – areas which had no previous (…) planning or sub-division, often referred to as 'spontaneous' or 'informal' areas (…)" (Jenkins, 2012).

The research focuses on the latter three statuses – the ones that show some kind of self-organization despite of any level of state/private intervention or planning. The grammar presented here is then the first approach to the most 'regular' status of the three that reveal 'informal' qualities - the 'Unofficially planned'.

The grammar is divided in three general stages. The first one relates the plots in order to create blocks. The second stage places the Type A house inside the plot and the third configures the house extensions and other components like outside toilets and trees.

Stage 1 - Plots and blocks

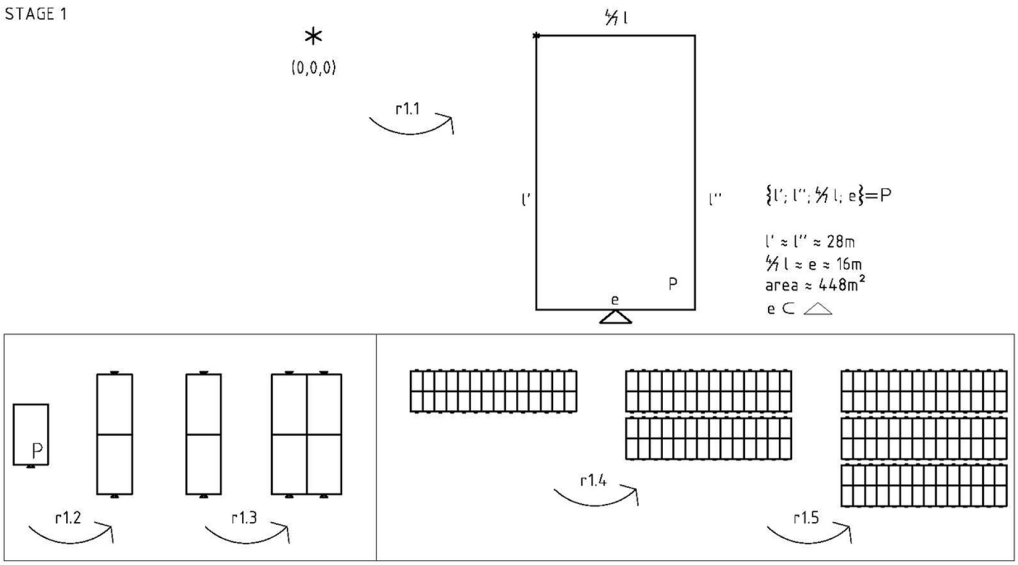
The composition starts with a given point (0,0,0) associated with the symbol * (Figure 3). To this initial shape is then established the location of the first plot. The plot is for now represented by the rectangle *P*. Rectangle *P* is 28m x 16m (average plot size from the sample shown in Figure 1) and it is composed by the lines *l'*, *l''*, *4/7 l* and *e* (which define the limits and the entrance side of the plot). Line *e* contains at its midpoint a triangle symbol for the entrance.

Once the first plot is established, other plots are added in order to create city blocks. Rule 1.2 mirrors *P* by its *4/7 l* line and Rule 1.3 copies the mirrored plots thirteen times until there is a twenty eight plots city block. From here the blocks are replicated orthogonally nine meters away from each other (the average street width). This presentation uses three city blocks (eighty four plots).

Stage 2 - House in the plot

After the city blocks generation, Type A houses are placed in each plot (Figure 4). *"Three general tendencies were recognized regarding how the houses of this type where located on the plot. The most common situation was the house located in the very far corner of the plot and with two sides of the house connected to the perimeter walls (situation 1). The next common location of the house on the plot is where the short end of the house was connected to the plot boundary and closer to the street (situation 2). Some cases also had their house centrally free standing on the plot (situation 3)"* (Andersen et al., 2012). Because this is the only quantitative information for each of the three situations, it's established the probability of occurrence for each of the situations: *situation 1* (the most common) will occur three times in every six cases; *situation 2* will occur two times in every six cases; *situation 3* will occur once in every six cases. The house is represented by the 7m x 3.5m rectangle *H*, composed by the lines *a'*, *a''*, *b'* and *b''*. Rectangle *H* can

Figure 3
Stage 1 in the grammar - Plots and blocks.



be positioned horizontally (if *a* = 7m then *b* = 3.5m) or vertically (if *a* = 3.5m then *b* = 7m) inside the plot. In no case Type A house appears in the front of the plot. One important issue raised was the probable pre-existence of trees. Trees are represented by circumference *i* and its diameter corresponds to each species average treetop diameter. To ensure that no house is placed under a tree, two conditions are established. The first is that circumference *i* cannot intersect rectangle *H* and the second is that circumference *i* cannot contain rectangle *H*.

To control the placement of rectangle *H* (or any other component) inside the plot, to each side of rectangle *H* (*a'*, *a''*, *b'* and *b''*) is added a dimension arrow *d* (*dh* for horizontal arrows and *dv* for vertical ones) that will manage the distances between each side of the house (rectangle *H*) and the limits of the plot (rectangle *P*).

Situation 1 (rule 2.1) is the most common location of the house (three in every six cases), where its corner coincides with one of the far corners of the plot. Whether the house in a vertical or in horizontal position, the condition is that *dv1* = 0 plus *dv2* = l - *b* and that *dh1* = 0 or *dh2* = 0 depending on the house being placed in the right or in the left corner of the plot.

In *Situation 2* (rule 2.2), where only the short end of the house is connected with the plot boundary (anyone but the front) there are different conditions depending on vertical or horizontal positioning. If it is horizontal then *dh1* = 0 or *dh2* = 0 depending on the house being placed in the right or in the left side of the plot. Also *dv1* ≥ 1 to ensure some space in the back of the house and *dv2* ≥ *l*/3 (since there is no case where the house is placed in the front of the plot it was established that the minimum distance to the front end is one third of the plot length – about 9.3 meters). If it's vertical then *dv1* = 0. Also *dh1* ≥ 1 or *dh2* ≥ 1 depending on the house being placed more to the right or more to the left side of the plot, ensuring some space in the back of the house in any of the cases.

In *Situation 3* (rule 2.3) the house has a centered position in the plot. None of its walls touch the boundaries of the plot which means that no distance *d* equals 0. So *dh1*, *dh2*, *dv1* ≥ 1 and *dv2* ≥ l/3,

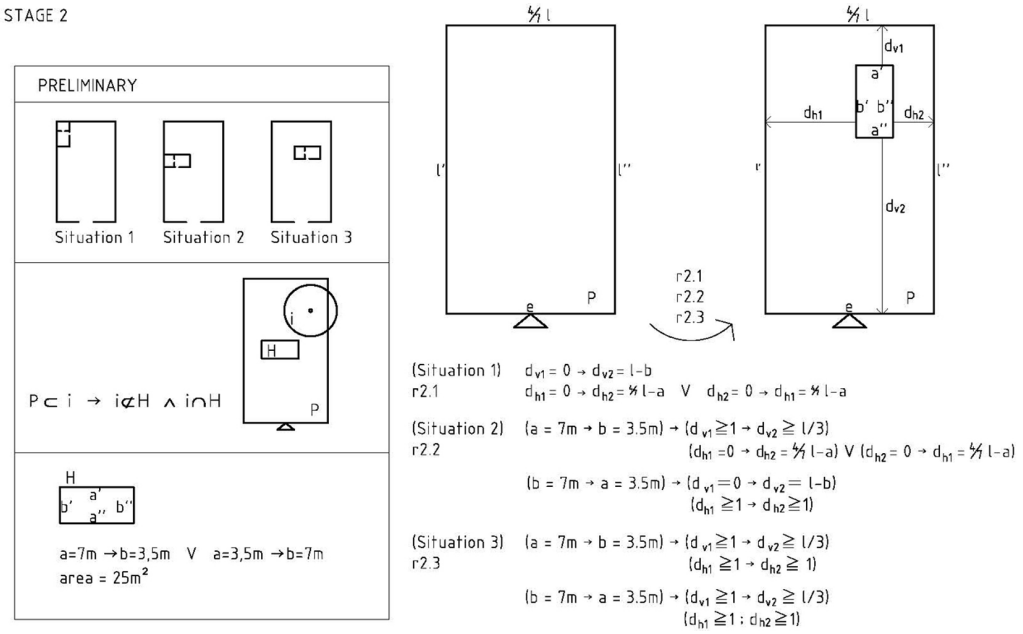


Figure 4
House location in the plot.

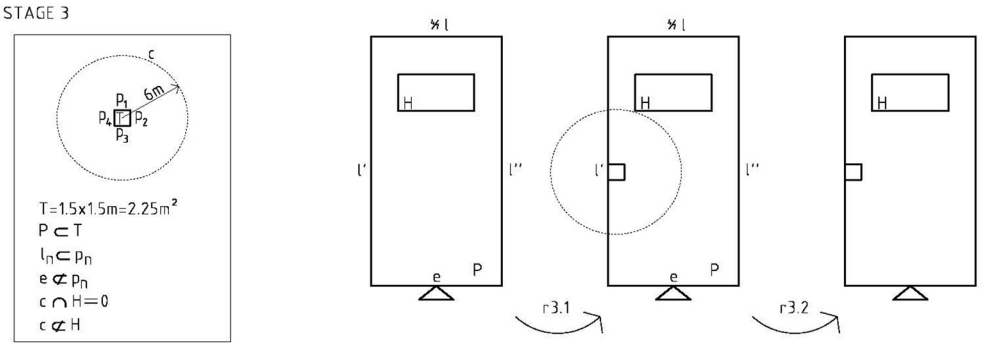
maintaining the same criteria of placing the house away from the front.

Stage 3 - Extensions and components

"The Home Space study provides evidence that the location of toilets and bathrooms most commonly are in a separate building or a screened off location as far as possible from the main house. This configuration was seen in 74% of the cases" (Andersen et al., 2012). It also shows that the transition from outdoor to indoor toilets corresponds to an upgrade process that seems to be slow due to the lack or insufficient sewage infrastructures. Because Type A house is the most basic one (associated with the lower income families) and corresponds to the starting stage of the house building construction, it is settled that for this type all toilets are outside of the house. For the grammar the toilets are represented by the 1.5m x 1.5m square *T*, composed by the lines *p1*, *p2*, *p3* and *p4* (Figure 5). Square *T* is inside rectangle *P* (plot). Another observation we can make is that none of the examples shown in Home Space have the toilet placed in the front end of the plot. So line *e* (from rectangle *P*) can not contain any line *p* (from square *T*). To ensure a considerable distance from the house, it is established that the toilet must be placed in one of the other three plot's limits and that the minimum distance to the house is six meters. This minimum distance is assured by the placement of an auxiliary circumference *c* with a six meter radius. Circumference *c* is centered with square *T*. Circumference *c* cannot intersect or contain rectangle *H* (house).

The next stage is to divide the house (rectangle *H*) in two labeled divisions – bedroom *B* (*B* = 3m x 3.5m = 10.5m2) and 'sala' *L* (*L* = 4m x 3.5m = 14m2) – and mark the door label with a triangle. As mentioned above, the main entrance is in the center of the long façade. Because there are two, the door label is to be placed in the one that has a longer distance *d* (whether it is a *dv* or a *dh*). This condition denies any chance of having a door facing directly at the boundary wall. It´s important to stress that the

Figure 5
Toilets location; House division.



yard is a scene for *"everyday life and a space for socialising, household work and sometimes also a space for economic activities"* (Ibid). The toilet door follows similar criteria. In this case the only condition is that it never faces the front side of the plot (line *e*). In other words, it can only be placed in its horizontal distance *dhn* or in its vertical *dv1*.

"House type A can be extended in various ways" (Ibid). The extensions used for the grammar follow the four examples shown in Home Space. Type A houses are extended with additional one or two rooms with similar size and shape as the existing ones (larger extensions would transform the Type A house into other types). Therefore, five different layouts are created for Type A house: *extension 0*, *1*, *2*, *3* and *4* (in *extension 0* the house keeps its original configuration - Figure 6). In the absence of quantitative information, it is established that all the five layouts are applied in the same number (each is applied once in every five cases). The application of these transformation rules implies the elimination of the labels in the house and the insertion of the doors.

Extension 1 adds one room to the front of the house. *Extension 2* creates a big living area in the front of the house and a new entrance way to the side of the 'sala' (formally labeled with *L*). The only condition here is that the distance *d* at this side must be greater than the opposite *d*. This will grant a larger yard area in front of the new entrance of the house. The only extension that can be made to the back of the house is *Extension 3*. It basically mirrors the house to the back or to the front, creating a new inner door. If the extension is to the back, the distance *d* in the back of the house has to be bigger than 4.5 meters (3.5m for the new body plus 1m for the new back door passage). *Extension 4* creates a large living room to the front plus a 'veranda'. *"The veranda is not only a transition space between outside and inside - which can be used for practical purposes as cooking, storage, or a social space for - but also a way of representing the house in the neighbourhood. Many of the verandas had burglar bars and some of these were richly ornamented"* (Andersen et al., 2012). This extension requires that the house have a horizontal position because the *"veranda is always facing*

Figure 6
House extensions.

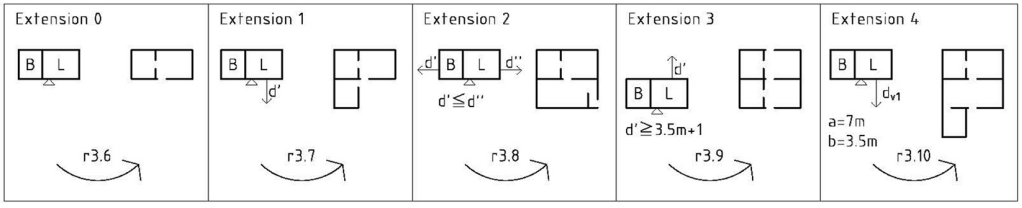


Figure 7
3D Model.

the street" (Ibid).

"Trees provide shade and hence create spaces for socializing and domestic work, bear fruit or can figure as decorative elements. Trees also had a spiritual function vis-à-vis the reverence for ancestors and traditional ceremonies often involve trees. The 'quintal' is a space for social interaction where e.g. visitors can be received in the shade under a tree. The majority of the cases, 73%, have a shade providing tree in their yard and in 2/3 of these cases, the tree is a big mango tree and in other cases there are mafureira (Natal Mahogany) or canhueira (Marula) trees, both producing fruits" (Andersen et al., 2012). As seen above there is a preliminary condition about the possible pre-existance of trees. In order to control the placement of planted trees, there is one first rule that defines the contour of the house. This contour line prevents that the tree is placed over the house. Thus the contour line cannot intersect circumference *i*.

Despite the fact that Type A houses only have one floor and for that the grammar is essentially bidimensional, there are a set of rules that extrude the print for visualization purposes. This third dimension uses basic façade composition shown in Home Space as well as the low pitched roofs (made of corrugated iron sheets). When applied to the eighty four plots, the 3D visualization gives us a better view of the set as it represents a powerful and effective way of communication (Figure 7).

CONCLUSION

The research described in this paper constitutes the first step towards the development of a computational model for Maputo informal settlements. The ultimate goal is to use this model to support decision in urban interventions that have similar spatial features and to improve them from the environmental viewpoint by manipulating the rules in the model. The model uses shape grammars to encode the underlying syntactic rules describing the language of the 'Caniços' which capture the social features underlying these morphological types. It aggregates two essential grammars: the grammar to generate the urban fabric and the grammar to generate the houses and its components. This paper describes the preliminary results of the second generative grammar.

An important point for discussion here is to evaluate the capacity of the grammar of really capturing what are the reasons behind the transformation happening in the 'Caniços'. In many situations, different grammars can be used to produce the same formal arrangements, in other words, in some circumstances different sets of rules are able to produce the same shapes. However, as analytical tools there is only one grammar which is capable of reproducing simultaneously shape and the generative process which originated the shapes of a corpus of designs used as case studies. Therefore, if a grammar

produces the shape of our case studies in Maputo, this is not enough evidence that the grammar is efficient for our purposes. We still need to validate the grammar against evidence of the real motivations behind one or another particular transformation to check if it is really replicating the social behavior underlying such transformations. This is important considering that the reuse of the grammar is the main goal in mind and that it is supposed to deal with the typical social behavior while providing some degree of control to improve the final outcome. This validation still needs to be done and is planned as the next step of the research.

According to Andersen et al. (2012), *"buildings are in continued process, always under construction and in various stages of being extended, appended, built or finished. This process sometimes spans over decades (…)".* It has to be stressed that this grammar deals only with what could be considered as the most basic module unit of house buildings in peri-urban Maputo though it encompasses some evolutions of the Type A (one of the cases may be included in Type B) houses. As Home Space Built Environment Study (Andersen et al., 2012) mentions, *"the size of the house was clearly linked to wealth of the residing household"* though *"the survey does not carry any clear evidence of a relation between economic status, location in the city or planning category"*. This means that Type A house evolution is in most cases linked with socio-economic changes in the household which need further understanding.

Evidence raised here was the low density occupation of the plots underlining the clear importance of the yard as a space for social interaction, domestic work or for small economic activities. Another aspect is that this low density occupation is responsible for an increasingly spreading urban sprawl effect which creates a great dependency on car use in a city with no adequate traffic infrastructure and a large amount of population with no motorized means of transport. Therefore, the study of densification strategies within the existing structures will be a key issue in terms of the development of planning strategies. Densification studies still need to be developed having in mind three kinds of extension opportunities: (1) plot subdivision; (2) house extension and (3) addition of areas for commercial activities. Evidence of possible valid occupations may be captured from the analyses of denser and more compact areas.

Another key issue will be the transformation of the grammar in terms of sanitation conditions. According to Andersen et al. (2012), one of the main aspirations of these populations concern improving water and sanitation facilities, such as having running water on the site, including building a bathroom inside the house. This is an essential aspect to be developed in order to improve the living conditions.

The current grammar is essentially a bi-dimensional one due the fact that the case studies worked until now refer to ground floor houses, but if a densification strategy is to be taken in consideration, evidence from other informal areas where density is already higher and construction includes taller informal buildings will need to be incorporated in a more complex grammar. This work is already under development. The only 3D approach done until now consists of a simple extrusion of the layouts generated by the grammar (Fig.2) which is used for visualization purposes.

Finally, one of the main problems involved in slams' sprawl is the fact that it generates continuously spreading homogeneous areas where no urban hierarchies are usually found. A bottom-up grammar will tend to simply replicate this behavior. Therefore, in planning terms it becomes evident the need for introducing evaluation and control mechanisms (and an additional grammar) which should react to the changes in the occupation conditions (and density) and generate the additional features that otherwise would not be defined by the grammar. This process will be the subject of a future paper.

REFERENCES

Andersen, JE, et al. 2012, 'Built Environment Study', *Homespace in African Cities*, Danish Research Council for Innovation, Maputo.

Berghauser-Pont, MB, Haupt, P 2010, *Spacematrix - Density and Urban Form*, NAi Publishers, Rotterdam.

Habraken, NJ 2000, *The Structure of the Ordinary*, MIT Press, Cambridge.

Hillier, B., and J. Hanson. 1984, *The Social Logic of Space*, Vol. 2. Cambridge University Press Cambridge.

Jenkins, P 2012, *Homespace in African Cities*, Danish Research Council for Innovation, Maputo.

Karimi, K, Parham, E 2012, 'An Evidence Informed Approach To Developing an Adaptable Regeneration Programme For Declining Informal Settlements', *Eighth International Space Syntax Symposium*, Santiago.

Raposo, I, Oppenheimer, J 2008, *Subúrbios de Luanda e Maputo*, Edições Colibri / Centro de Estudos sobre África e do Desenvolvimento, Lisboa.

Stiny, G 1980, 'Introduction to shape and shape grammars', *Environment and Planning B*, vol. 7: p.343-351.

UN-HABITAT 2010, *State of African Cities, Governance, Inequalities and Urban Land Markets,* United Nations Publications.

UN-HABITAT 2006, *State of the World's Cities Report 2006-2007: The Millennium Development Goals and Urban Sustainability - 30 Years of Shaping the Habitat Agenda*, United Nations Publications.

UN-HABITAT 2003, *The Challenge of Slums: Global Report on Human Settlements*, Earthscan Ltd.